CONSERVING BIODIVERSITY OUTSIDE PROTECTED AREAS: ANALYSIS OF A POTENTIAL WILDLIFE CORRIDOR IN CHITTOOR DISTRICT, ANDHRA PRADESH, INDIA

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CHAPTER I

INTRODUCTION

The latter half of the twentieth century has seen a change in the conceptualization of natural resources. Prior to this, rampant extraction took place for development and industrialization, while today there is a growing awareness for the need to conserve natural resources. Although there are innumerable reasons that contributed to this awareness, there is no doubt that extinction of species and diminishing resources are primary causes. This change in perspective was global, and India followed suit post-independence, although the British introduced formal protection of resources during colonial rule. Independent India was designed to preserve its natural resource base through state control over common lands, water, and forests (Murali 1995). As the state played its role, the communities that historically used and managed resources found themselves at the mercy of policy makers, and subject to rules they did not understand. The late 1970s and 80s saw a gradual shift in perspective which was motivated by international conservation paradigms, as well as the realization that state control of resources isolated the very people who depended upon them for their livelihoods. Additionally, forest resources all over the country were decreasing and management of common lands and water by the state was proving to be unsustainable. Apart from these factors, government policy in postcolonial India was biased towards managing a growing population, industrialization, and economic development. Consequently, flora and fauna continued to deplete, degrade and in several cases became endangered, while some species faced extinction.

In keeping with global trends and an urgency to protect India's flora and fauna, the Wildlife Protection Act was established in 1972, which brought with it a whole new gamut of rules and regulations aimed at conservation (Gadgil 1992). This led to a rapid increase in the number of National Parks and Wildlife Sanctuaries, which stood at five prior to the implementation of this act. As of 2007, there were 96 National Parks and 510 Wildlife Sanctuaries in India (MoEF 2007). An increase in the number of National Parks and Wildlife Sanctuaries (WII 2002) was supplemented by the initiation of Joint Forest Management programs in 1988 (World Bank 2006). The Joint Forest Management program was a reflection of changing perspectives on conservation (even at an international level), as it involved communities in forest protection. All these measures had significant impacts on the biodiversity of India, and success stories were reported across the country. More recently, the Forest Survey of India, the body responsible for survey and assessments of forests, reported that there was an increase in forest cover by 2795 km^2 or 0.411% between 2001 and 2003 (FSI 2003). While these statistics have been cited a number of times, specifically in the media, the next line of the report is ignored, which states, "It is also found that there has been a net reduction in dense forest by 26,245 km^2 while the open forest has shown net gain of 29,040 km^2" (FSI 2003, 35). For conservationists, the latter is a cause for alarm as the conversion of a forested area (for the purpose of this research the terms 'forest area' and 'forest cover' are used interchangeably) from dense to open signifies fragmentation and/or degradation.

Fragmented landscapes produce smaller habitat patches[1] that are usually isolated, leading to smaller populations with reduced genetic diversity, a disruption in migratory routes and vegetation succession cycles among other concerns (Forman 1995). These issues plague biodiversity and ecosystem functions, and the situation is further complicated by pressure from growing human populations and unplanned development. The Global Gap Analysis (Conservation International 2003) showed how Protected Areas around the world were not sufficient to meet conservation needs. A similar study was undertaken by the Wildlife Institute of India in 1988, and again in 2002 (WII 2002) due to pressure from researchers and conservationists who thought that the Protected Area network in India was inadequate. The study was designed to review existing Protected Areas and identify gaps across different biogeographic zones in India. This report identified areas of concern, leading to interventions which further resulted in an increase in the land area covered by Protected Areas from 3.34% in 1988 to 4.70% in 2002 (WII 2002).

Based on the background provided, the question that arises is whether establishing Protected Areas is enough to conserve biodiversity. Several researchers (Anand et al. 2010; DeFries et al. 2010; Hayes and Ostrom 2005) have commented on the lack of success of Protected Areas and suggest more stringent measures for protection, including local people in the planning process, focusing on buffer zones, and creating alternate livelihoods for forest dependent people. A study conducted by Hayes and Ostrom (2005) questioned the basis of Protected Areas as the only means to conserve the world's forests. They analyzed data from across the globe to conclude that Protected Areas are certainly

1 Habitat patches are relatively homogenous areas in the landscape that differ from the surrounding area (Forman 1995) and provide resources necessary for survival and reproduction.

not the only way, but show that the success of “forest conservation depends upon a web of factors, including, but not limited to, local recognition and validity of the protected area policy, biophysical features, financial and human resource support, and mechanisms for conflict resolution” (Hayes and Ostrom 2005, 617). Thus, their study indicates that multiple factors need to be considered to ensure conservation and sustainability of the initiatives undertaken to protect a specific area or species.

The regional approach, which encompasses diverse habitats and species, is another approach to conservation that has gained currency over the past decade. This approach goes beyond homogenous ecosystems and embraces the heterogeneity in the landscape (Noss 1983). Sanderson et al. (2006) take this a step further and discuss the concept of large-scale biodiversity conservation corridors at the regional scale. They define biodiversity conservation corridors as “a network of parks and reserves, interspersed with areas sustaining varying degrees of human occupation where management is integrated to ensure the survival of the largest possible spectrum of species and specifically avoiding the extinction of threatened species of regional, national and global value” (Sanderson et al. 2006, 625). These corridors take a macro perspective, incorporating both protected areas and biodiversity-rich areas, which lie outside the domain of protected areas. Additionally, they take into consideration communities living in the area along with endangered and threatened species. Based on this definition one can surmise that biodiversity conservation corridors are not only a potential solution, but in all probability the only way forward given the varied land uses in India.

Using Sanderson et al.’s definition as the underpinnings, this research is based in southern India and assesses the feasibility of a biodiversity conservation corridor (henceforth referred to as a corridor) between two biogeographic zones – the Eastern and the Western Ghats (Figure 1.1).

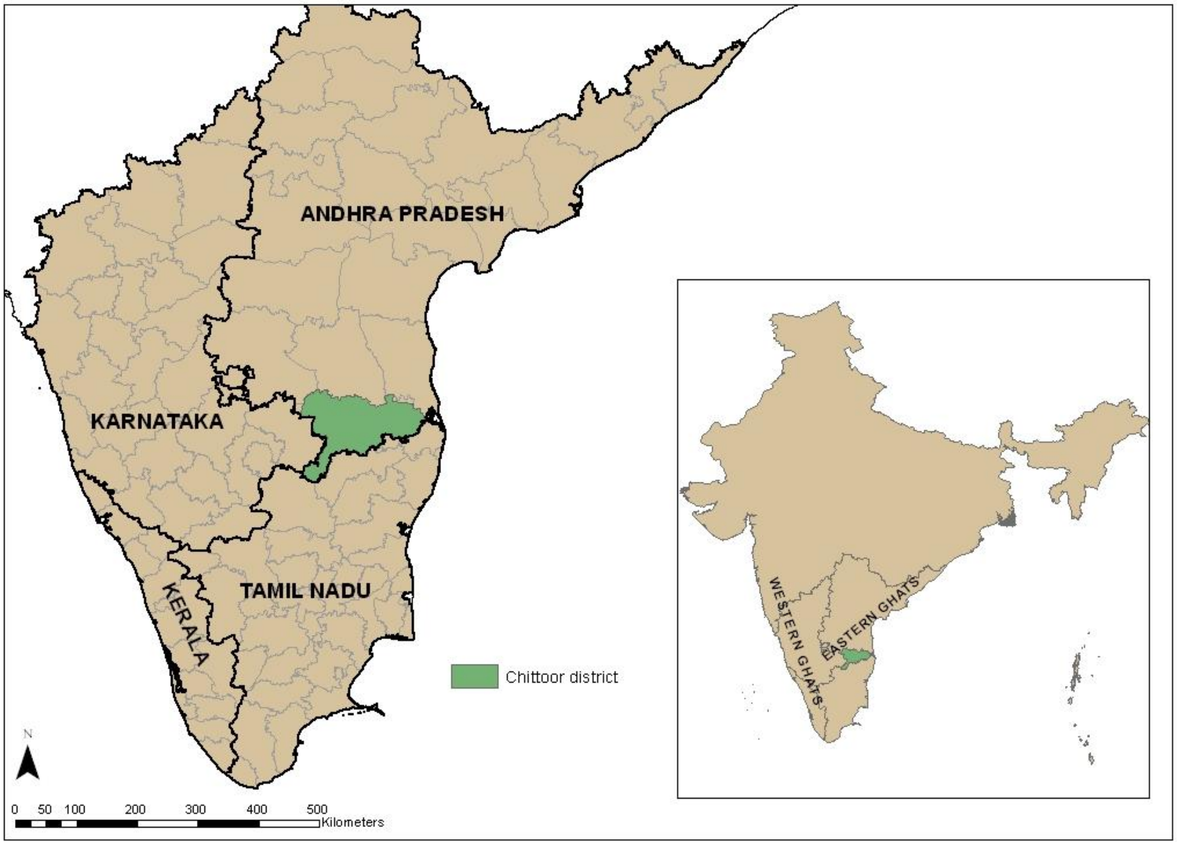

Figure 1.1 Location of Chittoor district in relation to the Eastern and Western Ghats

The Western Ghats are the better known of the two regions as they have been identified as a biodiversity hotspot and hence are better protected. Biogeographically the Western Ghats are also favored as they consist of a contiguous range of mountains with a combination of tropical and subtropical moist broadleaf forests harboring a rich repository of flora and fauna (Anand et al. 2010). Conversely, the Eastern Ghats are a broken range of hills dominated by dry deciduous and scrub forests with a few patches of tropical, sub-tropical, and evergreen species (WWF 2010). Yet, the Eastern Ghats are also host to many species of both local and international significance. A corridor between these two biogeographic regions would need to be large and assessing the area would be difficult within the scope and time frame of this research. Therefore, this study focuses on one segment of the potential connection between the Rayala Elephant Reserve and Sri Venkateswara (SV) National Park in the Eastern Ghats (Figure 1.2).

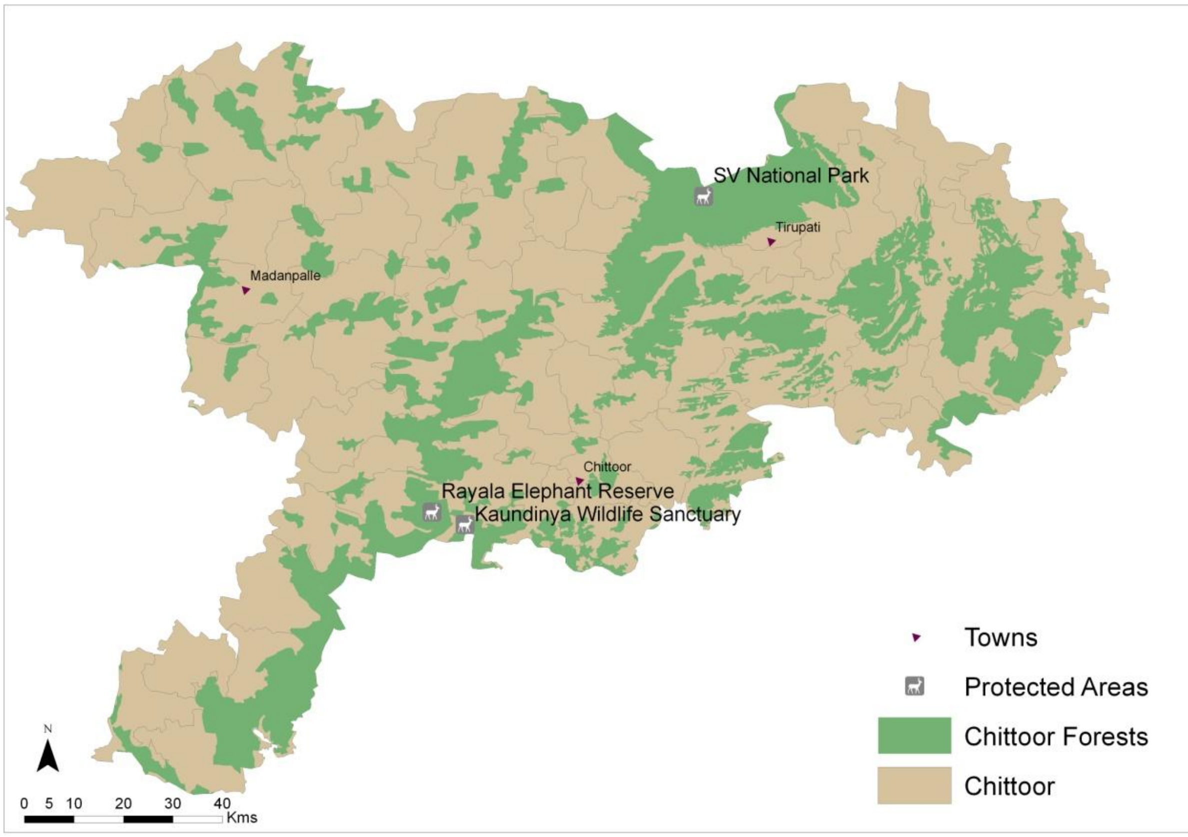

Figure 1.2 Protected areas and major towns in Chittoor district, Andhra Pradesh

The rationale behind selecting this area is both administrative and practical. The larger connectivity network between the Eastern and Western Ghats crosses over the boundaries of three states in southern India. This will involve dealing with state-specific policies and diverse ecological conditions in terms of the flora, fauna, climate, and soil, thus further complicating the problem. The area between the Rayala Elephant Reserve and Sri Venkateswara National Park (henceforth referred to as the study area) encompasses one district (i.e. Chittoor) within the state of Andhra Pradesh (Figure 1.2). The aim of the study is to identify the most appropriate corridor location(s) based on multiple criteria such as biogeographic, socioeconomic, and administrative components to assess the feasibility of conservation/restoration of this area. This study aims to address the following research goals:

1. Identify socioeconomic factors contributing to forest area in Chittoor district and determine their relative contributions.

2. Propose a potential corridor based on the social and biogeographic factors present between the Rayala Elephant Reserve and Sri Venkateswara National Park.

3. Provide conservation recommendations based on the potential corridors identified.

Chapter II is a literature review that explains the significance of this research and puts it into context within the study area. Once an overview of current trends is presented, Chapter III explains the data and methods used to address the research goals. Then the results of this study are discussed over the next four chapters. Chapter IV identifies socioeconomic factors such as agricultural area and poverty, which contribute to forest area and includes a regression analysis to determine the contributions of each factor. Chapter V analyzes the composition and configuration of the landscape in Chittoor district based on land use/land cover. Chapter VI uses the output from Chapters IV and V to identify a conservation priority zone and shows potential linkages within this zone. Finally, Chapter VII analyzes the conservation priority zone and provides recommendations based on the findings.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

The rationale for creating wildlife corridors is to alleviate the negative effects of habitat fragmentation by connecting otherwise isolated patches of habitat. Thus this review of literature begins with the state of forest fragmentation in India. This is followed by current research being conducted in the study area which in turn will explain the significance of this study. The next section provides a framework for corridors as a tool and assesses their ability to curb habitat fragmentation. In conclusion, a brief review on the politics of conservation in India is provided as the final goal of this research is to provide conservation recommendations.

2.2 Habitat fragmentation and socioeconomic factors in India

Biodiversity conservation and habitat fragmentation are terms that are often used together because of the burgeoning human population and rapidly declining biodiversity all over the world. A logical consequence of an increasing human population and subsequent use of land for development projects is less space for flora and fauna and greater pressure on remaining habitat fragments. The perils of a fragmented landscape are highlighted in academia and popular media at both the international and national level (FSI 2003; World Bank 2006; WRI 2009).

However, defining habitat fragmentation is important to provide a spatial and temporal context for it. Yrjo (2002) captures the (over)use of the term 'habitat fragmentation' and states that the "concept turns into a subject that has the power to define research priorities, resolve disputes, and justify conclusions" (323). Additionally he expounds on the fallacies of interpretation and emphasizes a need to define place-specific and context-specific notions of habitat fragmentation (Yrjo 2002). For the sake of this study the following definition of habitat fragmentation assigned by the Food and Agricultural Organization will be used:

> Habitat fragmentation is the breaking up of a continuous habitat, ecosystem, or land-use type into smaller fragments, which is considered to be one of several spatial processes in land transformation. It is commonly used in relation to the fragmentation of forests. Habitat fragmentation is mainly caused by human activities such as logging, conversion of forests into agricultural areas and suburbanization, but can also be caused by natural processes such as fire. (FAO 2011)

Forests cover twenty-two percent of the total land base in India, and twenty-seven percent of the population depends on forest resources (to some extent) for its livelihood and basic energy needs (World Bank 2006). As mentioned in Chapter I, the Forest Survey of India identified a net increase in forest cover of 2795 km^2 from 2001 to 2003 (FSI 2003). Davidar et al. (2010) use these statistics in their study to assess the actual extent of forest degradation in India and compare it to the reported value. They use field surveys to show how claims made by the Forest Survey of India based on satellite images fail to capture degradation within forest boundaries (Davidar et al. 2010). The authors assess the reliability of satellite data and explain that forest degradation is more a result of biomass harvesting and not clear felling. They suggest a need to "understand the socioeconomic variables associated with forest loss and degradation" in addition to an analysis of remote sensing images (Davidar et al. 2010, 2937). A similar suggestion made by Gorenflao and Brandon (2006) based on the Global Gap Analysis found that several unprotected areas across the world provide habitat to a number of endemic species, and these areas are "highly irreplaceable and threatened" (Conservation International 2003, 7). Gorenflao and Brandon (2006) further state that it is essential for planners and conservationists to encompass both protected and unprotected areas in the purview of "considering socioeconomic issues on conservation planning, recognizing that economic and political considerations often compete with biodiversity for land use" (724).

Robbins et al. (2009) describe the Indian context and state that conservation values have largely been imposed on a patchwork of high population density agricultural land, settlements, and wildlife habitat. Although the Joint Forest Management program did facilitate removing the superstructure imposed by the state (by involving local communities), the effects of the hegemonic power structures are deeply rooted. This was seen in the results of the research conducted by Robbins et al. (2009) in households bordering the Kumbhalgarh Wildlife Sanctuary in India. They state that, "these results paint a picture of deeply institutionalized forest use that suggests serious barriers to any simple enforcement solutions or governance reforms" (Robbins et al. 2009, 559). The authors suggest a compromise between state authorities and local users of forest resources to formulate rules for resource governance (Robbins et al. 2009). Comparable complexities imposed by the socioeconomic and political structure are dealt with by Ravan et al. (2005) in their study which looks at ways to overcome habitat fragmentation (between the Kanha Tiger Reserve and Achanakmar Wildlife Sanctuary) through the inclusion of areas outside Protected Areas within the realm of conservation. They state,

> In a domain of socio-political realities where there are increasing protests against bringing more areas under the Protected Area network, many existing intra-PAs perform one of the most essential functions for biodiversity conservation viz., providing genetic connectivity to spatially separated wildlife populations … linking up existing better-quality forest patches (PAs) through strips of land with similar habitats (thus) offer(ing) the much needed contiguity for exchange of genetic materials … (that) mitigates the negative biological impacts of habitat fragmentation. (Ravan et al. 2005, 1441)

The authors echo the sentiments of many wildlife scientists, practitioners, and researchers across the country, who are working towards linkages in the landscape (Anand et al. 2010; DeFries et al. 2010; Venkataraman 2005). Yet the authors do not address how these linkages may be made viable in such a dynamic and contested socioeconomic context.

2.3 Habitat fragmentation in the study area

With reference to the study area for this research, the Eastern Ghats are a discontinuous range of mountains which makes them naturally fragmented. Additionally, anthropogenic factors have exacerbated this. A survey in the Eastern Ghats conducted with the objective of assessing the efficacy of conservation in five Protected Areas (PAs) highlighted the importance of conserving biodiversity rich areas outside PAs in order to reduce the pressure on them (Rawat 1997). In addition, Rawat (1997) also suggests involving local communities to protect habitats. Even though the Eastern Ghats lag behind the Western Ghats in terms of biodiversity conservation, a handful of efforts have been made to protect this area too. The World Wildlife Fund (WWF 2010) recently undertook a study, *Biodiversity Conservation in the Eastern Ghats using Remote Sensing* *and GIS*, with a specific focus on fragmentation, patch size, and land use patterns in the area. The larger goal of this study was to help design a conservation plan specific to the Eastern Ghats (WWF 2010). A recent report called *The State of Forests Report 2010: Andhra Pradesh*, claims a net loss of 69.92 hectares in Chittoor East division and no change in Chittoor West division between 2007 and 2008. Similarly, the reports on the state of the forests in the Western Ghats also show consistent patterns of degradation and fragmentation (Anand et al. 2010). Kale (2010) estimates a loss of 25.6% forest cover over a period of 22 years in the Western Ghats and an annual loss of 0.53% over a period of 20 years. Thus, evidence suggests that forests are undergoing degradation in both the Eastern and Western Ghats which invariably leads to a fragmented landscape for many, if not most, species.

2.4 Corridors as a tool to curb habitat fragmentation

The establishment of wildlife corridors is one of the many options in the conservationist's toolbox to curtail the negative impacts of degradation/fragmentation. Chetkiewicz et al. (2006) state that conservation corridors are a possible way to strike a balance between the needs of organisms affected by fragmentation and the human need to develop (urbanize/industrialize). The authors recommend the integration of process-based approaches in designing corridors. Multiple design inputs are provided by biogeographers and landscape ecologists (Beier and Noss 1998; Forman 1995; Goldman 2009) working in the field and more often than not a combination of stepping stone[2] and contiguous corridors[3] is recommended. In addition to these approaches, modification of the

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2 Stepping stones are a series of small patches connecting otherwise isolated patches (Baum et al. 2004).
3 Corridors are linear strips of habitat connecting isolated habitat patches (Forman 1995).

matrix[4] is also suggested as an alternative to stepping stones and contiguous corridors (Sanderson et al. 2006), as the matrix influences the effectiveness of conservation initiatives (Baum et al. 2004). Considering the multiple factors involved in this research, a combination of approaches to increase connectivity will be a natural choice, as the fragmented landscape in the study area includes rural settlements, agricultural, forest and grazing lands.

Before providing a detailed review of literature on corridors, it is essential to clarify the current use and definition of corridors as used in this study. Corridors have been defined and debated upon for the past three decades and Forman's definition is most often used as a starting point (Burgman et al. 2005; Hobbs 1997; Wu 2008). According to Forman (1995) the landscape consists of a matrix, patches, and corridors. He provides an elementary definition by stating that "a corridor is a strip of a particular type that differs from the adjacent land on both sides" and it functions as a habitat, a conduit and/or a barrier (Forman 1995, 38). But landscape ecology did not originate through the concept of corridors; rather it was initiated by the "Island Biogeography Theory" (IBT) proposed by MacArthur and Wilson in 1967 (MacArthur and Wilson 1967). The application of IBT to conservation has been controversial, and while some scientists have disproved its validity for terrestrial environments (based on its focus on islands, which was overlaid on the mainland), others still rely on it to support their research. The IBT was originally developed to predict the number of species on an island based on its size, shape, and distance from the mainland, distance from other islands, and the rate of colonization and extinction, among various other biogeographic factors (Forman 1995). One can assume

4 The background land-use type in a mosaic, characterized by extensive cover, high connectivity, and/or major control over dynamics is referred to as the matrix (Forman 1995).

that a larger island will contain a larger habitat area and therefore greater habitat heterogeneity, which will in turn mean a higher number of species immigrating to this island to colonize it (Forman 1995). In addition, isolation or the distance of the island from the mainland also affects these factors, along with time since isolation, which plays a role in the rate of extinction (Forman 1995).

Over the years, with the advancement of research techniques and methodologies, this theory too has evolved and has been superimposed on habitats on land to be used in many more ways than just species prediction. The IBT essentially provides a base to understand the function of habitats, corridors and patches in a landscape matrix. When dealing with fragmented landscapes, especially when the matrix differs substantially from habitat patches identified by IBT, it is necessary to design a corridor that takes into account these nuances.

Although corridors are considered practically feasible and "doable", Goldman cautions that the connectivity provided by corridors depends upon the scale, the species, and the matrix (Goldman 2009, 336). As the specifics of the corridor vary, it is integral to keep in mind that while a corridor may function as a habitat for one species, it may be a conduit for another and a barrier for yet another species. The author presents corridors as a concept and a conservation tool that must be designed based on place-specific requirements rather than creating a standardized package (Goldman 2009). Thus, designing a corridor requires researchers to consider the effects it may have on the entire biotic community instead of a single species, as what may benefit one may lead to unstable population dynamics for others. Yet, most often corridors are designed with a single target species in perspective as dealing with multiple species requirements is difficult. Detailed guidelines are provided by Majka et al. (2007) on the steps to designing a wildlife corridor in *Conceptual Steps for Designing Wildlife Corridors*. In this document the authors outline pre-modeling steps which include what to connect (identifying and prioritizing linkages, and selecting the focal species), an overview of habitat and corridor modeling (selection of GIS factors, estimating suitability, creating a habitat map, designing and evaluating corridors), and an analysis of linkage designs (Majka et al. 2007).

In India, wildlife corridors are a relatively new concept. The feasibility and implementation of wildlife corridors are primarily carried out by the Ministry of Environment and Forests in collaboration with the Wildlife Trust of India specifically for elephant migration (Venkataraman 2005). More recently, Murthy et al. (2008) called for an Elephant Reserve to be established in Andhra Pradesh, based on their findings in several forest patches used by the pachyderms. With reference to the study area, the Rayala Elephant Reserve (Figure 1.2) was established primarily for migratory herds from the Koundinya Wildlife Sanctuary (KWS). Research has shown that the KWS was not large enough for the herd which originally migrated there during the 1980s (Manakadan et al. 2010; Menon et al. 2005). The local population living in and around the study area has often reported sightings of elephants, wild dogs, leopards, and barking deer (Jones 2012). These sightings are considered seasonal migratory patterns. In a segment connecting the Eastern and Western Ghats, Diemer (2003) carried out a study to assess environmental suitability for Asian Elephants in Southern India. Her study used geospatial data to show that environmental suitability in the northeastern parts of the Nilgiri Biosphere Reserve (in the Western Ghats) was high and it was possible to work on a habitat model with the available data (Diemer 2003). Similarly, a feasibility assessment for conservation corridors was also undertaken (by the International Centre for Integrated Mountain Development, ICIMOD) in the northeast Himalayas (Chettri et al. 2008). Thus the discourse on corridors, though at a nascent stage, is gaining relevance and priority.

2.5 Feasibility of corridors

With regard to the usefulness of corridors, Beier and Noss (1998) assessed 32 corridor initiatives across the globe to review their success or failure in providing landscape connectivity. They provide empirical evidence to suggest that the design of a corridor is of paramount importance along with the social, political, economic, and cultural influences that are involved (Beier and Noss 1998). The authors conclude that, although assessing the success (or lack of) of corridors is difficult, the presence of a corridor is of more value than a fragmented landscape, because fragmentation reduces genetic variability and exchange between populations (Beier and Noss 1998). More recently, Gilbert-Norton et al. (2010) conducted a meta-analytic review of corridors in 35 studies to assess the effectiveness of corridors across species, in both natural and manipulated settings. The authors found that "corridors increased movement between habitat patches by approximately 50% compared to patches that are not connected with corridors", thus providing statistical evidence to support their establishment (Gilbert-Norton et al. 2010, 660). Considering that fragmentation of the landscape is more likely to increase, one can assume that corridors, though not a perfect solution to the problem, are certainly a way to increase the prospects of genetic exchange, migration and maintenance of biodiversity. At the same time, it is essential to note that corridors can also lead to potential negative consequences such as spread of disease and the disturbance of population dynamics.

A similar question is posed by other authors (Boitani et al. 2007; Chetkiewicz et al. 2006; Williams 1998) with regard to Ecological Networks in Europe and Tanzania, which use linear corridors and stepping stones to connect (protected and unprotected) areas to ensure the functioning of ecological processes and the viability of populations. In their analysis, the authors reveal the monetary costs involved and the over-simplification of this concept (Boitani et al. 2007). This over-simplification is also referred to by Chetkiewicz et al. (2006) as the main problem with corridors, lies in designing them based on binaries of habitat suitability (i.e. defining a habitat as suitable or unsuitable, when many habitats fall along a gradient of more to less suitable). Yet, they too conclude, along with Boitani et al. (2007), that Ecological Networks do not have any negative repercussions and can only help ecosystems function, provided they are designed to suit the place. Furthermore, corridors are not limited to connecting fragmented landscapes only, but “they connect people with a common language and a common vision” (Goldman 2009, 352). Thus, one can conclude that, although establishing corridors designed to connect fragmented landscapes is an expensive proposition in terms of money and logistics, the benefits far outweigh the costs.

With reference to the binary patterns of habitat suitability mentioned in the previous paragraph, Watling et al. (2010) suggest that it is the matrix of the landscape that matters in patchy landscapes rather than the patch attributes alone. Based on a meta-analysis of fragmented populations, the authors argue that metrics based on the composition of the matrix (diversity, cover and modified distance) may offer a better analysis of the landscape (and vis-à-vis species) than those based on Euclidean distance in terms of connectivity and distribution (Watling et al. 2010). In other words, since the matrix is the basis on which species operate, the resistance (or lack of) offered by the matrix influences the effectiveness of a corridor. Similarly, Baum et al. (2004) evaluate the role played by the matrix in connectivity, and focus on the planthopper (*Prokelisia crocea*) and its host plant, prairie cordgrass (*Spartina pectinata*). The authors conclude that a low resistance matrix[5] in combination with corridors and/or stepping stones is an effective approach when dealing with fragmented populations (Baum et al. 2004). More recently Prevedello and Vieira (2010) conducted a quantitative review of 104 studies to determine the role played by the type of matrix. They also conclude that the type of matrix is important, but add to the discourse by providing evidence on the role of patch size and its isolation in the matrix with regard to biodiversity parameters (Prevedello and Vieira 2010). Further, they attempt to understand the influence of the matrix on biodiversity as well as the factors determining matrix quality (Prevedello and Vieira 2010).

Based on the above discussion one can deduce that planning for the matrix is essential for the conservation of fragmented landscapes. The concept of a biodiversity conservation corridor considers the matrix, as it aims at planning and conserving and /or restoring a larger area based on specific criteria which are not limited to simply linear and stepping stone corridors.

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5 A low resistance matrix essentially "facilitates high rates of interpatch dispersal", while a high resistance matrix impedes movement between patches (Baum et al. 2004).

2.6 The politics of conservation

Planning for the matrix involves incorporating multiple land use categories. An understanding of policies guiding conservation practices is essential for this. This provides impetus to the third research goal, which aims at providing conservation recommendations for the study area. Unlike the United States and Europe, in India and other developing countries, National Parks and Wildlife Sanctuaries are not biodiversity rich areas devoid of people. Rather, they are areas set aside or 'fortressed', first by the British and then the Indian government for conservation. This demarcation in most cases dislocated people who have lived there for centuries to the buffer zone of these Protected Areas. It would be factually incorrect to suggest that Protected Areas in the West were devoid of people, as history shows that Yellowstone National Park was created after the "indigenous peoples who lived and made use of the extensive woods… were thus excluded leading to resistance and killing of hundreds of Indians" (Colchester 2004, 146). Apart from the '(American) Indian wars' that were being fought across America, the concept of "wilderness"[6] (Colchester 2004) came to the forefront. This is still a highly debated concept as seen in the compilation of essays in *The Wilderness Debate Rages On* (Nelson and Callicott 2008). Nevertheless, it was this model of "wilderness" which was replicated in most parts of the world including the Soviet Union, India, and Africa, until the 1970s (Colchester 2004). Although claimed to be successful in some contexts (and places), there are differing viewpoints with regard to the fortress or enclosure strategy of conservation. Huggan quotes Deane Curtin (2005), author of *Environmental Ethics for a*

6 A concept that has a myriad of meanings and definitions but most certainly here refers to the contentious 'pristine myth' or in other words that there were parts of the natural world that were untouched by humans, and therefore needed to be protected.

Postcolonial World, to elaborate on this point as saying, "What makes sense as a preservation strategy in the first world, often has disastrous consequences in the third world" (Huggan 2004). However, there are parts in the West that have also rejected this conservation model over the past four decades (Adams and Mulligan 2003). Thus, understanding the theoretical framework will play an integral role to frame the conservation recommendations accordingly, and provide a more holistic approach.

One can hypothesize that the evolution of conservation policies in India has occurred through both national and international pressure and has moved away from the colonial approach. However, Singh and van Houtum (2002) argue that conservation (specifically Trans Frontier Conservation Areas (TFCAs), which are based on connecting Protected Areas across international boundaries through wildlife corridors) in Southern Africa, are akin to the "same emperor's new clothes" (Singh and van Houtum 2002, 253). The authors evaluate the two stages of the conservation paradigm, primarily colonial and postcolonial, and conclude that,

> The neo-liberal market ideology combined with romantic 'dreams' of bioregionalism and touristic nature parks has allowed international actors and western states to re-colonize southern Africa through new conservation. In addition, the discourse on transboundary conservation will further re-map the configurations of power, identities and movement of capital and people while further re-configuring post-colonial geopolitical and geo-economic territorial claims. (Singh and van Houtum 2002, 261)

Another study undertaken by Picard (2010) on the Selous Niassa Wildlife Corridor in Tanzania examines the 'how' or the social and political processes that contribute to conservation interventions and, in this case, the specific wildlife corridor. The focus of Picard's dissertation was an appraisal of the wildlife corridor as a model for large scale conservation in which she scrutinized the historical, socio-cultural and economic conditions of the area in addition to the bureaucratic and other processes that resulted in the making of the Selous Niassa Wildlife Corridor (Picard 2010). Although she does not discuss the postcolonial aspect in detail, there is an allusion to it. The Indian context is naturally different, although similarities exist with other postcolonial countries.

The colonization of ecological space in India has been discussed extensively by Gadgil and Guha in their book titled *The Fissured Land: An Ecological History of India* (1993). In another book, *Nature, Culture and Imperialism*, Murali (1995) discusses forest practices in Andhra Pradesh (the state in which the study area is located) between 1600 and 1922. Murali (1995) uses oral texts and archival information to retrace the processes and happenings in forests in Andhra Pradesh. As already mentioned, one of the basic tenets of forest management under the British was a move to fortress forest areas by removing the people who depended on the forests. Murali recounts several incidents based on 'social memory', and discusses how "the peasants perceived this reordering of geography and space as illegal" contrary to what the rulers termed as "illegal" (Murali 1995, 104). Additionally, he also narrates how the customary laws of peasant society were in stark opposition to the capitalistic laws of nature imposed by the British (Murali 1995).

In more contemporary research, the discourse shifts to the realm of political ecology, and several practitioners and academics (Borrini et al. 2004; Bryant 1998; Gadgil and Guha 1995; Williams and Mawdsley 2006a) assert that environmental laws exclude the poor both culturally and politically (Williams and Mawdsley 2006b). A primary cause of this has been the "unwillingness to question the 'holy cow' of unlimited economic growth" (Williams and Mawdsley 2006b, 665) which has resulted in persistence of the colonial legacy (Bryant 1998). Bryant succinctly sums up the situation,

> In countries as politically, economically and culturally diverse as India, Burma and Indonesia, for instance there has been a comparable tendency to affirm, whenever possible, the supremacy of a state-organized system of 'scientific forestry' that has served the political and economic interests of colonial and postcolonial regimes alike. If anything, resource extraction has intensified in these and other third-world countries as a postcolonial quest for rapid national 'modernization' … (Bryant 1998, 85)

In the book C*olonial and Postcolonial Geographies of India* (2006), Williams and Mawdsley refer to the 'Standard Environmental Narrative', which "identifies the state as its main target and offers an idealized vision of the community as its only political alternative" (Williams and Mawdsley 2006a, 266). The authors contend that this is simplistic and results from an essentialist perspective, which reifies traditional livelihoods and practices. While the focus of this study is not intended to be an attack on the state, it is as essential to understand conservation policies in India and how the concept of a biodiversity conservation corridor may fit, as it is to understand the social and ecological parameters. Quoting Schmink and Wood (1987, 51), Bryant writes that, "… ideas are never innocent but 'either reinforce or challenge existing social and economic arrangements'" (Bryant 1998, 87). While the biodiversity conservation corridor is not designed to challenge existing policies, it is important to evaluate its significance in the larger discourse of conservation politics.

In this context Figgis (2003) states that the concept of bioregionalism (with reference to moving away from isolated protected areas to networks) "… allows for creative tools to be developed in order to deal with the imposition of myriad human jurisdictions over natural systems" (201). Additionally, Adams and Mulligan (2003) discuss the new drivers of conservation and elaborate on the island biogeography theory, thus contextualizing the perils of islands of protected areas in terms of species colonization and extinction. They suggest that linkages in the landscape are more sustainable than the strictly 'fortress approach' to conservation, and also discuss the 'multiple-use model', which is based on the idea that conservation can be practiced along with activities like forestry, mining and grazing (Adams and Mulligan 2003). This particular model will feed into this research as the extent of human settlement and dependence on forest resources in the study area is pervasive.

2.7 Conservation recommendations

With reference to the reviewed literature, the last section of this review aims at providing conservation recommendations in conjunction with an appropriate corridor design for the study area. This will essentially be a synthesis of the output of the first two research goals. The recommendations will be based on the corridor design, the socioeconomic factors leading to fragmentation, and set within the existing conservation policy framework in India.

"Connecting people" has become the catch phrase for many capitalist endeavors over the past two decades, especially with regard to the information revolution. However, connecting people in conservation has a different meaning. In the 1970s, the notion of involving people in conservation emerged from a practical realization that keeping those who depend upon forests out was leading to insignificant benefits. National parks were originally designed (globally) to exclude people from Protected Areas, but today people and biodiversity are a part of the plan.

The argument that connects poverty and environmental degradation is often used to criticize the approach that involves communities in conservation. This critique is based on the assumption of a vicious cycle between poverty and environmental degradation where one perpetuates the other, but research has proven this to be fallacious. Scholars in various disciplines and the Bruntdland Report[7] advocated this infamous liaison for over three decades (Gray and Moseley 2005). The poverty-environment debate has been refuted both empirically and theoretically by a focus on issues of power and scale specifically through a political ecology lens (Gray and Moseley 2005). Gray and Moseley (2005) highlight the process by which the poverty-environment discourse dominated research, and how on assessing real life situations the role played by wealth, economic development, globalization and power politics turned out to be far more significant factors in environmental degradation.

In the Indian context, Gadgil (1992) emphasizes the need for a reorientation of conservation strategies and makes a case for the involvement of local people. This was also coupled with the initiation of the Joint Forest Management program started by the government in the late 1980s, as discussed earlier. This paradigm shift was not restricted to the Indian subcontinent; rather it was evolving in different ways all over the world and even now is developing based on place-specific dynamics. Recent literature on the issue of communities and conservation cover the Americas, Africa, Australia, and India, among other countries (Adams and Mulligan 2003; Brown and Harris 2005; Chan et al.

7 The Brundtland Report was an outcome of the Brundtland Commission set up by the UN to discuss global issues related to the environment and, since then, has been a popular reference point for the framing of the term ‘sustainable development’.

2007; DeFries et al. 2010; Goldman 2009). Brown and Harris (2005) take up this issue and demonstrate the need for citizen participation in the proposed wildlife corridor across Algonquin to Adirondack, which lies between New York and Ontario. Goldman (2009) provides an identical suggestion for a study conducted in Kenya. Her study identified gaps that point to a lack of a cultural understanding of the Maasai people, their practices, and systems in the planning process for the wildlife corridor established between Tanzania and Kenya (Goldman 2009). Similarly, DeFries et al. (2010) comment on the need for regional scale planning for areas around protected areas, especially in human dominated landscapes, so that a balance between conservation goals and livelihood needs can be achieved. Hence, people's participation, whether in the form of community based natural resource management or participatory development, has become a norm and an accepted practice. Although its success has been contested, there are numerous case studies from across the globe to suggest that involving communities in conservation is one of the most feasible options available.

It is no longer a question of whether conservation should be pursued or not, instead, it is about "how to achieve conservation given that economics is more likely than ecology to inform policy and that the same ethics that justify conservation also demand that we be mindful of poverty and associated human suffering" (Chan et al. 2007, 60). In understanding the larger framework, one must realize that the problems involved are not singular, nor is there one way to solve them. While it is important to address the concerns that revolve around protection of the remaining biodiversity on the earth, it is equally important to work towards human-centric goals aimed at ending hunger and poverty (Earth Summit 2012). In the developing world, finding a balance between these multiple objectives is difficult, and the ability to foresee short term versus long term costs and benefits needs to be included in the process of conservation planning across time and space (Chan et al. 2007). Given that it is "impossible to maximize imperfectly correlated goals simultaneously" (Chan et al. 2007, 61), a combination of biological and social factors must be taken into consideration to reach some kind of a solution.

"Conservation development" is one possible solution to this issue. Although it refers to urban spaces, it is described "in contrast to conventional development (as a form of development that) acknowledges spatial heterogeneity by protecting areas with key habitat or ecological functions" (Pejchar et al. 2006, 72). Both Chan et al. (2007) and Pejchar et al. (2006) fuse the biophysical, economic and institutional needs of an area in their recommendations. This combination of addressing those needs fits in well with the conservation context in the developing world, given the configuration of people, settlements, wildlife habitats, and agricultural land. This further reinforces the concept of planning for a matrix (biodiversity conservation corridor) rather than a linear corridor. To do so, components in the matrix must be identified and corridors must be used as a "conservation tool" designed to suit specific conditions and ecosystems (Gustafsson and Hansson 1997, 182). Last, but not least, to sum up in Forman's words,

> ... for any landscape, or major portion of a landscape there exists an optimal spatial arrangement of ecosystems and land uses to maximize ecological integrity. The same is true for achieving basic human needs and for creating a sustainable environment. If so the major but tractable challenge is to discover the arrangement. (Forman 1995, 522)

To conclude, habitat fragmentation is a threat to biodiversity in India and conservation plans need to work within the complexities of a growing population, extension of agricultural land, development initiatives and socio-cultural dynamics of the people. While an in-depth analysis of all these factors is not practically feasible, this research attempts to conduct a preliminary analysis into the biogeography and socioeconomic aspects in Chittoor district, which will be the basis for providing conservation recommendations. The chapter that follows elaborates on the various methodologies used for this research.

CHAPTER III

DATA AND METHODOLOGY

3.1 Introduction

Given the state of habitat fragmentation in India, a need for wildlife corridors to supplement the existing network of Protected Areas is evident. Several wildlife corridors have already been identified and efforts are being made to link fragmented landscapes (Menon et al. 2005). These initiatives aim to ensure the survival of remaining populations of flora and fauna and conservation of the landscape matrix. This research will assess the feasibility of a wildlife corridor between the Rayala Elephant Reserve and Sri Venkateswara National Park in Chittoor district of Andhra Pradesh, India. According to Casterline et al. (2003), "the corridor feasibility analysis is a process that assesses the likelihood that an ecological corridor can be implemented" (75). To assess the likelihood of a corridor in the study area the analysis is divided into three research goals. The first two analyze the biogeographic and socioeconomic dynamics within the district. In addition, potential linkages are identified between the two Protected Areas and the feasibility of these linkages is assessed. The third and final dimension of this research aims at integrating the results from the socioeconomic and biogeographic analysis to provide conservation recommendations based on the feasibility analysis. A detailed review of the methodologies will be described in the following subsections under each research goal.

3.2 Identify socioeconomic factors contributing to forest area in Chittoor district and determine their relative contributions

To address issues related to forest degradation and/or habitat fragmentation, understanding the causal factors contributing to the current distribution and configuration of forests is important. While there are many studies (Anand et al. 2010; Davidar et al. 2010; Rawat 1997; Robbins et al. 2009) that have dealt with the reasons which can often be generalized across space, there are space-specific causal factors too. More specifically, this study analyzes the influence of the extent of agricultural land, extent of non-agricultural land, poverty, tribal population, and number of livestock on forest area in Chittoor district using an Ordinary Least Squares (OLS) regression analysis. In the state of Andhra Pradesh, each district is subdivided into administrative divisions called mandals. Since the study area comprises one district with 66 mandals, data were required at the mandal level to analyze factors contributing to forest area.

3.2.1. Data collection and manipulation

Data have been extracted from the A. P. Government's *Handbook of Statistics for Chittoor District 2010* for the independent variables and from A. P. Forest Department's *The State of Forests Report (2010) Andhra Pradesh* for the dependent variable. Since data at the required scale were unavailable online, the printed version of the *Handbook of Statistics for Chittoor District 2010* was acquired from the district headquarters in Chittoor town. Scanned copies of the required data sheets were sent via email, by the Executive Director of LORIS, an organization working on conservation issues in the area. Subsequently, the data were entered manually into PASW (a program used for statistical analysis). To spatially delineate the selected variables, a mandal level map was created using ArcGIS 10. Based on an image of the district retrieved from the Andhra Pradesh Government online portal, a district map with the mandals was digitized.

The data were also manipulated for use in an Ordinary Least Squares (OLS) regression analysis. This involved standardizing the variables based on either geographic area, forest area, or in some cases calculating the density. The metadata are provided in Appendix 1, and the final variables used are listed in Table 3.1.

Table 3.1. Variables selected for the OLS regression

Dependent Variable*	% Forest cover
Independent Variables	% Agricultural area
	% Area used for non-agricultural purposes
	% Poverty
	% Tribal population
	Goats per km^2 of forest area
	Cattle per km^2 of forest area

Source: *A. P. Forest Department, The State of Forests Report, 2010.
A.P. Government, Handbook of Statistics for Chittoor District, 2010.

3.2.2. Exploratory data analysis

An exploratory data analysis was conducted for each variable to assess its distribution, check for normality, and assess the value of including it in the analyses.

The rationale behind selecting each variable along with choropleth maps to assess the spatial variation is addressed in Chapter IV. The choropleth maps use the natural breaks method of classification and were developed using ArcGIS 10. A Pearson's correlation analysis was also conducted to assess correlations between variables.

3.2.3 Regression analysis

An OLS regression analysis was conducted to assess the level of influence of each independent variable on the dependent variable. This was followed by an assessment of the assumptions of a regression model in order to validate the results. The assumptions of a regression model are analyzed using the residuals in the model (Burt et al. 2009). The four assumptions tested were:

a) Mean of residuals is zero

b) Constant variance of the variables

c) No autocorrelation in residuals

d) Normal distribution of error terms

3.3 Propose a potential corridor based on the social and biogeographic conditions between Rayala Elephant Reserve and Sri Venkateswara National Park

The second research goal was split into two parts. The first part involved examining the feasibility of creating a biodiversity conservation corridor based on the spatial configuration of land use in the study area. The second part involved assessing the study area to prioritize conservation areas and identify potential linkages.

3.3.1 Assessing the spatial configuration of the landscape

To assess the spatial configuration of land use in Chittoor district, Fragstats (a commonly used software for spatial analysis of landscape metrics), was used. Landscape metrics are defined as "algorithms that quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics" (McGarigal et al. 2002). These metrics facilitate an understanding of the landscape context with a focus on the pattern and process in a given landscape, in relation to the scale and species under reference. Although review of literature shows an extensive use of landscape metrics in the past two decades, there is still little consensus about which metric or set of metrics represents a landscape optimally (Gustafson 1998; Li and Wu 2004; McGarigal et al. 2002; Peng et al. 2010). The issues often discussed are based on the correlation between indices, the ecological relevance and the lack thereof, or misinterpretation of what the index represents. Most reviewers and critics suggest that the research objective, the scale of the study, and the species of interest play an integral role in determining which landscape indices should be used. Connectivity metrics are a group of metrics often used to measure the continuity (structural connectedness) and connectivity (functional connectedness as perceived by the organism) of a landscape (McGarigal et al. 2002). Thus, identification of relevant metrics and the level (patch/landscape) at which they can be used will be the first step. This will be followed by computation of the metrics and finally an analysis will provide insight into the likelihood of developing a biodiversity conservation corridor.

Further, since biodiversity wildlife corridors are typically designed for a particular species, the Indian Wild Dog or Dhole (*Cuon alpinus)*, an endangered species endemic to the area, was selected for this study. The habitat requirement of the Dhole and its migratory behavior were considered in the process of identifying an area for conservation priority and in assessing the linkages proposed. However, since the focus is on conservation recommendations for the study area, these will not be solely based on the specific requirements of the Dhole. Rather it will be an amalgamation of inputs from the biogeographic, socioeconomic, and practical perspective. This approach is in line with Morrison and Reynolds (2006), who state,

> … than investing a great deal of planning and analytical effort into the ideal placement of a corridor from a biological perspective, it could be more fruitful to first identify a range of feasible corridors and then simply ask if any of the practical options will meet the biological needs. (542)

While the choice of species is not entirely arbitrary, specific methodologies have not been used for the selection process. The choice is based on several factors, including the Dhole's conservation status on the International Union for Conservation of Nature (IUCN) Red List and the Convention on Trade in Endangered Species of Wild Flora and Fauna (CITES) (Grassman et al. 2005). Secondly, Majka et al. (2007) suggest that selecting ecologically important species is one of the ways to select a focal species and also emphasize that selecting large carnivores in the process of designing a corridor is not advisable. In this context, the Dhole is ecologically important since other predators in the area are absent or limited to small pockets within the district. The Dhole also has large area requirements in comparison to other predators like the tiger, estimated at needing a critical reserve size of 723 km^2, while tigers require only 135 km^2 (Woodroffe and Ginsberg 1998). Thirdly, studies (Grassman et al. 2005; Venkataraman et al. 1995) on the spatial ecology of the Dhole suggest that they often move in packs based on prey availability, and the decision to move is based on "temporal changes in hunting success" (Venkataraman et al. 1995, 559). Last but not the least, local knowledge (with regard to seasonal migration of animals through this area) of villagers has also been a contributory factor in selecting the Dhole as a focal species for my research. Villagers consider the Dholes a menace since they prey upon cattle and goats grazing in the forest (Jones 2012). Although specific information on the Dhole has not been used to calculate the metrics, references have been made to the habitat requirements and migratory behavior of the species for this study.

The metric calculations use the land use/land cover (LULC) raster data available for the study area. This dataset is based on 2002 satellite imagery and has been classified by World Wildlife Fund (WWF), India into the different land uses which encompass forests, agricultural land, fallow land, and human settlements. A description of the cover type classifications is shown in Table 3.2.

Table 3.2. Classification of LULC data

Cover Type	Description
Dry Evergreen Forest	Areas of thick and dense canopy of tall trees, which remain predominantly green throughout the year.
Moist Deciduous Forest	Forest types that are predominantly composed of species that shed their leaves once a year, often during winter. Receive more rainfall than areas having dry deciduous forests.
Scrub Forest	Forest areas where the crown density is less than 10% of the canopy cover.
Dry Deciduous Forest	Forest types that are predominantly composed of species which shed their leaves once a year, especially during summer.
Thorn Forest	Similar to scrub forests but consists of more thorny species (which have often evolved as an adaptation to over-grazing).
Wasteland	Degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of water and soil management or because of natural causes.
Plantation	Areas under tree crops (agricultural/non-agricultural) planted adopting certain management techniques.
Agriculture	Areas used for agriculture
Fallow Land	Lands used for cultivation but are temporarily uncropped for one or more seasons, but not less than one year.
Water Bodies	Areas with surface water, ponds, lakes or reservoirs or flowing as streams, rivers and canals.
Open/barren/rocky exposed	Similar to wastelands, but predominated by rocks
Settlements	Areas of human habitation developed due to non-agricultural use

Source: National Land Use and Land Cover Mapping, NRSA (2006)

3.3.2 Identifying conservation priority areas

There are numerous methods to identify conservation priority areas. Brooks et al. (2006) review the nine templates often used at a global scale (the crisis ecoregions, biodiversity hotspots, centers of plant diversity, megadiversity countries, global ecoregions, high-biodiversity wilderness areas, frontier forests, last of the wild, and endemic bird areas) and state that the methods used at a global scale are often not in tune with reality at the local scale. Other authors (Bonn and Gaston 2005; Menon et al. 2001) echo similar sentiments and have used local information which includes data on species, environmental variables like climate, topography and vegetation, fragmentation, and methods of land use modeling to prioritize conservation areas. Often specific criteria are designed to categorize the land based on a vulnerability index. With the objective of identifying corridors and barriers, Cushman et al. (2010) map landscape resistance for elephant movement in southern Africa. As part of this process the authors assess the influence of water sources, human settlements, roads, and wildlife fences on the movement of elephants in South Africa (Cushman et al. 2010). With the constraints of the data available for the study area, the location of Protected Areas, forest cover, settlements, and roads in combination with water availability (streams and tanks[8]) is used to identify logical connections in the landscape matrix. Details on the data layers have been listed in Table 3.3.

Table 3.3. Raster and vector data layers used in the analysis *,+

	Layers	Data Model	Description
1.	Land Use and Land Cover	Raster	Details given in Table 3.2
2.	Forest Cover	Vector (polygons)	Different forest blocks and other patches of trees in the form of scrub or plantations
3.	Water (streams and tanks)	Vector (line and polygons)	Streams and tributaries and tanks/ponds
4.	Settlements	Vector (point)	Towns and villages
5.	Roads and railways	Vector (line)	Highways, arterial roads and un-metalled roads(gravel)
* Datum: World Geodetic System: WGS_1984			
+ Scale: 1:50,000 (approx. 30m resolution)			

[8] Tanks in southern India are an ancient method of harvesting and storing rain water in a watershed area. They are traditionally used for agriculture and for livestock, especially in areas where streams are seasonal in nature.

In addition to using the vector data to identify potential areas, another consideration was the criteria for biodiversity conservation corridors outlined by Sanderson et al. (2006), which include a protected area system, a connectivity network, and compatible land use with varying degrees of human occupation. After selecting a segment of the study area, the land use in this segment is assessed in addition to calculating three landscape level metrics to assess structural contiguity. The reason for carrying out this analysis is to compare the selected area to the rest of the study area in terms of its landscape composition and configuration.

3.3.3 Identifying potential linkages in the landscape

a) Connectivity in the landscape: Quantifying connectivity in a landscape is of paramount importance prior to designing a corridor as it assesses both the structural and functional potential of a landscape to act as a linkage. Connectivity is often studied from this perspective (the structural and functional), but Fagan and Calabrese (2006a) further break down functional connectivity into actual and potential connectivity. Structural connectivity refers to the physical connectedness of patches and does not necessarily include species specific data. On the other hand, actual connectivity is based on species movement data and provides a direct estimate of linkages in the landscape (Fagan and Calabrese 2006a). Potential connectivity is assessed based on indirect knowledge of the concerned species in combination with the spatial configuration of the landscape (Fagan and Calabrese 2006a). Thus, connectivity is best analyzed based on the species selected and its corresponding landscape, although data availability often defines the process.

Fagan and Calabrese (2006b) offer six methods to quantify connectivity based on specific data requirements for each (Table 3.4).

Table 3.4. Methods to quantify connectivity

Method	**Data required**	**Potential use for this study**
Patch occupancy and nearest neighbor distance	Occupancy Nearest neighbor distance	Low
Spatially explicit habitat data	Raster/Vector form of habitat data (quantifies structural connectivity)	Moderate
Point or grid based occurrence data	Species level data	Low
Spatially explicit habitat data with dispersal data	Dispersal data Graph theoretic approach to assess connectivity	Moderate
Spatially explicit patch occupancy	Patch level & Dispersal data	Low
Individual movement data	Calculates actual connectivity based on observation data	Low
Source: Adapted from Fagan and Calabrese (2006b)		

Based on the data available for this research, using any of the methods would be difficult, although the one based on “spatially explicit habitat data with dispersal data” (Fagan and Calabrese 2006b, 304) seems the most reasonable. This method addresses the potential connectivity of a landscape with some preliminary data on the species dispersal ability. The graph theoretic approach establishes potential connections between patches and can also simulate the destruction of habitat patches in the matrix (Fagan and Calabrese 2006b). Chetkiewitz et al. (2006) also suggest using graph theory to assess connectivity in their review on tools and techniques to model corridors to better integrate pattern and process. The graph theory approach borrows from other disciplines like transportation and computer network analyses, and combines aspects of percolation theory and least-cost path modeling to assess landscape connectivity (Chetkiewitz et al. 2006). This approach has been tested across various landscapes and landscape models to assess connectivity, and has been recommended by various authors (Laita et al. 2011; Minor and Urban 2008; Pascual-Hortal and Saura 2006; Urban et al. 2009). Although highly recommended, there are limitations to using this approach, like the identification of a single link between nodes even though there may be multiple connections (Laita et al. 2011), the inability to interpret graph models in an ecologically relevant manner (Urban et al. 2009) and the process of identifying nodes that often tend to be based on binary depictions of the matrix (Chetkiewitz et al. 2006). Each of the six methods discussed by Fagan and Calabrese (2006b) identify structural, potential, or actual connectivity which implies that the research objective in combination with the available data determine the method used to assess connectivity in the landscape. In context of the study area, the constraints of the data available and the context of a biodiversity conservation corridor determine the extent of this research.

Sanderson et al. (2006) state that biodiversity conservation corridors are a response to both present habitat fragmentation and anticipated losses of habitat due to development objectives. Despite the fact that biodiversity conservation and economic development are often opposing objectives, biodiversity conservation corridors are designed precisely to incorporate these two objectives and allow them to coexist. The study area includes the S.V. National Park, Rayala Elephant Reserve and Koundinya Wildlife Sanctuary, making it a part of the Protected Area system, which is an essential component in the connectivity network between the Nilgiri Biosphere Reserve in the Western Ghats and the rest of the Eastern Ghats. Secondly, the study area is interspersed with human settlements, the majority of which are rural. Thus land use in this region is an amalgamation of agriculture, grazing, forests, and revenue wastelands[9]. Potential linkages were identified based on the distance between forest patches, presence of roads, settlements, and availability of water. Prior to finalizing this method, various permutations were attempted to use graph theory to identify the potential linkages in the study area.

b) Assessing the linkages: Once potential linkages are identified, their viability needs to be tested. A number of methods can be used, some of which have been discussed earlier. The most common and the most criticized method is the least cost path model, which can be employed with little data. Other methods like boundary permeability and perceptual range models have also be used (Urban et al. 2009) to assess the weight of proposed linkages. For this research, owing to lack of data on the species dispersal, an alternative method was chosen to assess the linkages. With the unavailability of raster data to estimate the least cost path using Arc GIS, a weighted matrix analysis was used to assess the feasibility of each linkage. A similar method was used by Cushman et al. (2010) in the process

9 Areas that do not generate revenue as per the definition of the Forest Department; this was essentially a land categorization initiated by the British which referred to a land’s revenue generating capacity, and not its biological productivity.

of “mapping landscape resistance for elephant movement” in South Africa (Cushman et al. 2010).

Prior to assessing the linkages, a hotspot analysis for forest area in the district was carried out. This was done using the Getis Ord-G_i^* statistical tool in ArcGIS 10 to obtain a visual approximation of the areas where there are clusters of high-high and low-low values. A fixed distance band was used that uses a critical distance across the study area to assess the hotspots. This helped assess the landscape visually, thus confirming that the linkages identified were situated in appropriate locations based on forest cover in Chittoor district.

3.4 Provide conservation recommendations based on the corridors identified

The final step covered in Chapter VII will be an amalgamation of the results of the first two research goals, essentially a product of both the biogeographic and socioeconomic factors in Chittoor district. Although fusing these two objectives is not easy, it is something that any conservation plan has to deal with, especially in developing countries. With the objective of developing a biodiversity conservation corridor between S. V. National Park and Rayala Elephant Reserve, the conservation recommendations will also have to be within the present policy framework in India. A review of literature provides a theoretical framework to the “institutional misfit” (Brown 2003) which is followed by an analysis of the empirical data. Different scales of intervention are identified along with specific policies, which may aid in the process of establishing a biodiversity conservation corridor. Finally, conservation recommendations are provided which target both biodiversity conservation and socioeconomic conditions in Chittoor district.

CHAPTER IV

FACTORS CONTRIBUTING TO FOREST AREA IN CHITTOOR DISTRICT

4.1 Introduction

Diverse socioeconomic factors affect the natural environment making it difficult to assign specific causal factors that lead to fragmentation of forests. In Chittoor district, forests cover 30% of a geographic area that includes dry mixed deciduous, dry evergreen, scrub, and thorn forests (AP Forest Department 2010). The district has three Protected Areas (with varying degrees of protection) namely the S.V. National Park, the Rayala Elephant Reserve, and the Koundinya Wildlife Sanctuary encompassing 1,235 km^2. These areas cover only 0.27% of the entire forest area within the district, exposing the remaining areas to precarious states of protection and exploitation. The underlying causes of forest decline are captured by Contreras-Hermosilla (2000) who explains the process as a “complex socioeconomic, cultural and political event” (1). Thus, attributing a cause-effect relationship is not only fallacious by itself, but also misleading, as relationships are constantly changing over time (Contreras-Hermosilla 2000). The objective of this chapter is to address the first research goal, to identify some socioeconomic factors contributing to forest area in Chittoor district and assess their relative contributions. In the following sections, I explain the rationale behind the variables selected and discuss the correlation between each variable and forest area.

Finally the results of an OLS regression analysis are presented followed with a test for the assumptions (of an OLS regression model) in order to validate the results.

4.2 Individual variable analysis

For the analysis of individual variables, a rationale is provided for selecting each variable followed by an assessment of its distribution in Chittoor district. In addition, the correlation between each independent variable and forest area, the dependent variable, is discussed. This section concludes with a discussion of the highlights of the correlation analysis. Choropleth maps are used to show the spatial distribution of each variable across the district, which includes 66 mandals[10]. A mandal map has been provided in Appendix 2. All maps were made using ArcGIS 10 and follow the natural breaks method of classification. The correlation between variables was determined using Pearson's correlation that essentially shows the linear relationship between two variables (Burt et al. 2009). The correlation coefficients are represented by r and range from -1 to +1, where a coefficient of +1 indicates a perfect positive relationship and a coefficient of -1 a perfect negative relationship. The strength of the coefficient is assessed based on how close it is to either end of the spectrum (-1 to +1). Prior to carrying out the correlation and regression analyses, an exploratory data analysis was performed to assess the normality of each of the selected variables. These have been summarized in Table 4.1.

[10] Mandals are administrative sub-divisions of districts.

Table 4.1. Univariate analysis for variables used in the regression analysis

Variables	Mean	Median	Skewness	Kurtosis
% Forest area	27.2	22.9	.703	-.188
% Agricultural area	27.70	27.86	-.033	.522
% Area used for non-agricultural purposes	10.33	10.16	.053	-.634
% Tribal population	1.51	1.10	1.540	2.834
% Poverty	22.81	23.91	-2.010	3.799
Cattle per km^2 of forest	.83	.53	2.576	7.527
Goats per km^2 of forest	1.01	.64	1.418	1.424

Among the variables, percent poverty and number of cattle per km^2 are the two variables showing a leptokurtic curve which may be of concern (as a regression model predicts the influence of the independent variables on the dependent variable best when they are normally distributed). Other than this, based on the mean, median and skewness, all seven variables appear to be normally distributed. Thus, one can postulate that using them for an OLS regression analysis is viable. The individual variables are discussed below.

a) Forest area: The rationale for selecting this variable as the dependent variable has been explained in previous sections. The mandals with high percentage of land covered by forests lie on the northeastern section while the northwestern portion show a higher number of mandals in the lower range of the classification system. The area between the two Protected Areas (S. V. National Park and Rayala Elephant Reserve) appears to have relatively high to moderate forest cover, which can be seen in the diagonal across the northeast and southwest portion (Figure 4.1).

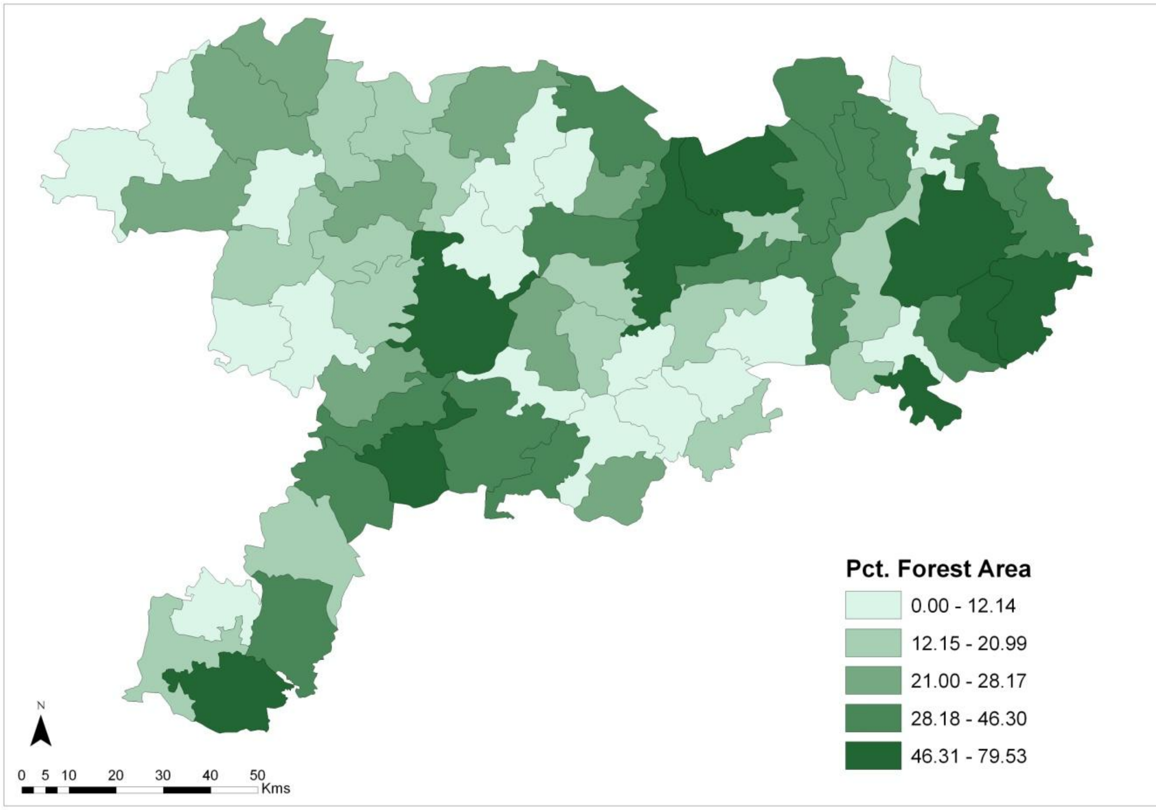

Figure 4.1. Percent forest area in Chittoor district

b) Agricultural area: In India, multiple factors lead to fragmentation and loss of forests as discussed in the literature review. Considering that use of land for agriculture still plays an important role in the landscape matrix, assessing the influence of this variable on forest cover is important. There are multiple reasons for an increase in agricultural area, such as population growth, change in farming practices, power politics and weak institutions governing common property resources. What starts as land encroachment, especially on the fringes of reserved and unreserved forests, often leads to an extension of agricultural area. There are three categories of forests in

India, namely Reserved[11], Protected[12] and Unclassed[13] Forests (Forest Survey of India 2003). The different classifications reflect the degree of protection a forest area receives and provides insight into the potential amount of pressure by humans on forests. On the face of it, expanding agricultural area depletes forests (considering deforestation, the influence of pesticides and other inputs on fields), but on the other hand, fields surrounding forests benefit from an increased availability of ground water and the presence of pollinators. The reason for selecting this variable was to assess whether there is a positive or negative association between agricultural area and forest area, and to gauge the level of influence.

Chittoor district has a relatively high percentage of land under agriculture. Agricultural area in the mandals on the lower end of the spectrum range from 1.7 to 16% and those at the higher end cover 40-50% of the total land area (Figure 4.2).

[11] Reserved Forests are areas designated under the Indian Forest Act of 1927. They are well protected as most activities are prohibited here unless allowed by the Forest Department.
[12] Protected Forests are also areas designated under the Indian Forest Act of 1927. Most activities are allowed here unless prohibited.
[13] Any forest area not designated as reserved or protected forests is an unclassed forest.

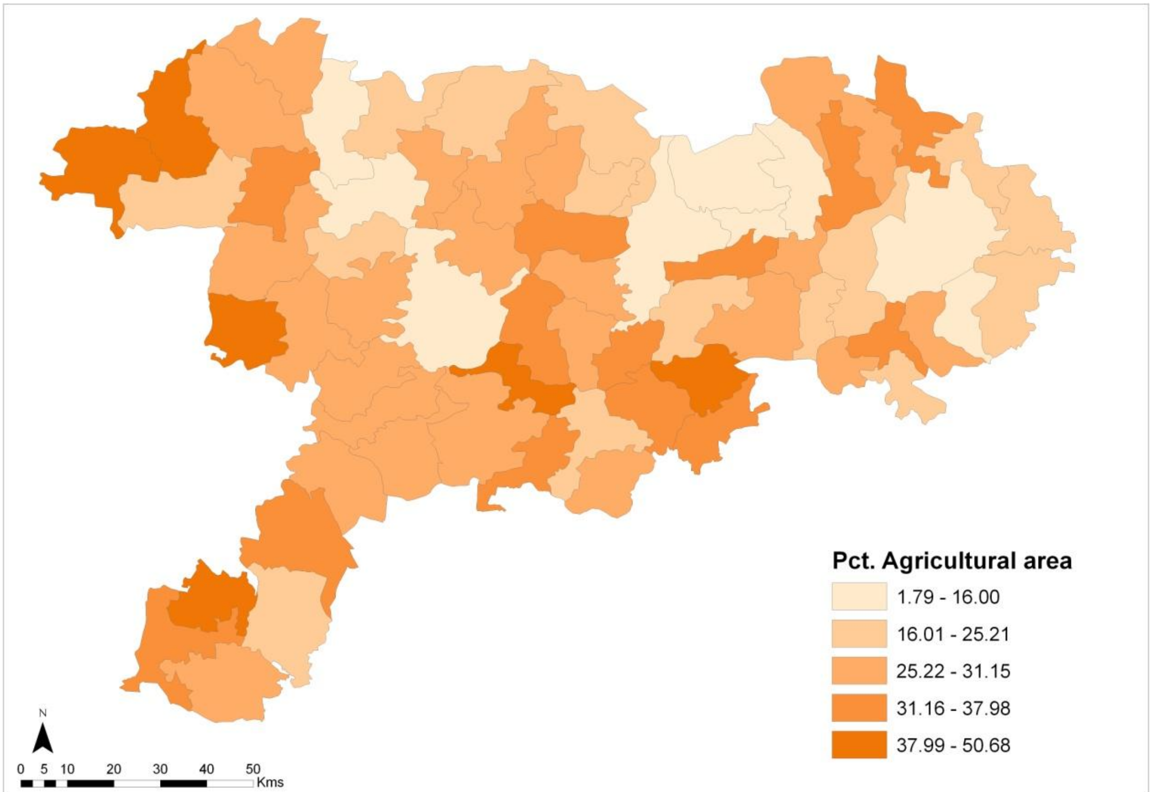

Figure 4.2. Percent agricultural area in Chittoor district

The district also has very few urban areas making agriculture a primary source of livelihood for a large majority of the population. The bivariate analysis based on Pearson's *r* value provides a negative correlation at -0.623, thus confirming the hypothesis that increased agricultural area implies less area for forests. In the context of the larger question, the implications of this will be to integrate agricultural area into the conservation recommendations that will be provided for the study area.

c) Area used for non-agricultural purposes: The second independent variable used for this analysis is area under non-agricultural use, which is essentially land used for any purpose other than agriculture (A.P. Government 2010). This includes land used by cottage industries, poultry farms and community owned land. Although the explanation provided is ambiguous in nature, this is not land classified as urban areas. Rather it is the area in a mandal unaccounted for under the categories of agriculture, fallow, or pasture/grazing land. The reason for including this in the analyses is that it may be a prospective area to be accounted for in the conservation plan because the community usually owns this land. Conversely, if the area includes built-up area, using it for the biodiversity conservation corridor will not be an option.

The percentage of area for non-agricultural purposes accounts for a small percentage of land in each mandal, ranging from 2.4 % to 19.29%, which does in some cases overlap with the more urbanized mandals (Figure 4.3).

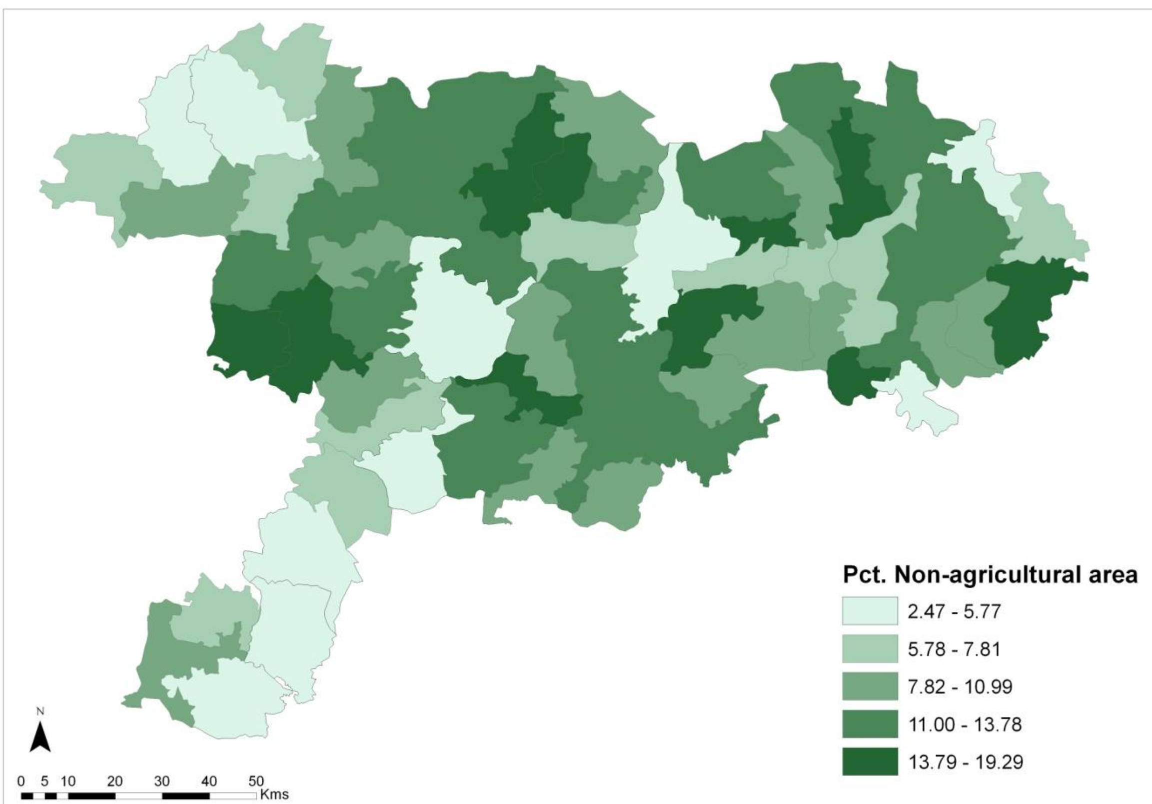

Figure 4.3. Percent non-agricultural area in Chittoor district

The bivariate analysis provides a negative correlation of -0.412 indicating a moderate relationship between non-agricultural area and forest area. Secondly, the correlations between this variable and other independent variables indicate that it does not correlate significantly with any other variable. This suggests the need to explore the precise use of this land category at the field level, and then assess whether employing it as a part of the corridor is an option.

d) Tribal population: The third independent variable used for this analysis is the percent of population that is tribal. The rationale for selecting this variable is that approximately 50% of the tribal population in India lives in or at the fringes of forest areas (World Bank 2006). Andhra Pradesh has a tribal population of 6.63% (Ministry of Tribal Affairs 2012) and although Chittoor district does not have the highest population, the numbers are significant. Another reason for including this variable is the highly skewed distribution (towards the three large towns) of population density in the district, details of which are in Appendix 3. Since the objective is to analyze the influence of specific socioeconomic factors on forest cover, taking the tribal population into account seemed logical.

Every mandal in the district has a tribal population and the population ranges from 292 to 8135, in Palasamudram and Srikalahasti respectively (see Appendix 4). The mandals that have a higher percentage of tribal population appear to form a cluster in the northeast part of the district (Figure 4.4), which does correspond with high forest area in the same section. There also appears to be a consistent area of relatively high populations in the area running from the northeast to the southwest part of the district. The bivariate analysis provides a moderate correlation between forest area and percent tribal population at 0.411.

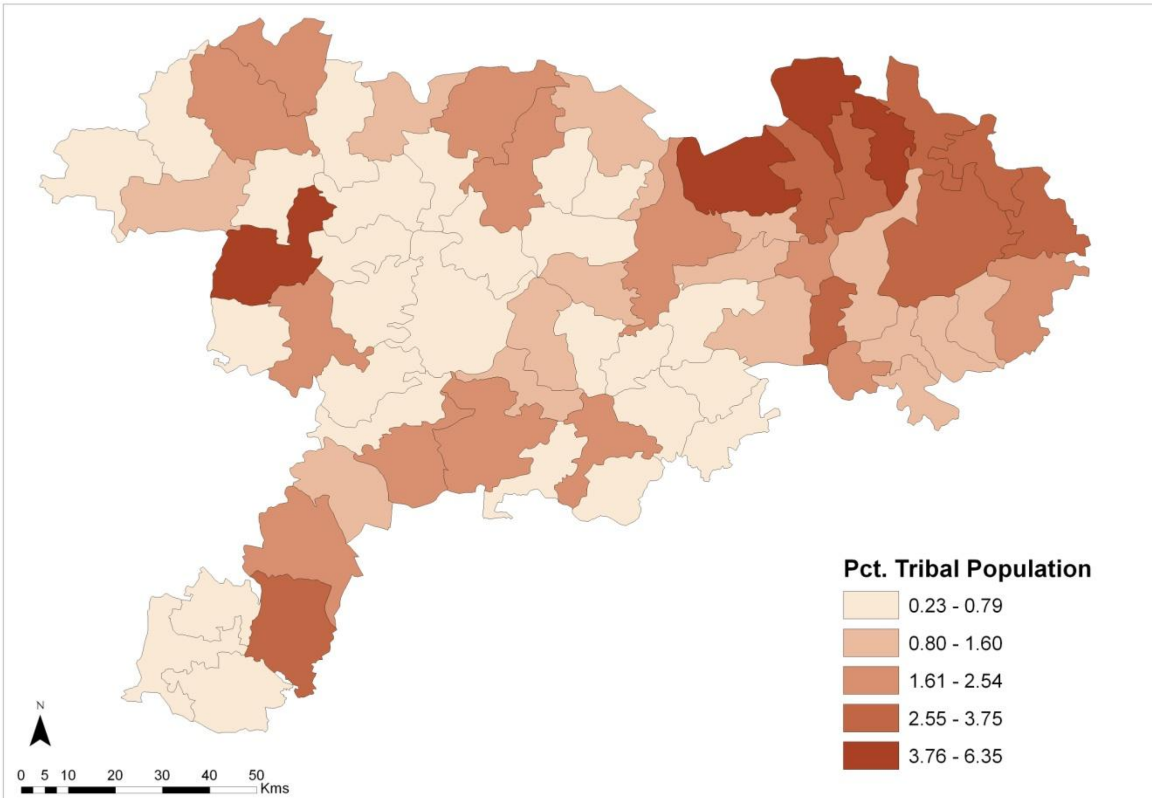

Figure 4.4. Percent tribal population in Chittoor district

e) Poverty: The fourth independent variable selected for this analysis is poverty. The variable is based on the number of (Below Poverty Line[14]) white cards, issued by the state government in each mandal. While poverty, and its contribution or lack of, to forests is a contentious issue as discussed in the literature review earlier, exploring the relation between these two variables will clarify the significance with regard to the study area. The map shows that the percentage of people living below the poverty line

[14] BPL or Below Poverty Line is an economic threshold proposed by the Government of India. Individuals/households who earn less than the stipulated amount are considered to be economically disadvantaged and are issued BPL cards (in Andhra Pradesh they are known as 'white cards').

are distributed across the district, with only a few mandals in the lower range of 6-12% and a large number in the segment of 22-30% (Figure 4.5).

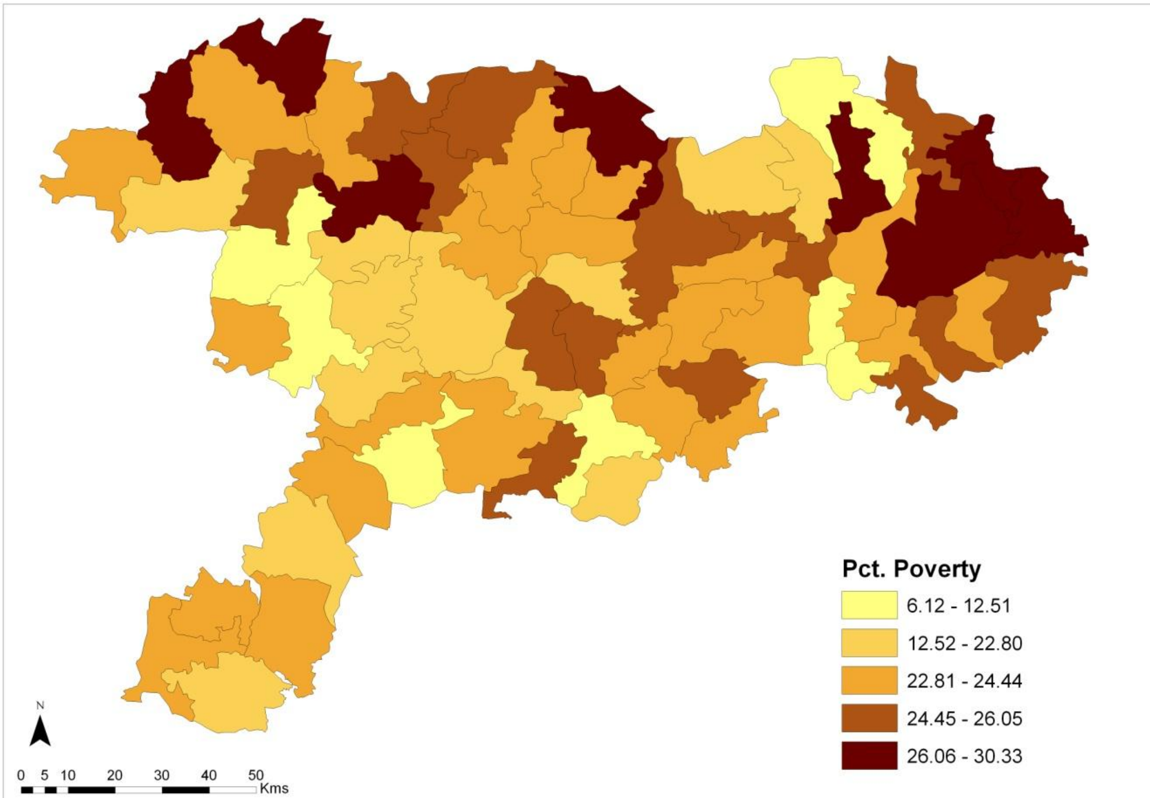

Figure 4.5. Percent poverty in Chittoor district

This also explains the inclusion of Chittoor district under the 250 (among 629 districts) "most backward districts" in the country (Ministry of Panchayati Raj 2009) as described by the Ministry of Panchayati Raj. Overall, from the spatial distribution of poverty one can infer that poverty rates are high in Chittoor district. Therefore, this will be an important factor in the conservation recommendations, even though the bivariate analysis shows a low positive correlation of 0.021 between forest area and poverty. The correlation indicates that areas with high rates of poverty have little relation to the area covered by forests in this district. Yet, considering that managing the needs of people (and biodiversity) is integral to the biodiversity conservation corridor one cannot ignore poverty as a factor, based on the lack of correlation.

f) Livestock: The rationale for the fifth and sixth independent variables selected was the extensive pressure of livestock on forests in Chittoor district (Srivastava 2002). Additionally, according to the document "Unlocking Opportunities for Forest-Dependent People in India" published by the World Bank (2006), forests sustain the fodder and/or grazing requirements of 471 million livestock in India. Based on my experience in villages in Chittoor district, specifically in Thambalapalle, Peddamandyam and Madanapalle mandals, cattle and goats usually graze in forests, unlike sheep, which graze on agricultural lands. Chittoor is a drought prone district where fodder and water sources are scarce. Thus, villagers generally depend on forests for sustenance of their cattle and goats.

For the purpose of this analysis, I used the number of goats and cattle in each mandal to study their influence on forest cover. Forest area in each mandal was used to standardize these variables for the analysis, rather than percentage or density of livestock. The reason was the need to assess the pressure livestock have on forest area specifically, rather than the geographical area of each mandal.

- Goats per square kilometer of forest area – The bivariate analysis shows a positive correlation at 0.609 between goats per km^2 and forest area, which can be interpreted as a high correlation. The spatial distribution of goats per km^2 of forest is shown in Figure 4.6 and the mandals with high number of goats correspond to those with higher area covered by forests.

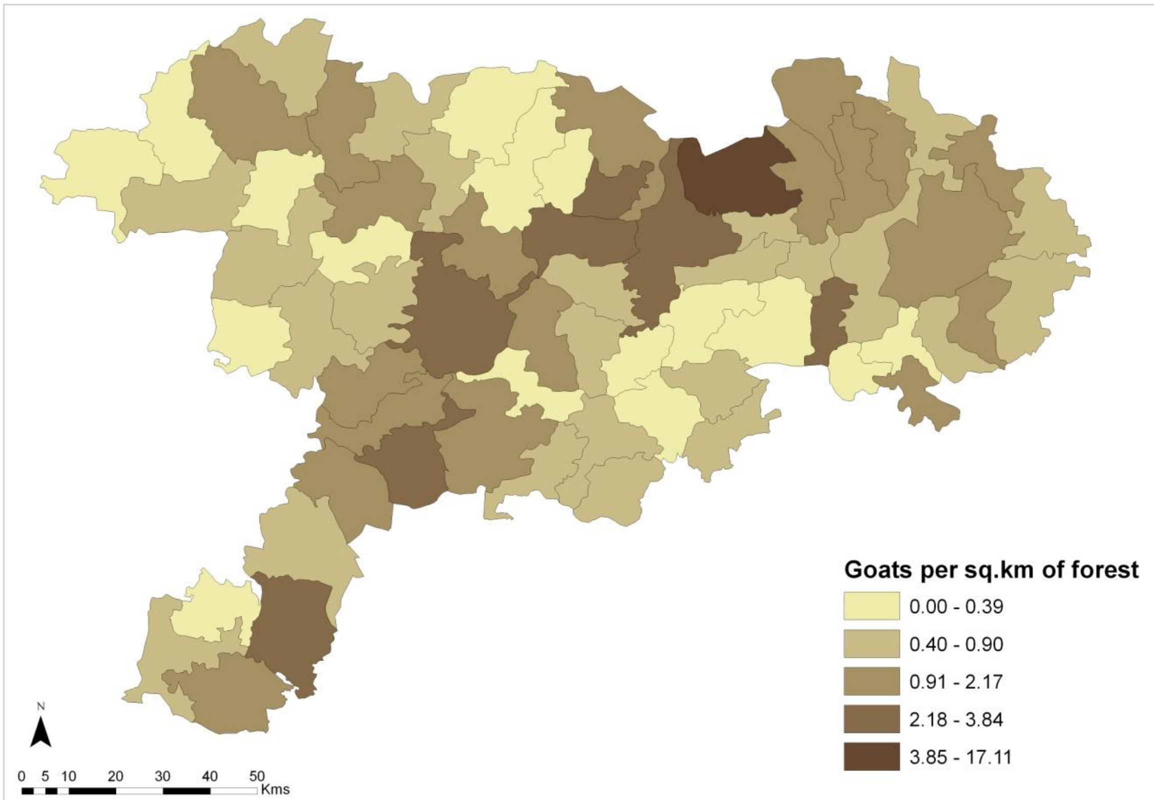

Figure 4.6. Goats per km^2 of forest in Chittoor district

- Cattle per square kilometer of forest – The bivariate analysis between cattle per km^2 and percent forest cover show a positive correlation at 0.720, which is high. The spatial distribution of cattle per km^2 of forest is illustrated in Figure 4.7.

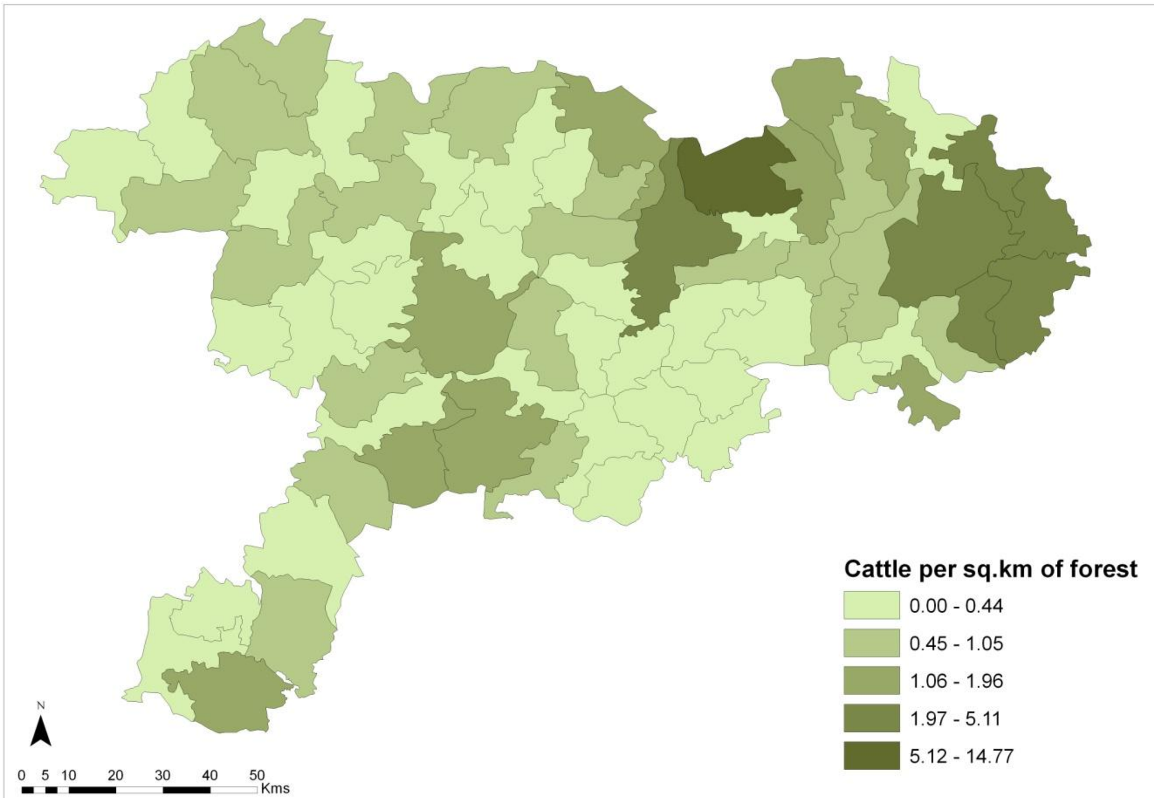

Figure 4.7. Cattle per km^2 of forest in Chittoor district

4.3. Correlation analysis

Based on the correlation analysis (Table 4.2) conducted with six independent variables and forest area as the dependent variable the following observations were made:

Table 4.2. Correlation analysis between forest area and the independent variables

Variables	Pearson's Correlation (r)	Significance (2-tailed)
% Agricultural area	-0.623	< .0001
% Non-agricultural area	-0.412	.001
% Poverty	0.021	.866
% Tribal population	0.411	.001
Goats per km^2	0.609	< .0001
Cattle per km^2	0.720	< .0001

- Both percent agricultural area and percent non-agricultural area correlate negatively with percent forest cover and the correlation is significant at a 95% confidence interval. This suggests that increases in both agricultural area and land used for non-agricultural purposes correspond to lesser area covered by forests.
- A moderate correlation exists between percent tribal population and percent forest area at 0.411, thus confirming that there is a sizeable tribal population living around forest areas.
- The only variable whose significance level is much higher than the accepted level of 0.05 is percent poverty, indicating that poverty and forest area are not correlated.
- Both cattle and goats per km^2 of forest area show a positive high correlation with percent forest area confirming the hypothesis that the number of livestock in an area is correlated to the amount of forest area.

Further, based on an analysis of the matrix scatter plot (Figure 4.8) of the six independent variables and the variance inflation factors[15] (VIF) values which range from 1.3 to 1.9, it is clear that multicollinearity between the independent variables is not an issue that needs to be considered.

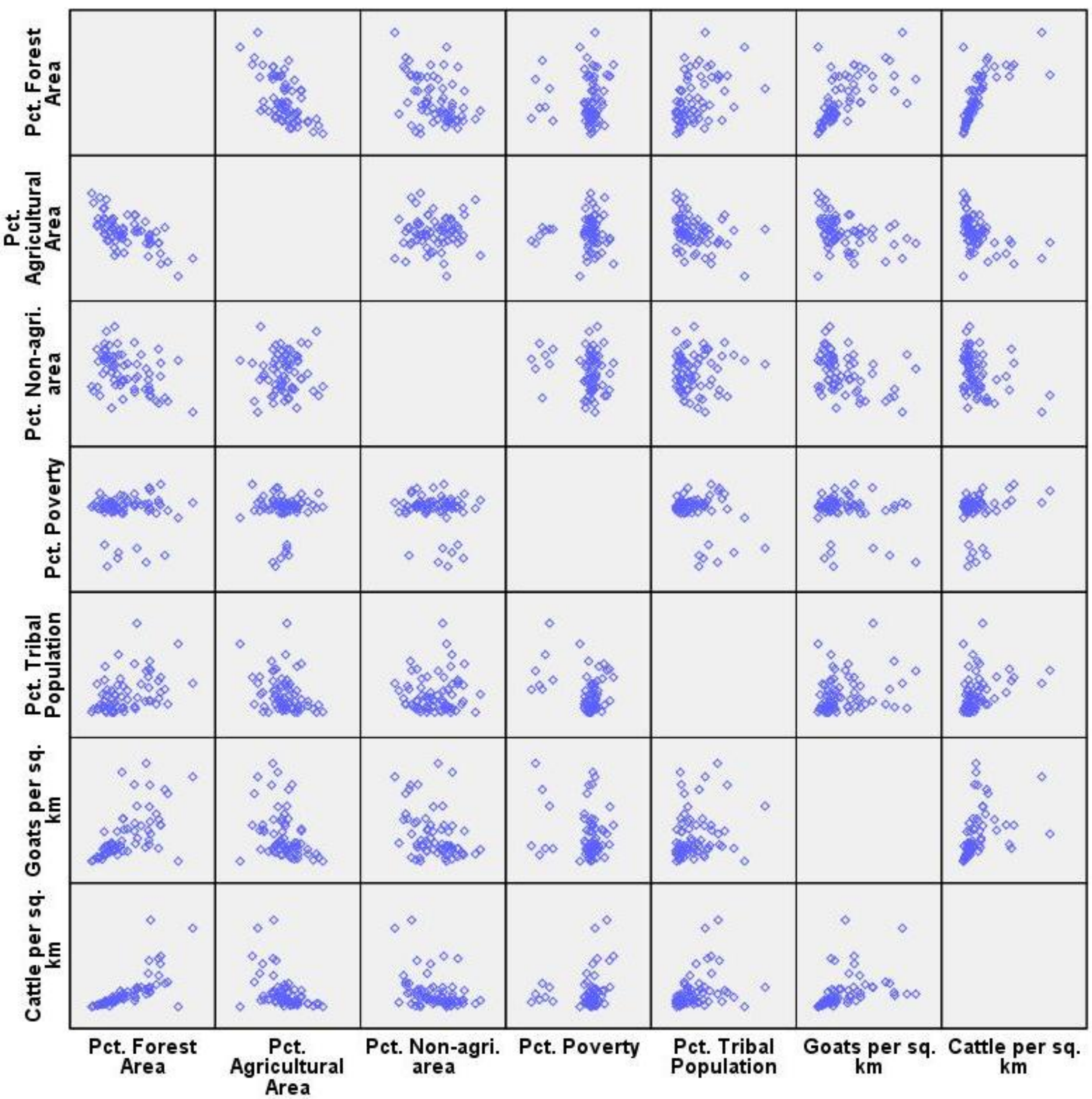

Figure 4.8. Matrix of correlation plots

[15] VIF factors are indicators of multicollinearity, and a VIF higher than 5 signifies a high degree of multicollinearity (Burt et al. 2009).

4.4. Regression analysis

Based on the exploratory data analysis and the correlation analysis, the Enter method for regression was used, as the aim was to include all the selected variables in the analyses. The regression analysis produced a significant r^2 value of 0.746 and an adjusted r^2 value of 0.720. Thus, the OLS regression explains 75% of area covered by forests in Chittoor district. The computed F-statistic (28.91) is larger than the critical value of F (2.26) implying that the six variables provide a significant explanation of forest area. Additionally the p-value of < .000 is significant which leads to the conclusion that the six independent variables are influential and significant in this model. Five of the six independent variables were significant at the 95% confidence level ($p < 0.05$). Poverty was the only variable that was not significant, at 0.775, indicating that poverty and percentage forest area are unrelated. The standard error of 9.52 shows good model fit. To establish whether this regression model meets the assumptions of an OLS regression (Burt et al. 2009), residual values were plotted against the dependent variable. Usually the assumptions of a regression model are tested prior to running the statistics based on a sample of the data (Burt et al. 2009). This was not an option with the sample size being used in this analysis, thus the test essentially checks whether the model meets the assumptions of an OLS regression. The following section deals with each assumption in detail.

Assumption 1: Mean of residuals is zero: This assumption implies that the regression model reflects a “true underlying process” (Burt et al. 2009, 472), which is practically unverifiable. Yet, since the sum of the residuals is zero the mean is also naturally zero, thus this assumption cannot be violated in practice.

Assumption 2: Constant variance of residuals: Based on the scatter plot of the standardized residuals one can see that the plot is homoscedastic (having equal statistical variance) (Figure 4.9), though one observation does fall outside the range (-2 to 2). Overall, the variance shows a constant variance of residuals.

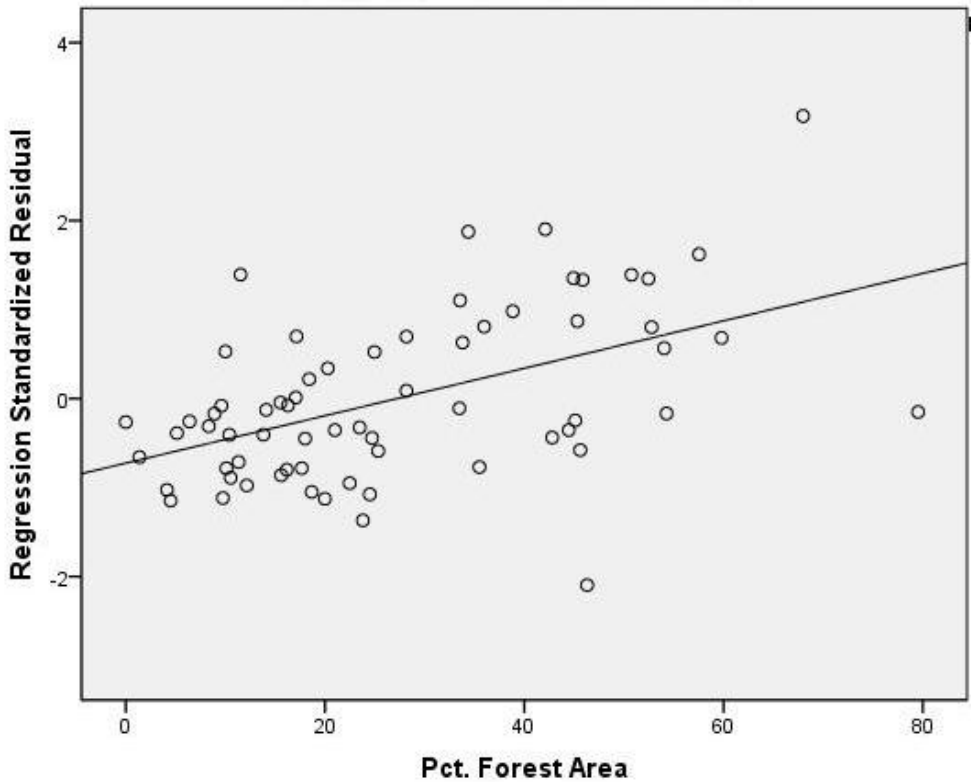

Figure 4.9. Scatter plot: Dependent variable: Pct. Forest Area

Assumption 3: Residuals demonstrate no autocorrelation: Based on a map of the residuals (Figure 4.10) a spatial pattern is visible, showing clusters of high-high (where high values are found close to each other) and low-low (where low values are found close to each other). Yet, it is not perfectly clustered, since there are areas where high-low patterns are also evident. The pattern appears to be more random than strictly dispersed or clustered. A test for spatial autocorrelation on the residuals using the Moran's *I* index in ArcGIS based on fixed distance and the Euclidean distance method was also conducted. The results showed that there was no spatial autocorrelation and the pattern was random as the Moran's index computed was 0.078. Moran's *I* ranges from –1 to 1, where values close to -1 indicate negative spatial autocorrelation or a dispersed pattern. Values close to +1 signify positive spatial autocorrelation and therefore a clustered pattern. When the values are close to zero it signifies a random distribution.

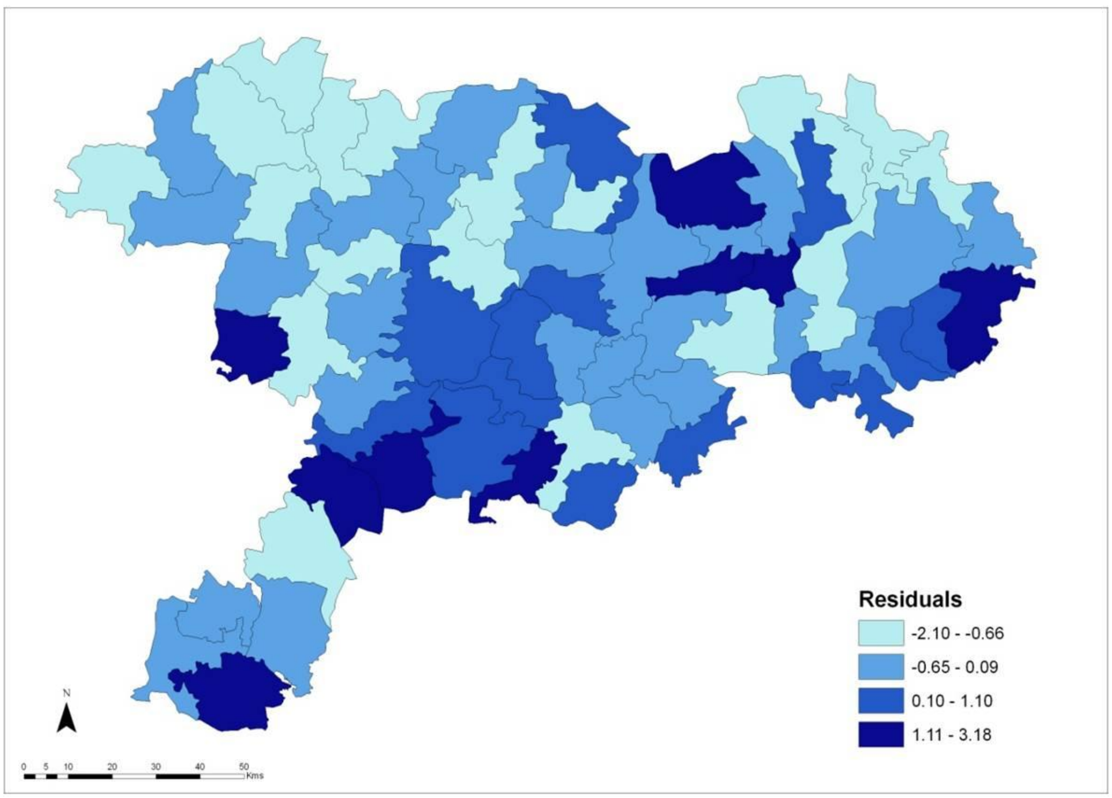

Figure 4.10. Residuals: regression analysis

Assumption 4: Error terms are normally distributed: Based on the histogram (Figure 4.11) and the P-P plot (Figure 4.12), the error terms or residuals are more or less normally distributed. This confirms that the OLS regression model used for this research is a valid model to estimate the factors influencing forest area in Chittoor district.

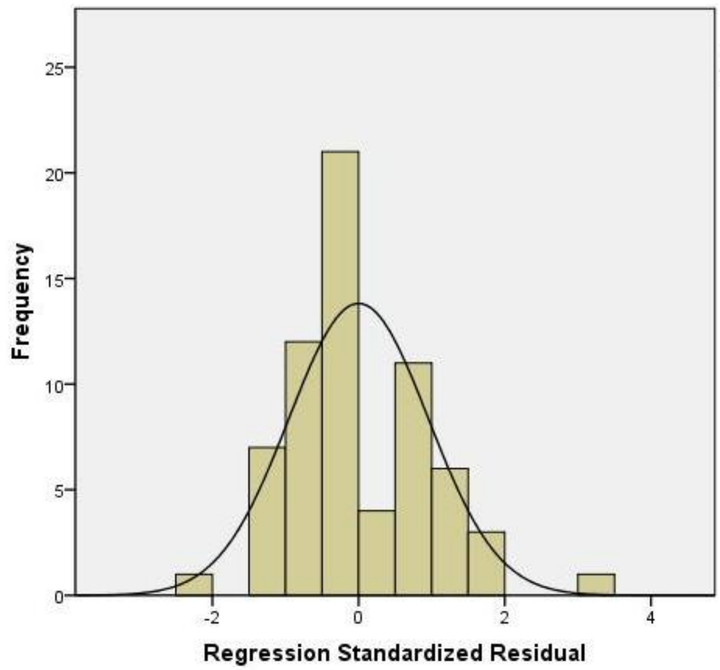

Figure 4.11. Histogram: Dependent variable: Pct. Forest Area

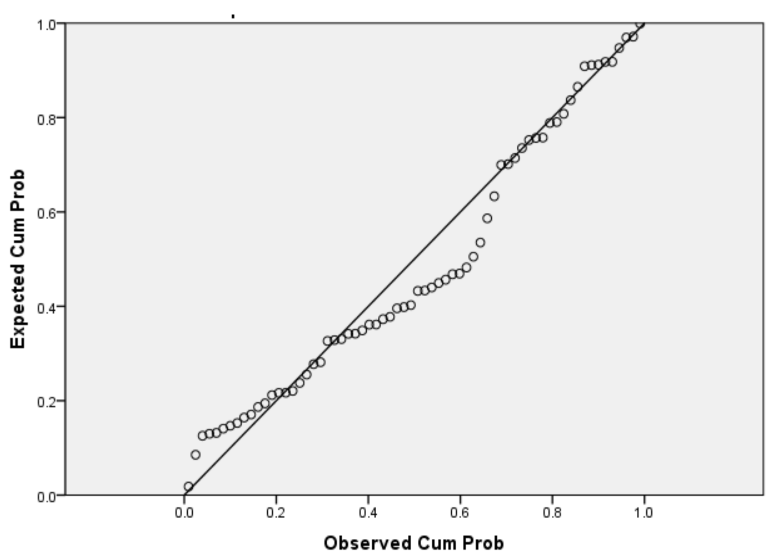

Figure 4.12. Normal P-P Plot of Regression Standardized Residual: Dependent Variable: Pct. Forest Area

Thus, one can conclude that the regression model mostly meets the assumptions, which is acceptable as a certain degree of dependence, and spatial autocorrelation is expected in the real world.

4.5 Conclusion

Considering the human-dominated landscape in Chittoor district as in the rest of India, assessing the influence of socioeconomic factors on forest area takes precedence over natural factors when considering conservation management strategies. The objective of this chapter was to identify the socioeconomic factors contributing to forest area in Chittoor district and assess their relative contributions. Based on the results of the bivariate analysis one can conclude that all the independent variables except percent poverty were significant. As expected, percent agricultural area was negatively correlated with forest area. Both the livestock indicators (goats and cattle per km^2) were positively correlated indicating that people invested in livestock with the assurance of having a place (forest area) to graze the animals. Percent tribal population and forest area were also positively correlated at 0.411 despite a large tribal population in the urbanized mandals. The OLS regression model explained 75% of the area covered by forests in the district, which can be considered relatively high. In the regression model, all the variables except percent poverty were significant at a 95% level of significance. This confirms the hypothesis that poverty and area covered by forests do not have an intrinsic link. Overall, the model showed a high explanatory power. However, it is possible that the model can be improved by including other factors based on observations at the field level, as well as by including the (protection) status of each forest. Nevertheless, these results are helpful for developing conservation recommendations for the area, which is the final goal of this research.

CHAPTER V

UNDERSTANDING THE SPATIAL CONFIGURATION OF THE LANDSCAPE

5.1 Introduction

Landscape metrics, as discussed in the methods section, are indices used to quantify categorical patterns on maps. While there are numerous metrics to understand the structural and functional configuration of a landscape, the applicability of each metric depends on the research objective and the question one is attempting to answer. The objective of this chapter is to address one part of my second research goal which is to propose a potential corridor based on the biogeographic factors present between the Rayala Elephant Reserve and Sri Venkateswara National Park. The first step in addressing this research goal is to assess the landscape composition and configuration in Chittoor district by analyzing the land use/land cover. The second step, which will be discussed in the Chapter VI, involves identification of priority areas for conservation, assessing the socioeconomic factors for the area, and proposing potential linkages. In the following sections, landscape metrics are used to determine the spatial configuration of the landscape, and examine the potential for the development of a biodiversity conservation corridor in Chittoor district. More specifically, based on the research objective several metrics are identified, the results presented, and the discussion is concluded by assessing the potential of developing a corridor in the study area.

5.2 Identification of landscape metrics

The metrics identified (Table 5.1) were based on guidelines provided by McGarigal et al. (2002) and through a review of studies that used landscape metrics to analyze the composition and configuration of the landscape (Gustafson 1998; Li and Wu 2004; McGarigal et al. 2002; Neel et al. 2004; Peng et al. 2010). McGarigal et al. (2002) group metrics developed in Fragstats[16] according to the level of heterogeneity and the aspect represented. The levels of heterogeneity are divided into patch, class, and landscape, although the authors specify that these divisions are not categorical and overlap to a large extent (McGarigal et al. 2002).

Table 5.1. Description of landscape metrics selected to quantify composition and configuration of the landscape

Level of heterogeneity	**Landscape Metric**	**Aspect**
Patch level	Patch area	Area/density/edge
	Patch radius of gyration	
	Patch core area	Core area
	Core area index	
	Edge contrast index	Contrast
	Proximity index	Contagion/Interspersion
Class level	Percentage of landscape	Area/density/edge
	Patch Density	
	Total Edge	
Landscape level	Contagion index	Contagion/Interspersion
	Interspersion and juxtaposition index	
	Subdivision	

The aspect corresponds to the area, density, edge, shape, core area, contrast, contagion, interspersion, isolation, connectivity, and diversity in the landscape pattern (McGarigal et al. 2002). The authors themselves caution users about the redundancy

[16] A software program (version *4.x*) designed to compute landscape metrics for categorical map patterns (McGarigal et al. 2002).

among the available metrics, as have many other researchers (Chetkiewicz 2006; Cunningham and Johnson 2011; Gustafson 1998; Li and Wu 2004; McGarigal et al. 2002; Peng et al. 2010). Therefore, the metrics for this research were based on criteria that would help in understanding the spatial configuration of the landscape, rather than from a specific level of heterogeneity or aspect of pattern. Under the different aspects measured by the landscape metrics, those based on shape were excluded due to data limitations. Metrics based on diversity and isolation were also excluded, as these two aspects are covered under other selected metrics. The following section describes the selected landscape metrics (based on the levels of heterogeneity) and how each of them contributes to the research problem.

5.2.1 Patch level metrics

Patch level metrics describe the spatial character of patches and their spatial configuration in the context of the matrix. They are often the basis of landscape and class level metrics thus providing rudimentary information on patches. Since patches are scale dependent, it is important that the scale of analysis be determined prior to calculating the patch level metrics (McGarigal et al. 2002). The following metrics were selected in conjunction with the research objective:

a) Patch area – Provides the area of each patch in the landscape under review (McGarigal et al. 2002). This metric will provide an estimate of patch sizes in the landscape and will consequently be used in the corridor design. For example, based on the assumption that larger patches contain more biodiversity, one can assume that they should be given maximum priority for conservation recommendations in order to reduce habitat fragmentation.

b) Patch radius of gyration – Provides the extent of each patch, or the average radius/distance a species can move (based on its dispersal ability) within the patch before reaching the boundary (McGarigal et al. 2002). This can be interpreted as one assessment of the habitat of a given species, as the area within the patch determines whether the particular species will stay there, travel through, or breed. For example, a smaller radius of gyration indicates a small patch which may be less suitable for the species under study.

c) Patch core area – Represents the interior area of a patch based on a defined buffer or edge depth, and the shape and area of a patch (McGarigal et al. 2002). It is an important metric as it provides the user with the functional relevance of the actual area within a patch that can be used by the species without the influence of edges or boundaries (McGarigal n.d). Thus, as the area of a patch increases so does its core area. A complex patch shape will provide a smaller core area than a simple shaped patch, and similarly a larger buffer or edge-depth will lead to a smaller core area (McGarigal et al. 2002) which in turn will affect the viability of the patch as a habitat for the species.

d) Core area index – Provides a relative measure or a percentage based on the edge-interior ratio of the patch, and can also be summarized at the landscape or class level (McGarigal et al. 2002). The core area index gives a measure of the amount of the patch that comprises the core area, which is an important measure, especially when dealing with edge-sensitive species (McGarigal n.d). This metric can be used as a fragmentation index allowing comparisons for a particular class.

e) Edge contrast index – This describes the relative difference between patches or the magnitude of contrast between adjacent patches based on one or more ecological attributes (McGarigal et al. 2002). This index reflects the ability of an organism to cross boundaries, or in other words the connectivity (or lack of) in a landscape. To calculate the index, each type of edge is assigned a contrast weight that is used to calculate the edge contrast index, which indicates whether the edge shows high contrast (implying low permeability) or low contrast (implying high permeability), thus providing an analysis of the resistance of the landscape matrix for the species concerned (McGarigal n.d).

f) Proximity index – This index takes into account the size and proximity of all patches within a specified radius of the focal patch (McGarigal et al. 2002). It is a useful index to evaluate the distribution of habitat patches. The proximity index highlights the sparse distribution of patches, from those that form a complex cluster. This can provide input into the optimum design for a wildlife corridor, as it facilitates the process of understanding the spatial configuration of the landscape.

5.2.2 Class level metrics

Class level metrics are based on patches in the landscape of a particular type (class) that measure the aggregate properties of each patch type. These metrics are often used to study habitat fragmentation which involves the sub-division of a landscape and leads to isolated habitat fragments. Using class level metrics helps in identifying the amount and distribution of a particular patch type in the landscape (McGarigal et al. 2002). For this analysis the following class level metrics have been selected:

a) Percentage of landscape – This metric provides an estimate in area of each patch type or class and also provides the percentage of the landscape that is comprised of a particular class (McGarigal et al. 2002). For example, with the output of this metric I will be able to quantify the percentage of the landscape covered by mixed dry deciduous forests, scrub forests, agriculture, etc. This will help in describing the landscape composition of the study area.
b) Patch density – Patch density gives the number of patches per unit area that allows for comparisons across landscapes of different sizes, unlike the simpler metric that only calculates the number of patches (McGarigal et al. 2002). This index will facilitate the process of designing a corridor, as it is another estimate of the composition of a landscape that will enable prioritizing areas for conservation.
c) Clumpiness index – This index measures the occurrence of different pairs of patch types contiguous or adjacent to one another in the landscape (McGarigal et al. 2002). It is another measure of aggregation in the landscape based on patch types that will be used to assess the degree of division, or conversely clumpiness, in the matrix.

5.2.3 Landscape level metrics

Landscape level metrics reflect aggregate properties of the entire landscape mosaic characterizing the composition and configuration (McGarigal et al. 2002). For this analysis the following landscape metrics have been selected:

a) Contagion index – This measures the clumpiness or the tendency of patches to be highly aggregated (McGarigal et al. 2002). It is a measure of both patch interspersion and dispersion, and the contagion index increases when there are large contiguous patches and decreases when the landscape is highly fragmented with interspersion of patch types (McGarigal n.d). This index will help in understanding the landscape pattern and also assess the scope of adapting different land uses in the proposed corridor.

b) Interspersion and juxtaposition index (IJI) – This refers to the spatial intermixing of patch types, or reflects how often each patch type is adjacent to another patch type irrespective of its size or continuity (McGarigal et al. 2002). Unlike the contagion index, which is based on cell adjacency, the IJI is based on patch adjacency (McGarigal et al. 2002). It is an important measure which is often used in conservation planning, as different habitats are usually juxtaposed with one another rather than a single monotonic patch of one habitat type.

c) Subdivision – This describes the degree of subdivision in the landscape that reflects the graininess of the landscape (McGarigal et al. 2002). Thus, a fine-grained landscape is characterized by high fragmentation and a coarse grained landscape shows less fragmentation, or a few large patches (McGarigal n.d). For the current research goal, this is an important index as it has implications for population subdivisions and metapopulation dynamics, as well as landscape continuity and implications for the spread of disturbance.

5.3 Analysis

Using Fragstats to compute the metrics identified and discussed above proved to be challenging, as the study area was too large and too possibly complex for the computer program. After attempting various permutations and combinations that included changing the file format of the raster data, reducing its resolution, clipping parts of it and working on the file properties, I was finally able to use the data in an ASCII format. However, the size of the study area and the complex landscape matrix made calculating the patch level metrics impossible. Thus, the results for the class and landscape level metrics are discussed below. Details on the raster data used and the parameters selected to run Fragstats are in Appendix 4.

5.3.1 Class level metrics

a) Percentage of landscape (PLAND) – Agriculture is the most dominant land use followed by scrub and mixed dry deciduous forests (Figure 5.1). Although agriculture is the most dominant, if the different forest types are combined, forests occupy a larger percentage of the landscape.

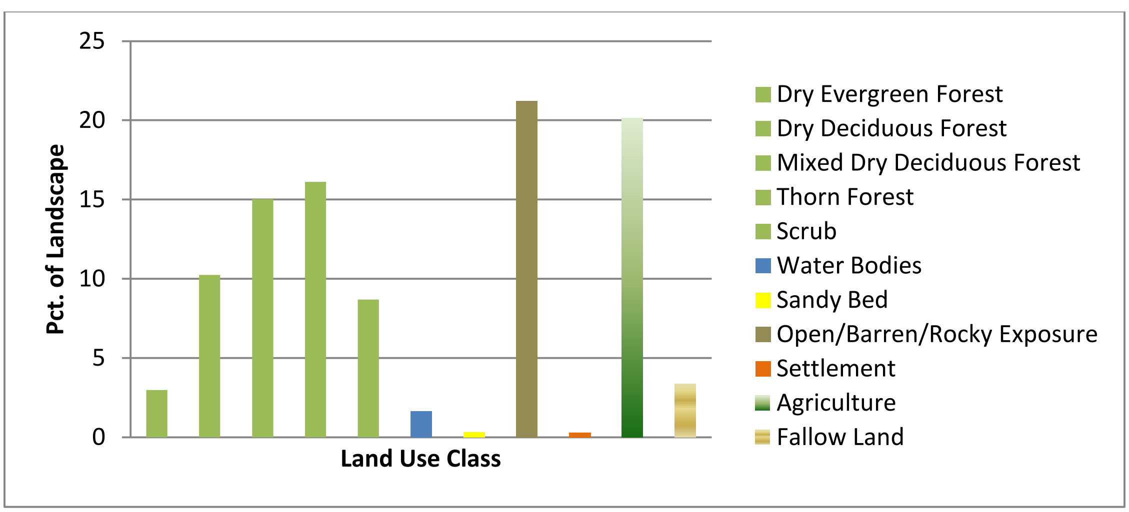

Figure 5.1. *Percentage of land use land cover in Chittoor district*

b) Patch density – The patch density metric represents the number of patches per 100 hectares and is constrained by the cell size. Similar to calculating the number of patches, using patch density provides a comparable estimate of the structural configuration of the landscape. Thus from the computed numbers in Table 5.2 one can see that the density of mixed dry deciduous and thorn forests are the highest at 15.96 and 14.34, respectively. Although patch density cannot be interpreted directly as an index of fragmentation, one can infer that scrub forests followed by dry deciduous and dry evergreen forests (based on the lower density estimates) are fewer in number and more fragmented (based on the cell size of 30m and the 4-neighbor rule) in comparison. While the Indian Wild Dog (the species selected as a focal species) or Dhole is found in a variety of habitats, in India tropical dry deciduous forests are considered optimal habitat (IUCN Red List 2011). Based on the patch density for the cumulative (optimal) habitat in the study area, it is apparent that this area serves as an optimal conduit, or habitat, for the species.

Table 5.2. Patch density in the study area

Land Use	Patch Density per 100 hectares
Agriculture	8.646
Open/Barren/Rocky Exposure	5.569
Fallow Land	3.750
Scrub	7.476
Thorn Forest	14.34
Mixed Dry Deciduous Forest	15.967
Settlement	0.271
Dry Deciduous Forest	4.175
Water Bodies	0.322
Dry Evergreen Forest	0.424
Sandy Bed	0.087

c) Clumpiness index – This refers to the extent to which the landscape is aggregated or clumped, based on an adjacency matrix. The clumpiness index lies between -1 and 1 representing “the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution” (McGarigal et al. 2002). Based on Table 5.3 one can see that the scrub, mixed dry deciduous and dry evergreen forests are all above 0.5 which indicates that these land uses lie between a completely random distribution (at 0) and a maximally aggregated landscape (at 1). The habitat of the Dhole can thus be interpreted as less subdivided than expected under a spatially random distribution.

Table 5.3. Clumpiness index for the study area

Land Use	**Clumpy (aggregation)**
Agriculture	0.635
Open/Barren/Rocky Exposure	0.787
Fallow Land	0.492
Scrub	0.567
Thorn Forest	0.497
Mixed Dry Deciduous Forest	0.509
Settlement	0.556
Dry Deciduous Forest	0.699
Water Bodies	0.819
Dry Evergreen Forest	0.823
Sandy Bed	0.770

The class level metrics provide a glimpse into the composition of land use in Chittoor district and their relative contributions to the matrix. The spatial configuration of land use in the district provides insight into the viability of conservation action keeping the Dhole as a focal species.

5.3.2 Landscape level metrics

a) Contagion index – This metric represents the continuity (or lack of) in a landscape based on the different patch types (calculated on cell adjacency) and is represented as a percentage. The contagion index increases when there are large contiguous patches and decreases in a fragmented landscape (McGarigal et al. 2002). A contagion index of 100 would indicate a landscape with a single large patch. For the study area the contagion index was 58.71% which indicates a moderately contiguous matrix where fragmentation is not substantially high but neither is it low enough to ignore.

b) Interspersion and juxtaposition index (IJI) – The IJI metric is based on patch adjacency and essentially represents how each patch type is intermixed/interspersed/juxtaposed in the matrix. It is also represented as a percentage. The study area gave an IJI of 66.99%, indicating a relatively contiguous landscape with moderate amounts of fragmentation.

c) Subdivision – This metric represents the graininess of the landscape, or the amount of division in the landscape based on the patches present. It is represented as a proportion on a range of 0 to 1 where 1 represents a maximally subdivided landscape, or when each cell is a different patch (McGarigal et al. 2002). For the study area the subdivision was 0.69. This can be interpreted as fairly high, thus indicating the presence of fragmentation (based on the structural configuration of different patch types).

Thus, based on the three metrics computed at the landscape level (Table 5.4) one can conjecture that the structural connectedness of land use in Chittoor district is ideal for conservation action as it is not in a state of absolute fragmentation, and nor are the different land classes highly disaggregated. There is a relatively positive level of interspersion and contagion in the landscape matrix which suggests that conservation measures should aim at protecting the matrix, to help create and restore a landscape that is sustainable in terms of the varied land use and land cover.

Table 5.4. Landscape level metrics for the study area

Landscape Metric	**Value**
Contagion index (cell adjacency)	58.71%
Subdivision	0.69
Interspersion and Juxtaposition Index(patch adjacency)	66.99%

5.4 Conclusion

Landscape metrics have been used extensively over the past decade for varied purposes. The use of landscape metrics in landscape research was analyzed by Uuemaa et al. (2009), who found that most studies concern biodiversity and habitat analysis. Although contentious in their scope to quantify spatial patterns, predict ecological processes, or to provide inputs for conservation planning, recent research (Cunningham and Johnson 2011; Peng et al. 2010; Sundell-Turner and Rodewald 2008; Tischendorf 2001) shows that landscape metrics provide useful indicators which can be used to understand the spatial configuration of the landscape and also as a connectivity measure. The common refrain with regard to the interpretation of metrics lies in recognizing the limitations of each metric and the complexities involved in landscape patterns. Uuemaa et al. (2009) mention another relevant issue that must be considered while using landscape metrics, namely the modifiable areal unit problem (MAUP). In the context of computing landscape metrics this includes the grain size and extent of the study area (Uuemaa et al. 2009). In this study, based on the data resolution, the grain size is 30m, and the extent of the study area is 15,359 km^2. While both the grain and extent have influenced the metrics discussed above, the land use classification scheme is another factor that must be considered. Land use/land cover was classified into 11 categories, if there were more details or conversely fewer categories the results would be different in terms of contiguity, interspersion and subdivision.

Overall, the landscape metrics used in the final analysis provided a relatively good indication of the spatial configuration of the study area. The class level metrics detailed the composition of the landscape while the landscape level metrics provided insight into the configuration of patch types in the landscape matrix. If patch level metrics were calculated, it may have been possible to identify specific areas for conservation based on the patch composition, patch area and edge density. Nevertheless, based on the analysis, it is apparent that land use/land cover in Chittoor district is at a vulnerable stage, which can be supported by the following observations:

- Habitat has not been completely destroyed although fragmentation is evident from the interspersion, subdivision, and contagion indices.
- The subdivision index indicates a divided landscape, yet the contagion shows that contiguity is also high within patch types.

- There are relatively large habitat patches outside the realm of protected areas based on patch density and clumpy indices.
- The landscape composition shows a forest-dominated landscape if all forest types are taken into consideration.
- Based on the criteria for biodiversity conservation corridors, the land use/land cover appears to be suitable, at least at this level of analysis.

Thus, based on an understanding of the structural/spatial configuration of the landscape there is potential to develop a biodiversity conservation corridor in Chittoor district. Further research must involve field level data analysis to be able to comprehend the field realities. This, coupled with an assessment of the landscape at a finer scale, will facilitate the process of establishing a corridor in the identified area.

CHAPTER VI

IDENTIFICATION OF A POTENTIAL AREA TO DEVELOP A BIODIVERSITY CONSERVATION CORRIDOR

6.1 Introduction

Chapter V established the need for conservation/restoration of the fragmented landscape in Chittoor district based on an analysis of the land use/land cover. The goal of this chapter is to address the remaining portion of the second research goal, which aims at assessing the feasibility of a biodiversity conservation corridor based on both biogeographic and socioeconomic factors. The first step involves identifying a priority area (for conservation) using the criteria for a biodiversity conservation corridor. Next, with the objective of assessing the potential of the area identified, the land use/land cover is analyzed in addition to computing specific landscape level metrics. Due to data limitations discussed in the methods section, basic strategies are used to identify potential linkages within the selected area for conservation. This involves overlaying vector data for roads, water resources, the rail network and settlements on the forest layer. In conclusion, an assessment of the selected area based on a hotspot analysis is carried out, and a weighted matrix analysis is used to quantify the strengths and weaknesses of the proposed linkages.

6.2. Identifying potential areas for conservation

Identifying areas based on structural connectivity included assessing the landscape based on criteria for a biodiversity conservation corridor. In addition, the road network, settlements, forests, and the availability of water in the linkage was taken into account. A biodiversity conservation corridor, as discussed earlier, requires a protected area system, a connectivity network, and compatible land use with varying degrees of human occupation (Sanderson et al. 2006). Chittoor district has three protected areas (with varying degrees of protection), some amount of connectivity, and scattered settlements which ensure a compatible land use as there are only three major towns in the district. Thus, taking into account the location of the three protected areas (PAs), an approximate location that could serve as a linkage was selected. As seen in Figures 6.1 and 6.2, I have demarcated an area lying between the S.V. National Park and the Rayala Elephant Reserve encompassing 25 mandals in the district as an area for conservation priority.

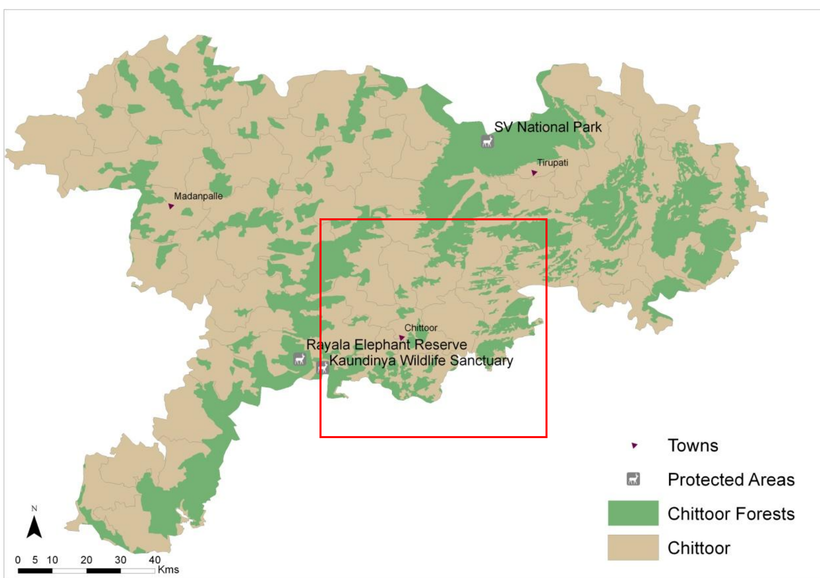

Figure 6.1.Protected areas and towns in Chittoor district

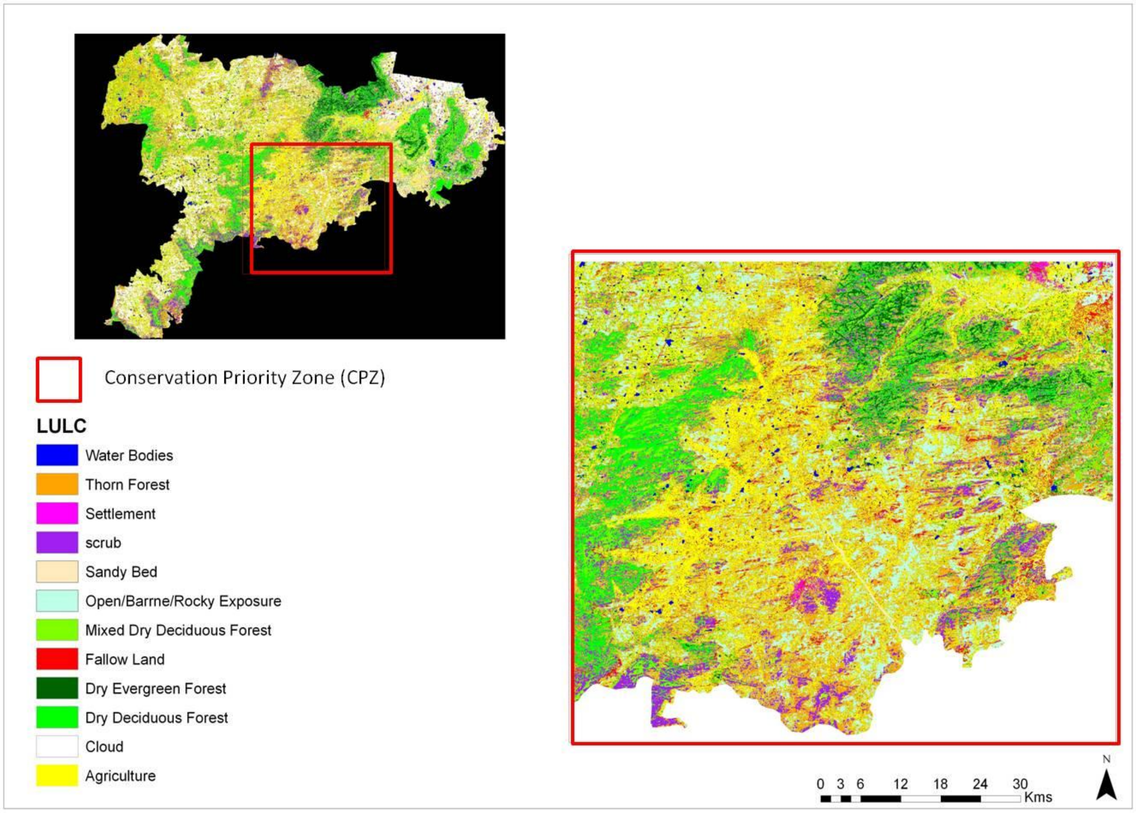

Figure 6.2. Land use/ land cover in Chittoor district and the conservation priority zone

To evaluate its potential for inclusion in the biodiversity conservation corridor, an assessment of the land use/land cover and structural connectivity for this area (henceforth referred to as the conservation priority zone) was undertaken.

6.2.1 Assessing the land use/land cover of the conservation priority zone (CPZ)

Considering that a biodiversity conservation corridor does not restrict itself to a linear corridor, the entire area selected was evaluated, as the matrix affects habitat patches (Baum et al. 2004). Agriculture and different categories of forest dominate the land use/land cover in this area, representative of the entire district (Figure 6.3).

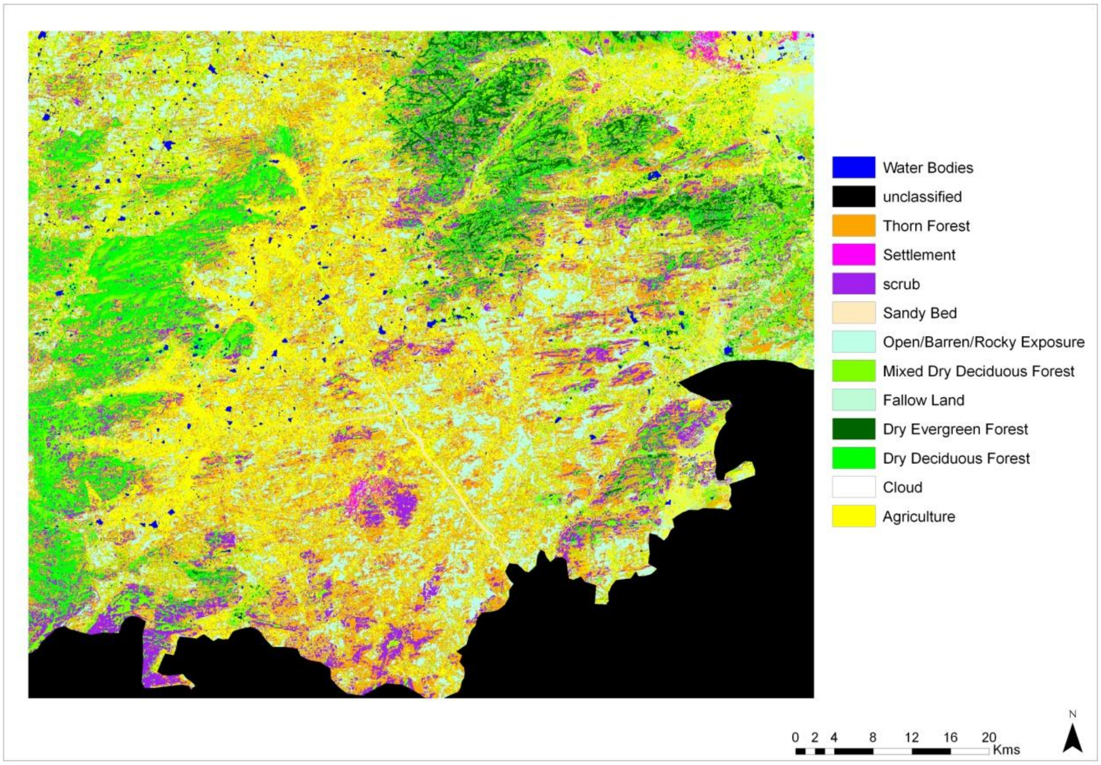

Figure 6.3. Land use/land cover of the conservation priority zone

The highest percentage of land use is under agriculture, followed by the different forest types, which if combined, are much higher than agricultural use (Figure 6.4). Based on the versatility of the Dhole (the target species selected), which uses a "mosaic of vegetation types" (Venkataraman 1999), one can safely assume that this patchwork of scrub and mixed deciduous forest is suitable for the species.

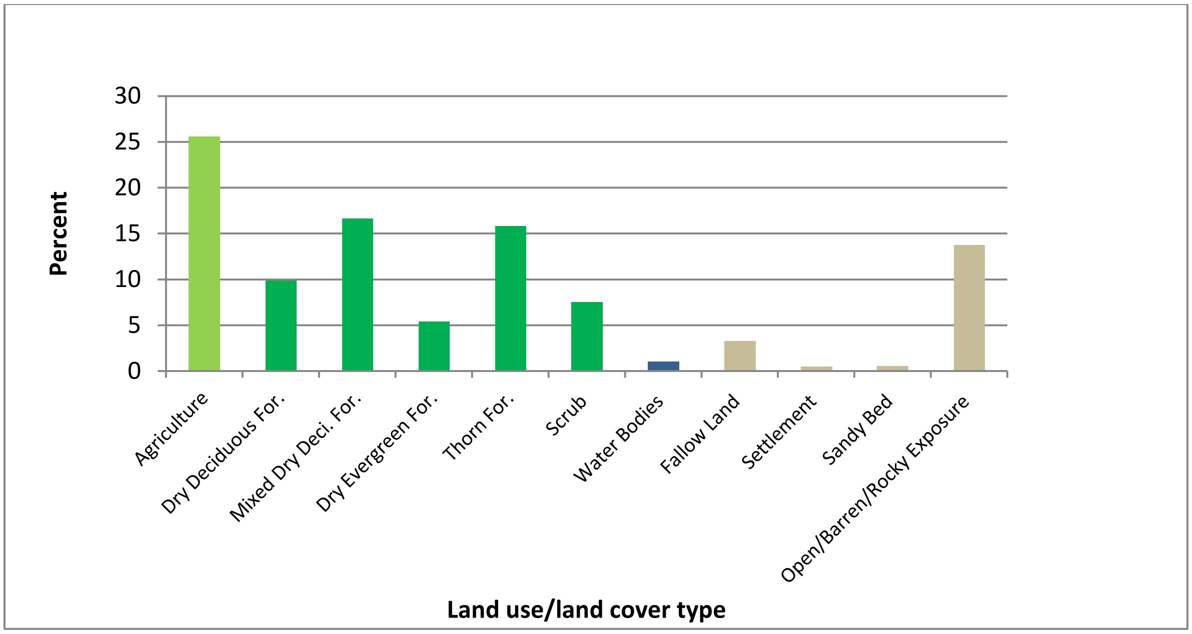

Figure 6.4. Percent land use/land cover in the CPZ

6.2.2 Assessing structural connectivity in the conservation priority zone (CPZ)

Similar to the metrics calculated for the entire study area, landscape level metrics were calculated for the CPZ (Table 6.1) with the objective of assessing structural connectivity in this section. The contagion index was much lower for the CPZ than for the entire district (23.41% versus 58.71%), implying that the level of fragmentation based on the land use is high. Subdivision in the CPZ is also very high at 0.99 (1 is the maximum), whereas for the district it was 0.69, indicating that based on the different patches the CPZ is highly divided. The interspersion and juxtaposition (IJI) metric based on patch adjacency essentially represents how each patch type is interspersed/juxtaposed in the matrix. The CPZ gave an IJI of 76.59% as compared to the IJI of the study area, which was 66.99%. The difference between the two shows that the CPZ has a better placement of patches in terms of structural contiguity as compared to the entire district.

Table 6.1. Comparison of landscape level metrics for the CPZ and the study area

Landscape Metric	**Value for the CPZ**	**Value for the entire study area**
Contagion index (cell adjacency)	23.41%	58.71%
Subdivision	0.99	0.69
Interspersion and Juxtaposition Index(patch adjacency)	76.59%	66.99%

Thus, the overall structural connectivity and land use in the CPZ indicates a highly fragmented landscape. A cumulative forest area of 55% within this fragmented landscape shows that there is a need to establish conservation measures to halt the process of habitat loss. While the varied land use provides a window to develop conservation recommendations accordingly, the metrics calculated show the need for conservation and restoration of the fragmented forests.

6.2.3. Assessing the conservation priority zone (CPZ) based on the transport network and settlements

The next step involved overlaying the road and rail networks along with the settlements on the forest layer for the CPZ. In order to provide a point of reference, the three Protected Areas have been identified along with the two towns (i.e. Chittoor and Tirupati) which lie within the CPZ in all the maps that follow. The presence of a railway line dissecting the area and national highways in the southwest portion is clearly visible (Figure 6.5). State highways are also visible, running parallel to the rail network. Unfortunately, two of the three big towns in the district are a part of the CPZ, thus making the transportation network a relevant factor in considering areas for conservation. Similarly, the location of the two towns along with the scattered villages is also relevant when selecting the area to propose conservation recommendations as human-animal conflict (Ogra 2009) is an issue that must be accounted for in a human-dominated landscape.

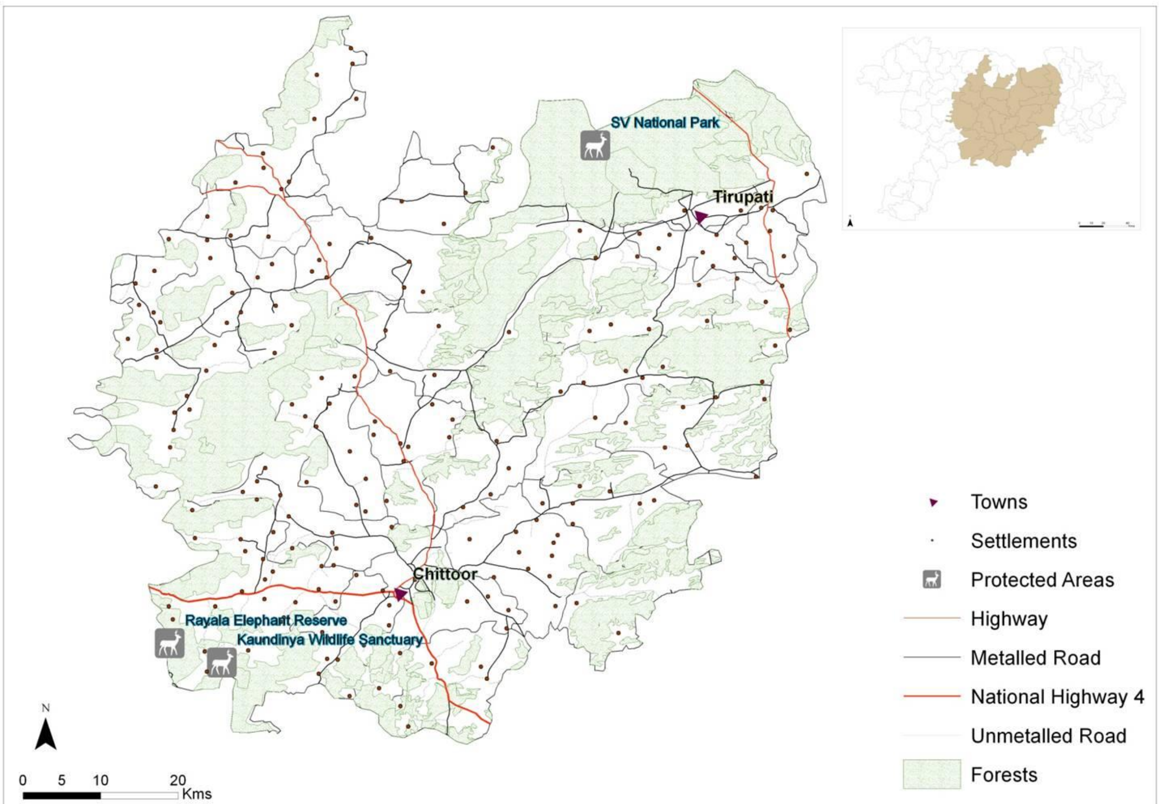

Figure 6.5. Transportation network and settlements within the CPZ

6.2.4. Assessing the conservation priority zone based on water availability

A likely hypothesis based on the climatic conditions (recurring drought) and sightings reported in villages in the study area is that the animals (Dholes and

Elephants among other species) use this area as a migratory corridor during periods of drought. Thus, availability of water becomes paramount in the process of designing a potential corridor. Using the river/streams network and presence of tanks in conjunction with the forest layer is one way to assess the most hospitable linkage. Water is available across the selected area (Figure 6.6) although one would have to verify at the field level whether these are seasonal or perennial sources.

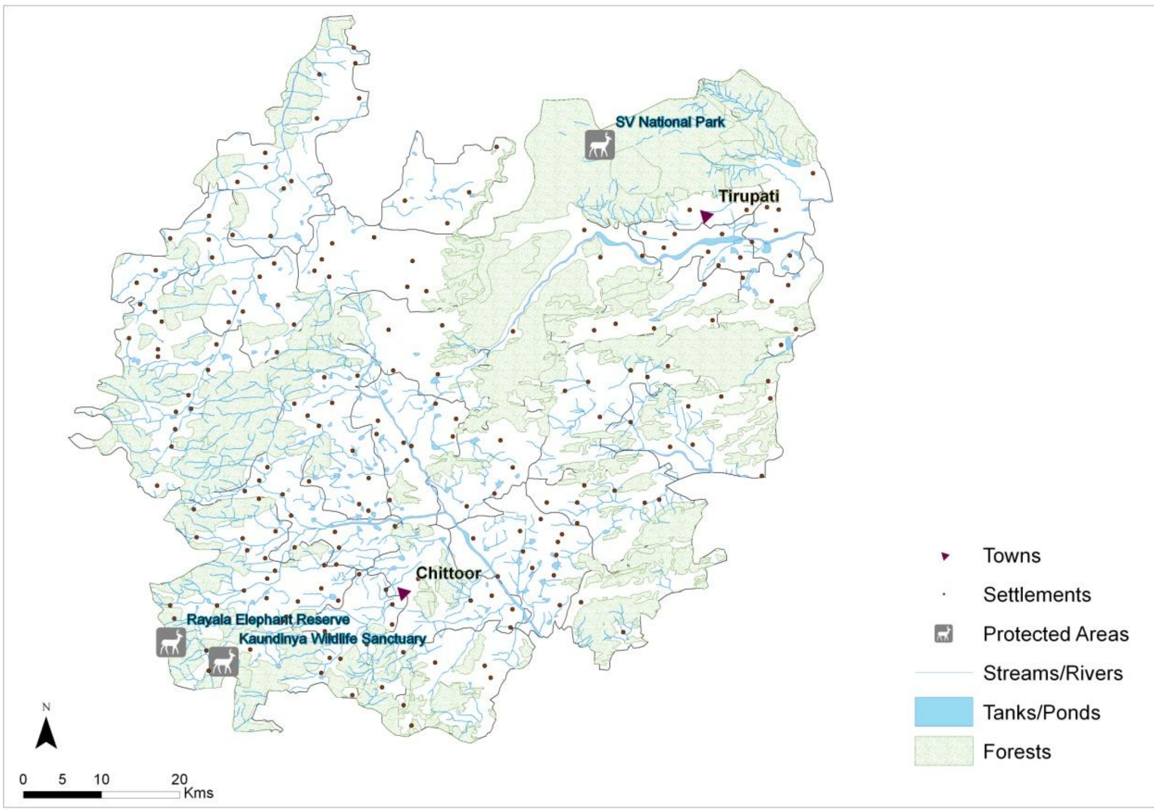

Figure 6.6. Water availability within the CPZ

6.3. Potential linkages

As discussed earlier, potential linkages were identified based on the distance between forest patches and the spatial distribution of forests between the S. V. National Park and Rayala Elephant Reserve. An assessment of the transportation network and water resources between the two protected areas was carried out. Two primary linkages were identified (see Figure 6.7, L1 and L2), where L1 is a linear corridor and L2 is a stepping stone corridor. L1 provides the shortest distance that is a 6 km long corridor connecting S.V. National Park to a forested area, which leads to the Rayala Elephant Reserve. On the other hand, L2 consists of six segments ranging from 1.5 km to 3 km that connect forest fragments between SV National Park and Rayala Elephant Reserve. The primary reason for identifying L2 was based on the lack of water resources across L1. Based on the seasonal migratory patterns discussed earlier, the availability of water is critical in either linkage. A detailed analysis of both these linkages follows in section 6.3.1.

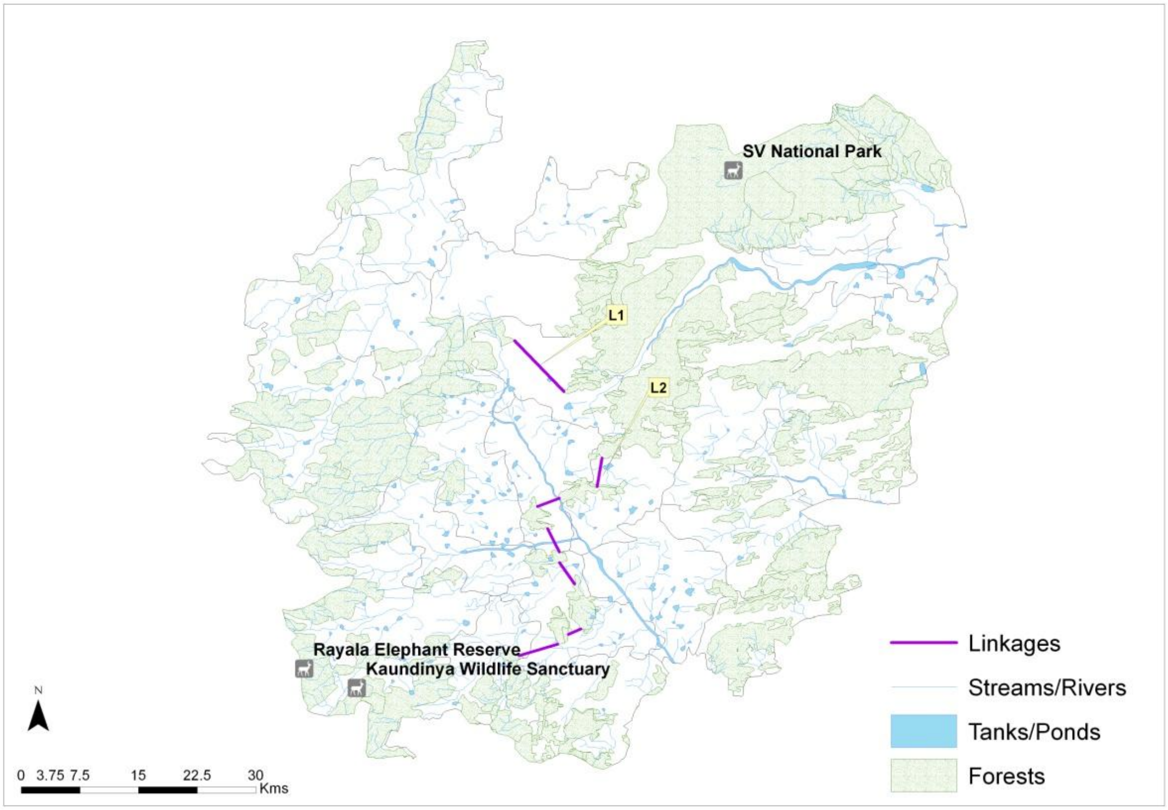

Figure 6.7. Linkages in the landscape: forests and water

6.3.1. Considering forests and water

With the aim of identifying the feasibility of creating or restoring a corridor between the SV National Park and Rayala Elephant Reserve in Chittoor district two possible linkages were selected (Figure 6.7). Linkage L1 appears favorable as it is a single stretch or a linear corridor measuring approximately 6 km between the two forest patches. L2 on the other hand includes six linkages between forest patches covering a total distance of approximately 15 km. However, L1 shows the absence of water sources, whereas there seems to be water available across L2. Considering the hypothesis that the importance of the linkage is apparent during drought, the presence of water is a critical component for maintaining connectivity for most species. From this perspective, L2 is more favorable in spite of the fact that it covers a longer distance. The distance covered by L2 is divided due to the presence of forest patches, making it a stepping stone corridor. Stepping stone corridors provide animals with pit stops during the process of migration, thus providing a relatively safe habitat (forest cover) away from the threats of roads and in some cases even humans.

6.3.2. Considering forests and the transportation network

The transportation network, which encompasses national and state highways, metalled[17] and unmetalled[18] roads and the railway line, have been superimposed with forests in the district (Figure 6.8). Given the layout of the roads and settlements in relation to the protected areas and forest patches, it is impossible to completely avoid them. L1 appears to be the better option at face value as it intersects with the railway line and a metalled road at only one point. On the other hand, L2 crosses the state highway and railway line at two points and the national highway once. A more in-depth analysis of the amount of vehicular traffic on these sections would need to be conducted to estimate the advantages of L1 over L2 and vice versa. In addition to traffic estimates, the land use/land cover along with the width of these roads will play a role in the assessment. Additionally, data on animal movement and road kills will also help in identification of risk areas, and consequently recommendations may be made to create buffer zones.

[17] Paved roads
[18] Unpaved roads which are usually seen in rural areas made of gravel, mud or locally available material

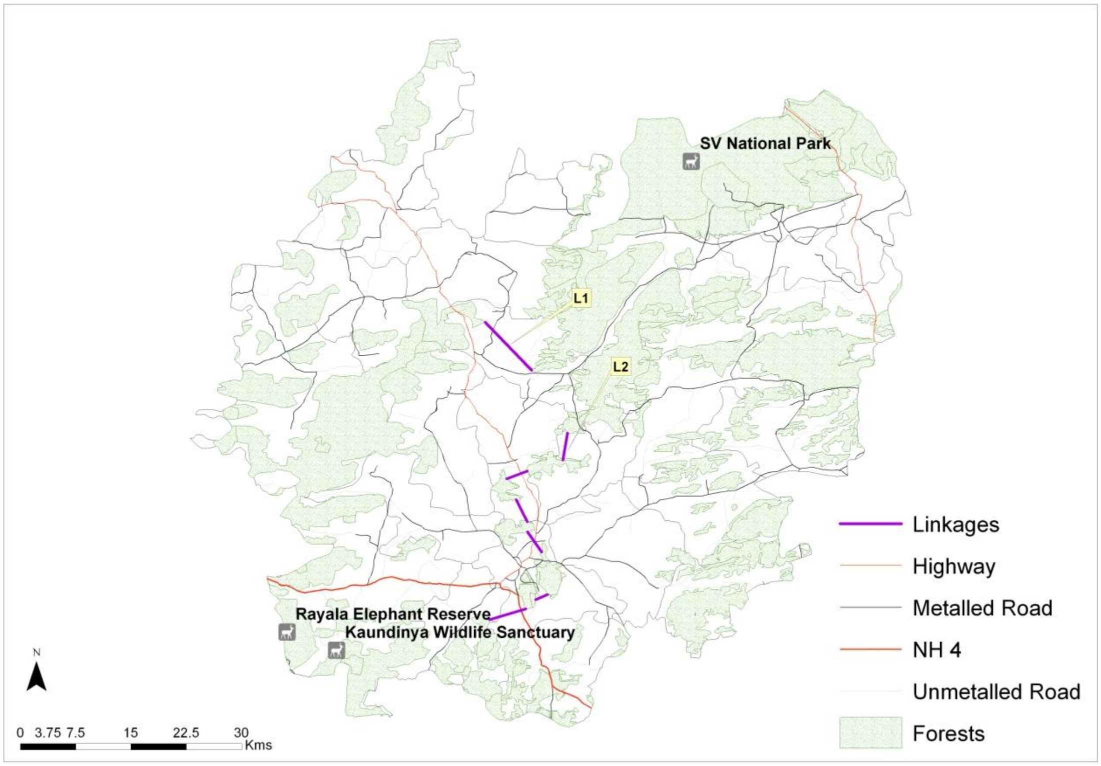

Figure 6.8. Linkages in the landscape: forests and the transportation network

6.4 Assessing the linkages

First, a hotspot analysis was used to verify whether the area selected (CPZ) was the best possible location for a conservation priority zone. Second, a weighted matrix analysis was used to assess the linkages identified and determine which of the two may be more appropriate.

6.4.1 Hotspot analysis

To assess the linkages identified, a hotspot analysis (or G_i analysis[19]) based on percentage forest cover in Chittoor district was conducted. This helped establish whether

[19] Getis-Ord G_i* analysis is a tool used to identify statistically significant hot spots (clusters of high values) and cold spots (clusters of low values).

the area selected (CPZ) was appropriate in terms of forest cover in the district. In addition, the hotspot analysis also allowed a spatial estimation of the high-high clusters and low-low clusters.

The G_{i*} statistic used to calculate hotspots has been mapped in Figure 6.8 based on percentage forest cover. The high-high clusters (between 0.0001 and 2.2953) can be visually seen from the southwest to the northeast of the study area. The low-low clusters (between –2.3168 and 0) spread across the northwest and southeast portion. While the hotspot analysis is intrinsically a "perceptual construct" (Levine 2010, 6.1) and is often used for crime statistics, it has also been used for detecting spatial hotspots in ecology, for species distribution, as well as locating disease or mapping the incidence of pests (Nelson and Boots 2008). In this study the hotspot analysis has been used as a means to explore the evidence of spatial autocorrelation in the district, especially in the area selected.

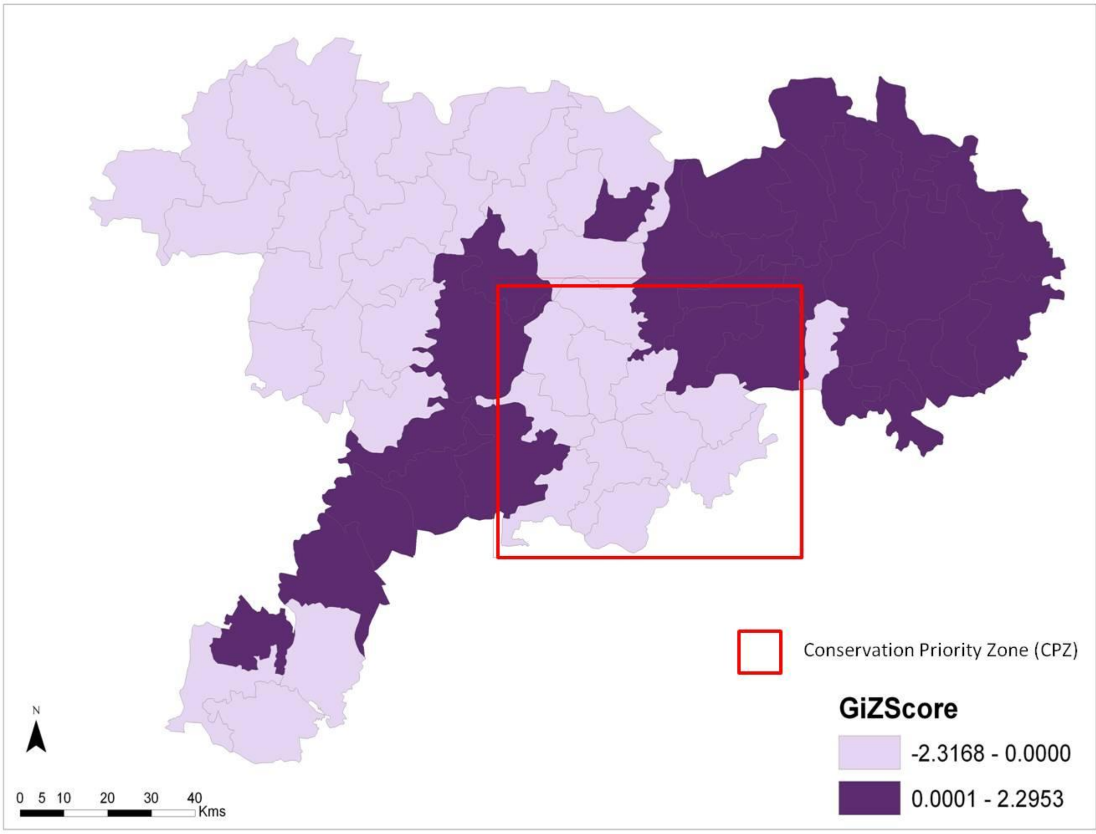

Figure 6.9. Hotspot Analysis

Since carrying out a regression analysis for 25 mandals is not a feasible option, assessing the distribution of forest area across the district provided insight to the suitability of the area selected. As seen in Figure 6.8, the area selected (highlighted with a red box) consists of high-high clusters around the periphery and low-low clusters in the remaining area. The proposed linkages are set in this area showing low-low clusters, thus confirming that the locations identified for L1 and L2 are congruent with the spatial distribution of forests in Chittoor district.

6.4.2. Weighted matrix

In order to assess various criteria to determine the feasibility of the linkages identified (L1 and L2), a weighted matrix to score different criteria in categories was used[20]. In Table 6.2 the criteria have been categorized into distance between patches (to be connected), roads, settlements, and water availability. Sub-categories have been developed under each of these to be able to numerically score each linkage.

Table 6.2. Criteria for evaluating the linkages

Criteria	**Sub categories**
Distance between patches	0-2 km
	2-4 km
	4-6 km
Roads & Railways	Presence of National Highway (NH)
	Presence of State Highway (SH)
	Presence of Railway line
Water availability	Presence of Streams
	Presence of Tanks
Settlements	Presence of Villages
	Presence of Towns

To assess the suitability of each linkage, the selected criteria were based on the data available. Using the template provided by Majka et al. (2007) in *Conceptual Steps for Designing Wildlife Corridors,* weights were assigned to each criterion based on its relative importance. Although assigning weights is often an arbitrary process (Majka et al. 2007), the discussion (under sections 6.2 and 6.3) so far on the criteria being used provides ample evidence for the importance assigned to each category. The category weights indicate the level of importance assigned to each category: Distance between patches, roads and railways and settlements all account for 20% each, while water

[20] Prior to deciding on this method, I was going to use graph theory to compare the two linkages, but data limitations led to a change in the method used.

availability accounts for 40% of the category weights, thus adding up to 100%. Each sub-category was assigned a score based on a 0-100 scale where 0 indicated unsuitability and 100 indicated perfectly suitable circumstances in the linkage (Table 6.3).

Table 6.3. Scores and weights assigned to each category

Criteria	**Weights**	**Sub categories**	**Scores**
Distance	20%	0-2 km	90
		2-4 km	80
		4-6 km	60
Roads & Railway	20%	No Roads	100
		Presence of a Railway line	90
		Presence of NH	70
		Presence of SH	80
Water Availability	40%	2 or more Tanks	100
		1 Tank	80
		No Tanks	0
		2 or more Streams	100
		1 Stream	75
		No streams	0
Settlements	20%	No settlements	100
		Less than 5 Villages	90
		Big town	60

An important distinction among the criteria is that distance between patches, roads and railways, and the presence of settlements in the linkage can be considered resistant factors, while availability of water is an attraction factor. The scores assigned (Table 6.3) reflect this difference based on the sub-categories of each criteria. Combining multiple factors to assess corridors has become a norm, as ecological costs have to be considered as much as economic and social costs (Morrison and Reynolds 2006), since they all play a significant role in determining the success of a corridor. For example, Majka et al. (2007) combine multiple habitat factors and discuss the benefits of using the geometric mean[21] instead of the arithmetic mean to compute a habitat suitability score. The advantage has been described as the "weighted geometric mean better models a situation in which a deficit in one factor cannot be compensated by high scores for other factors" (Majka et al. 2007, 39). Taking into consideration the criteria that I have selected and the difference in their ability to affect accessibility in the linkages, using the geometric mean seemed appropriate.

Next, scores were assigned to each linkage (L1 and L2) based on the specific criteria. A magnified view of each linkage is provided in Figures 6.10 and 6.11, validating the scores assigned. The average score under each subcategory was calculated to get a total score (Table 6.4). As mentioned above the scores are based on a 0-100 scale, where 0 indicates unsuitability and 100 shows a perfectly suitable condition. In the case of roads and railways, absence of any one subcategory has been assigned a score of 100, while in case of water availability, absence of a stream or tank has been assigned a score of 0. The same has not been done for distance as presence or absence was not relevant. In the case of settlements, there was no big town present in either linkage.

Table 6.4. Scores for Linkage 1

Criteria	**Scores**	**Final Scores**
Distance	60	60
Presence of NH	100	
Presence of SH	100	96.67*
Presence of railways	90	
Presence of streams	0	
Presence of tanks	80	40*
Presence of settlements	90	90
* Average of the scores under the specific criteria		

[21] The geometric mean is a method to estimate the central tendency of a set of numbers, especially when the numbers have multiple properties.

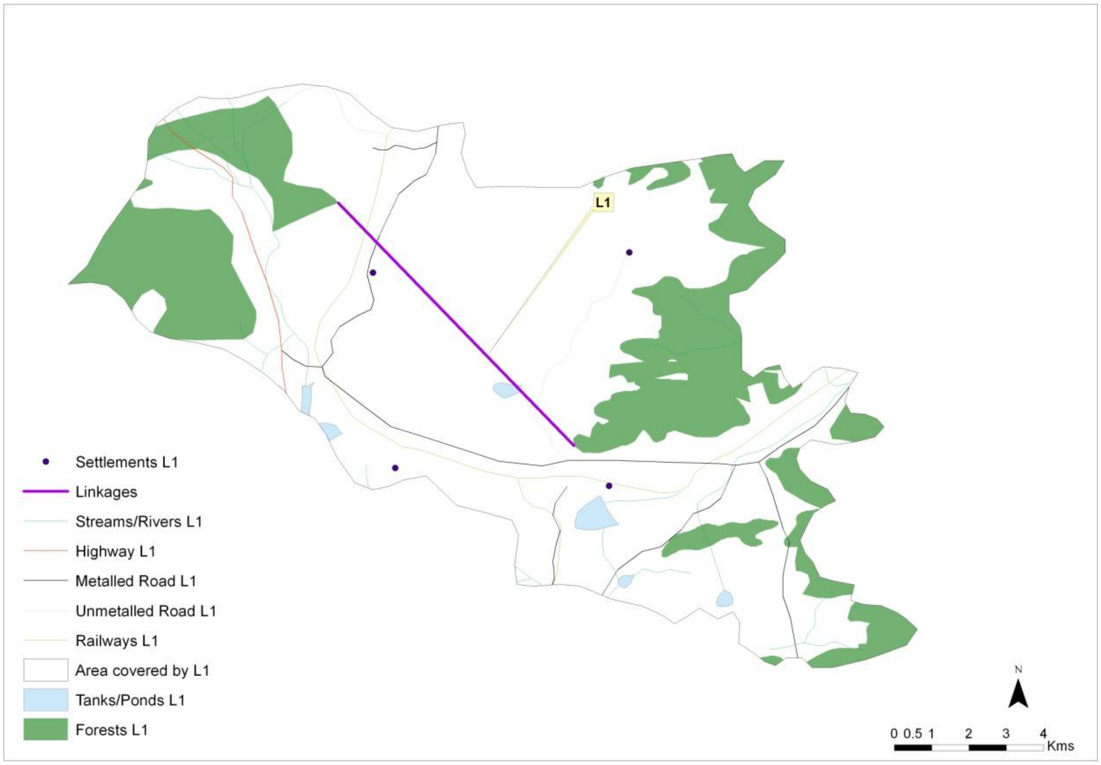

Figure 6.10. Linkage 1

Assigning scores for L2 was slightly more complex as it consisted of six parts. Scores for each part have been assigned and have been labeled a-f (Table 6.5).

Table 6.5. Scores for Linkage 2

	a	b	c	d	e	f
Distance	90	90	80	80	90	90
Presence of NH	100	100	100	100	100	90
Presence of SH	100	80	100	80	100	100
Presence of railways	100	90	100	90	90	100
Presence of streams	0	100	100	0	0	100
Presence of tanks	100	0	0	100	0	0
Presence of settlements	100	100	100	100	100	90

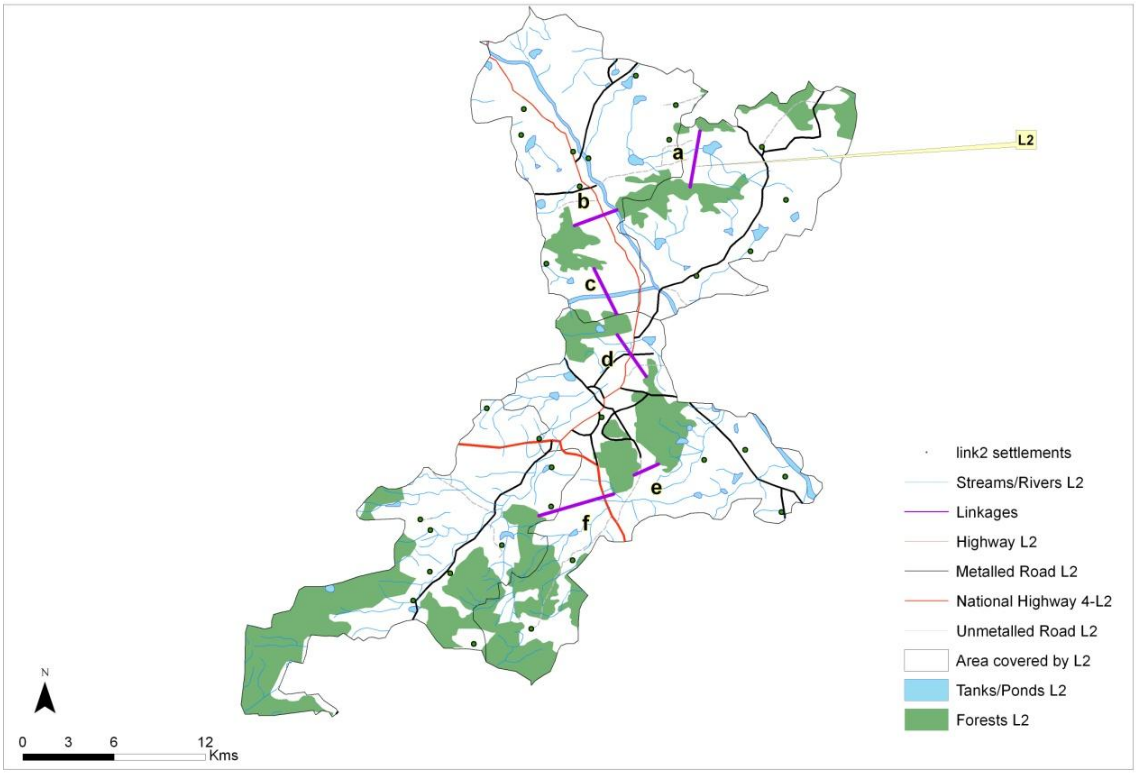

Figure 6.11 Linkage 2

After assigning the scores, the geometric mean was calculated to obtain a final score for both L1 and L2. The calculations for L1 are in Table 6.6, while those for L2 are provided in Appendix 5 as the steps were lengthy. The individual scores for the parts of L2 have been averaged to provide a single score for the entire linkage (Table 6.7). Finally, the suitability of each linkage was compared to determine the more feasible option: L1 scored 60.86 and L2 scored 62.92.

Table 6.6. Suitability of L1

Criteria	L1 score	Weight	Geometric Mean
Distance	60	20%	2.27
Roads & Railways	96.67	20%	2.49
Water Availability	40	40%	4.37
Settlements	90	20%	2.46
			60.86

Table 6.7. Suitability of L2

L2	**Geometric Mean**
a	74.20
b	72.65
c	72.47
d	70.97
e	15.05
f	72.16
Average	62.92

Since the scale was based on a 0 to 100 range, one can see that L2 has a better score (62.92), or is slightly more suitable, than L1 (60.86). In spite of the advantages that L1 seemed to have based on distance, L2 is more feasible primarily due to the availability of water through the linkage. This criterion was given the highest priority/weight in the matrix. One segment of L2 (i.e 'e') seems to be the weakest part (based on the geometric mean) due to the absence of water but since the distance involved is below 2 km it may not act as a barrier to corridor use. At the same time one must admit that there are multiple and complex factors that need to be considered at the field level (like the most optimal habitat, patch area, core area and land use in the matrix), and this assessment is based on limited criteria. Thus, although not comprehensive, the identification of the linkages and their assessment is a starting point for further research.

6.5 Conclusion

An amalgamation of methods has been used to identify conservation areas and linkages within the selected area to assess the feasibility of a biodiversity conservation corridor in Chittoor district. The importance of establishing connectivity in fragmented landscapes to “maintain gene flow, metapopulation dynamics and vegetation succession” (Cerdeira et al. 2005) has been extensively discussed in the literature. While wildlife corridors have been established between many protected areas in the world, in India, their development is at a nascent stage. Although creating linkages for larger mammals invariably takes precedence, these linkages also create habitats and act as conduits for many other species.

Based on the final output which involved identifying and assessing the potential of the linkages between the S.V. National Park and the Rayala Elephant Reserve, one can construe that the Dholes (the target species for this study) can use L1 or L2. However, L2 appears to be more favorable owing to circumstances already discussed. Because the distance traversed across L2 is well within the home range of the Dholes, the land use/land cover appears to be suitable, along with the availability of water and a prey base. Venkataraman et al. (1995) discuss the resource dispersion hypothesis in context of the Dholes and state “resources should be dispersed in patches which vary both spatially and temporally in richness” (558). According to their research on Dholes, the animals move often, within and outside their home range (which ranges from 50 to 80 km) based on hunting success in patches (Venkataraman et al. 1995). The only possible drawback with the preferred linkage (L2) is the need to cross the state and national highway, but these are issues that can be resolved through strategies like building underpasses, or overpasses in combination with road signs. Alternatively, creating a source for water in L1 should be explored, although this may not be a feasible option during periods of drought.

In addition to serving the needs of the Dhole, such a linkage will also help other species and may establish a potential route for elephants. Elephants have been reported to migrate from the Koundinya Wildlife Sanctuary and the Rayala Elephant Reserve to S.V. National Park in the peak summer months when all the water sources in these areas dry up completely (Manakadan et al. 2010). Though the migratory route used by the elephants is not officially demarcated (due to the sporadic intervals of migration), it is one that needs attention as there have been cases of human-animal conflict reported (Manakadan et al. 2010). Unfortunately, Dholes, are considered a menace by local villagers, are often killed without provocation, as they pose a potential threat to livestock. Establishing a biodiversity conservation corridor has the potential to mitigate these unnecessary killings and the involvement of local people in the process (of establishing a wildlife corridor), may also reduce the biases, and in turn create a safe zone for this endangered species.

CHAPTER VII

CONSERVATION RECOMMENDATIONS FOR THE PROPOSED BIODIVERSITY CONSERVATION CORRIDOR

7.1 Introduction

This chapter focuses on the third and final research goal that aims to provide conservation recommendations for the study area. The first research goal identified socioeconomic factors that help explain differential forest cover in the district, while the second goal assessed the structural configuration of the landscape and identified potential linkages for wildlife corridors. Since field level analysis is not a part of this research, the conservation recommendations focus on exploring a theoretical framework to meet the needs of both the local people and biodiversity. The empirical data used for the quantitative analysis in Chapter IV is reviewed with a focus on the spatial distribution of relevant variables. A discussion on the different scales of intervention and an identification of potential legal frameworks within which the proposed corridor can be established follows. Finally, conservation recommendations to address both biodiversity conservation needs and socioeconomic realities are provided for the study area.

7.2 Theoretical framework

Meeting the needs of people and biodiversity in the process of conservation have often been represented as imperfectly complementary goals. Within this complex network there are two themes which are conspicuous in the literature. The first theme is the socioeconomic needs of the local people, which includes the livelihood base, traditional practices in relation to forests and wildlife, and the changing agricultural practices. The second theme is poverty, and the debate on poverty and conservation (discussed in the literature review) has undergone a reversal over the past three decades. The next sections provide a brief overview to the two themes, which provide a theoretical framework to the conservation recommendations.

7.2.1 Linking biodiversity conservation and socioeconomic needs

Conceptually speaking, combining biodiversity conservation and socioeconomic development in an area is compelling, yet has been difficult to implement. Conservation literature that aims at combining biodiversity and socioeconomic development is replete with varying degrees of success (Berkes 2004; Leisher et al. 2010) and in developing countries it is essential to target both of these objectives simultaneously. The circumstances involved in weighing the costs and benefits have been articulated best by Chan et al. (2007). They state,

> … benefits are often difficult to identify, slow to materialize, diffuse(d) or discouraged by high transaction costs. Moreover, the benefits may accrue only to certain sectors of society, such as local political elites or geographically remote firms, while shutting out some local stakeholders whose actions may ultimately determine the fate of the landscape. (Chan et al. 2007, 60)

Chan et al. (2007) do not propose a single-minded approach, or a solution to the conflicts and lack of congruence that arise. Rather, the authors suggest a more nuanced, integrated approach that allows researchers and practitioners to design strategies with inputs from various disciplines and stakeholders (Chan et al.

2007). Thus, the magnitude and complexity of the problem is not simple, nor are the solutions clear-cut. As discussed earlier, the question is no longer whether conservation measures should be implemented, but rather how they can be designed to ensure mutual benefits for people and biodiversity. The concept of the biodiversity conservation corridor discussed by Sanderson et al. (2006) suggests precisely this and the authors provide a brief overview to the challenges, opportunities, tools and approaches to be considered.

7.2.2 Linking biodiversity conservation and poverty alleviation

The shared geography of biodiversity and poverty has been discussed extensively (Agrawal and Redford 2006; Barrett et al. 2005; Hernandez-Morcillo et al. 2010; Roe and Elliott 2010) over the past two decades. Although at first it comes across as a simplistic hypothesis, numerous studies such as one conducted by Hernandez-Morcillo et al. (2010) "… suggest that at a variety of scales and in many different ways biodiversity and poverty do coincide" (Roe and Elliot 2010, 9). Yet at the same time it is inappropriate to draw conclusions which suggest that biodiversity loss causes poverty, or conversely biodiversity conservation can alleviate poverty (Agrawal and Redford 2006; Roe and Elliott 2010). The inextricable link between the two which has been demonstrated repeatedly does not allow for such conclusions, simply because the aspects and dimensions of poverty and biodiversity vary, making the two concepts specific to place and cultural context. A recent publication by the Convention of Biological Diversity, *Linking Biodiversity and Poverty Alleviation: A State of Knowledge Review* (CBD

2010) examines case studies across the globe and comes to the following conclusion:

> the poor depend disproportionately on biodiversity for their subsistence needs—both in terms of income and insurance against risk and, biodiversity conservation can be a route out of poverty under some circumstances (8).

Along with these findings the report provides caveats that include the distinction between low and high value forest resources and differential access (created by social structures and neoliberal agendas) to these; the distinction between conserving biomass and biodiversity, and the complexities of addressing poverty beyond provision of cash benefits (CBD 2010). In addition, the report extensively discusses the need to recognize "which poor, what biodiversity" (Vira and Kontoleon 2010, 13) and whether biodiversity conservation can actually work to alleviate poverty. The dimensions of poverty are naturally vast, and biodiversity conservation is one possible method to target poverty alleviation, among others. Thus, place-specific solutions based on in-depth analysis are the only way to bridge the gap between the needs of biodiversity and people. Thus conservation recommendations must be specific and based on socioeconomic realities. The next section deals with an analysis of the empirical data for the conservation priority zone.

7.3 Analysis of empirical data

The OLS regression model that assessed the influence of various socioeconomic indicators on forest area in Chittoor district explained 75% of the variation in area covered by forests. While the indicators selected (agricultural area, non-agricultural area, poverty, livestock, and tribal population) are not inclusive, based on the results one can conclude that they do play a significant role in predicting the amount of forest cover. Before providing recommendations it is essential to look at the spatial distribution of the individual variables in the area selected, henceforth referred to as the conservation priority zone (CPZ). The individual variables were mapped using ArcGIS 10 in which natural breaks are used to classify the data. The assessment does not include a detailed analysis of each mandal; rather, it is an attempt to understand the distribution within the CPZ. 'Area used for non-agricultural purposes' was omitted as the explanation for it (provided in the Handbook of Statistics) was not very clear (A. P. Government 2010). Secondly, it did not correlate significantly with any of the other variables selected. Although 'percentage poverty' was the only insignificant variable in the model, it is included in this analysis. The reason for considering poverty is based on the fact that poverty was an insignificant variable in relation to forest area, which indicates that it did not influence forest area in Chittoor district. Yet, based on the poverty data and the fact that the district is among the "most backward … in the country" (Ministry of Panchayati Raj 2009, 13) it is impossible to eliminate poverty as a factor. The individual variables for the CPZ are discussed below.

a) Agricultural area: This variable has a large range (2 to 42%) within the CPZ showing that agriculture is a predominant form of land use in the area (Figure 7.1).This was also evident from the land use/land cover analysis for this area. Looking at the mandals that encompass the proposed linkages, it is seen that agricultural area is relatively high in all of them ranging from 27 to 42 percent. This means that the conservation recommendations can and should include agricultural area as they will play an important role in creating linkages and ensure that the matrix is suitable for wildlife movement. Appropriate interventions might include involvement of farmers at the planning stage, encouraging native tree plantations around fields and promoting sustainable farming options.

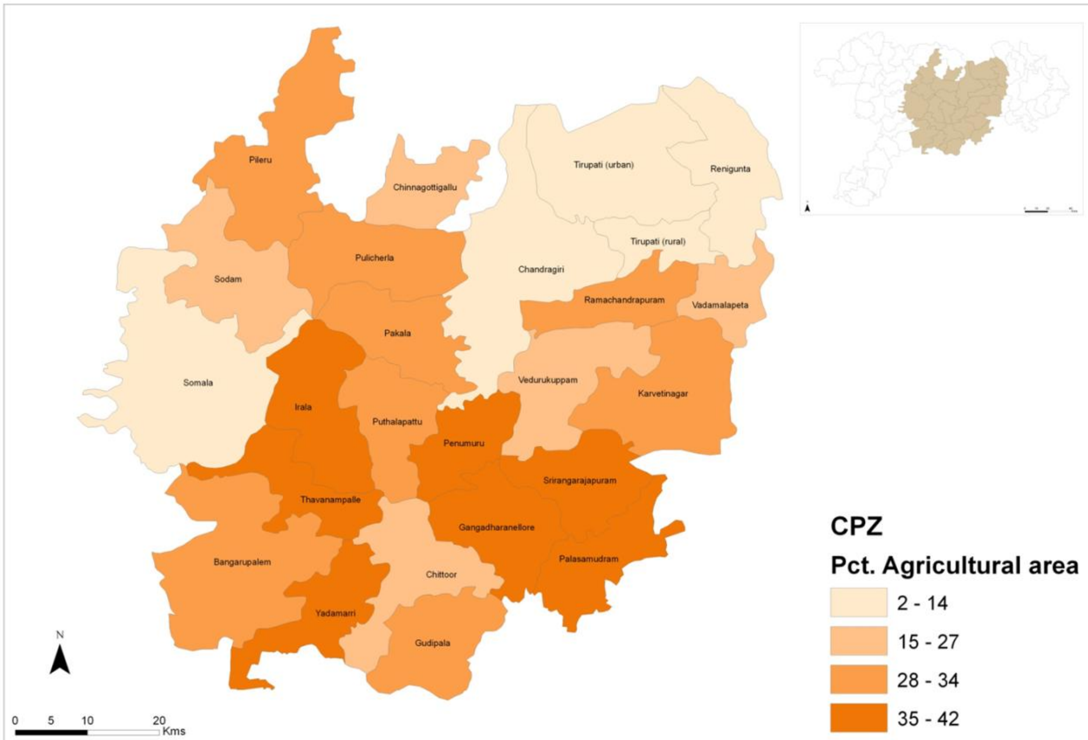

Figure 7.1. Percent agricultural area in the CPZ

b) Poverty: The percentage of poverty in the CPZ is relatively high. The areas consisting of the proposed linkages show 22 to 25 percent of poverty. Keeping in mind that Chittoor district is ranked as one of the most backward regions in the country by the government, a high level of poverty is evident (Figure 7.2). The only mandal at the lowest end of the spectrum is Chittoor (mandal), at six percent. This is apparent as the district headquarters are located in Chittoor town, thus making it a central place for commerce and other activities. Elsewhere, poverty is high and thus cannot be ignored in the process of making suggestions to conserve the forests in the area. Such high levels of poverty may hamper any kind of conservation strategies if they are not designed to meet the needs of the poor. More specifically, the mandals containing the proposed linkages also show high rates of poverty and hence the recommendations for conservation must entail both conservation initiatives and those that address poverty alleviation.

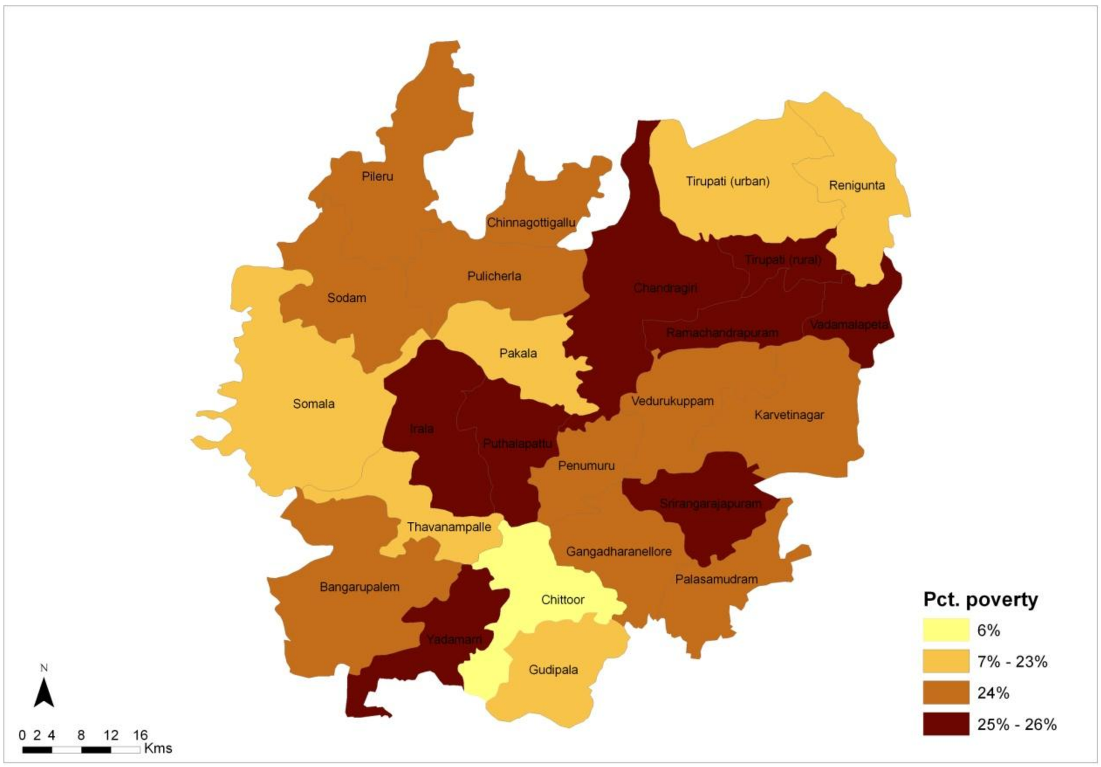

Figure 7.2. Percent poverty in the CPZ

c) Livestock: As already discussed, livestock play an important role in the state of the forests as well as the lives of the poor. Goats cause more destruction than cattle in forest areas (Jones 2012) but they are still the primary choice for the poor due to their low maintenance costs. Additionally, goats are distributed under the poverty alleviation schemes employed by the state government without considering the availability of grazing lands. As a result, forests are used to graze these animals (Turner 2004). The distribution of the number of goats and cattle in the conservation priority zone can be seen in Figure 7.3 and 7.4.

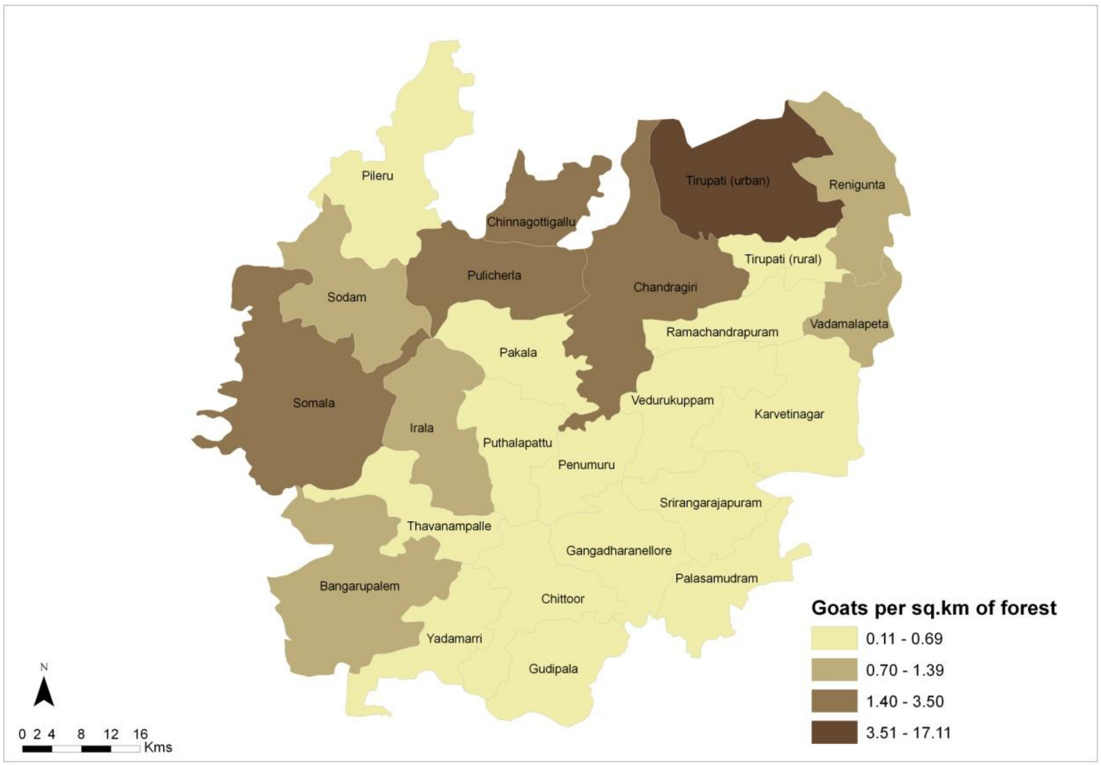

Figure 7.3. Goats per km^2 of forest in the CPZ

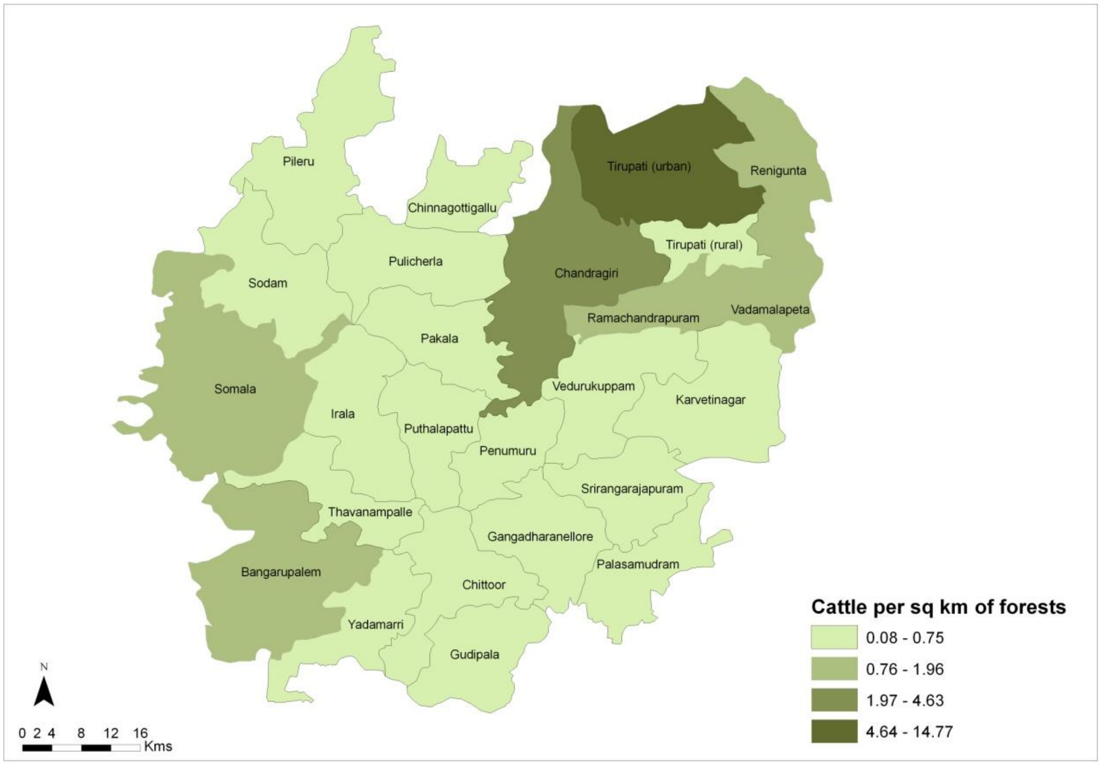

Figure 7.4. Cattle per km^2 of forest in the CPZ

The presence of large numbers of livestock in the area under consideration reflects one of the imminent threats to the forests. Thus, the conservation recommendations should include potential alternatives to livestock grazing. Promoting fodder species in other common lands surrounding the village and around agricultural fields is one option. Another alternative is rotational grazing[22] which has been promoted in this region, especially under the Joint Forest Management (JFM) program implemented by the Forest Department.

[22] Rotational grazing is the practice of demarcating the forest/grazing land into three or four parts through village meetings and participation of all the members of the JFM committee. Once the land is divided theoretically, the village agrees on allowing one or more portions to rest for a season/year while they use the other for grazing livestock.

d) Tribal Population: Though the CPZ does not have a very high percentage of tribals (Figure 7.4), interestingly there is a relatively higher percentage of tribal population in the areas proposed as potential linkages. Based on the scale of data used it is difficult to make conclusive suggestions regarding the need to involve the tribal population in the process of conservation. This variable will need to be analyzed further at the village level. Thus making any suggestions at this scale will be pointless. Secondly, although one can hypothesize that tribal populations depend on forests for their livelihood (World Bank 2006), there is evidence to suggest that due to multiple factors many tribes have moved to alternate livelihood options (Purshothaman 2005). Therefore, making a distinction will be inappropriate at this stage. Rather, recommendations should be made after the identification of specific groups of people (stakeholders) who are heavily dependent on forests and their spatial distribution within the CPZ.

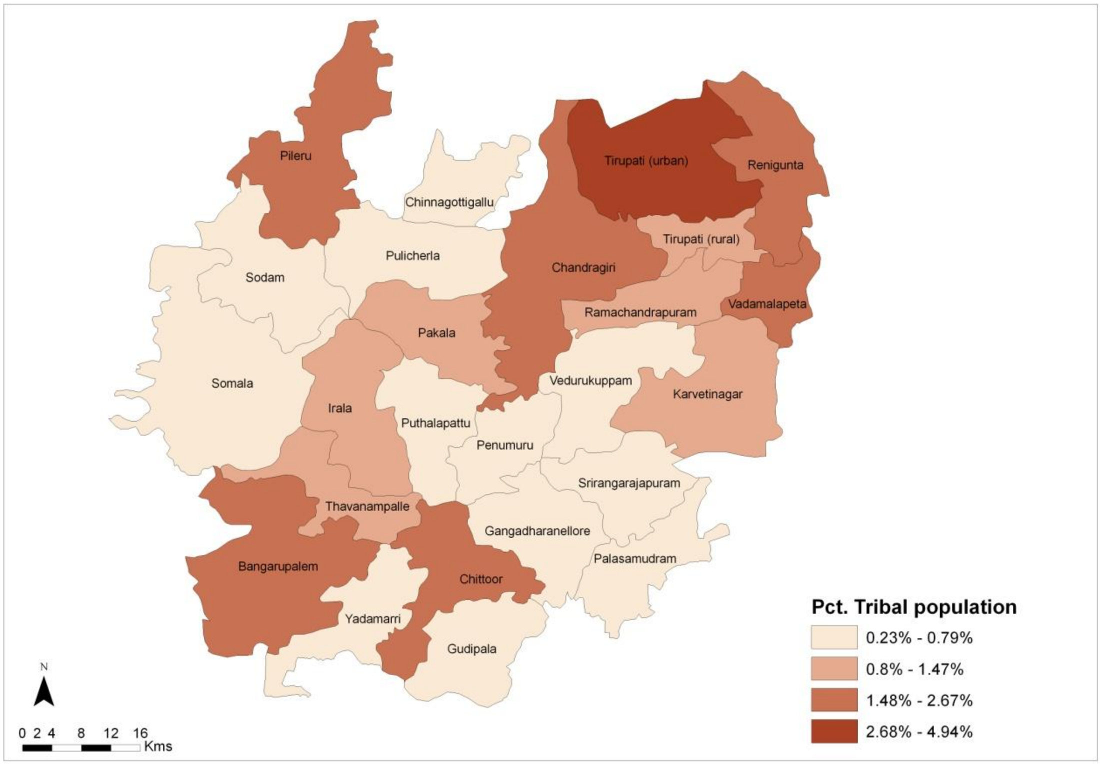

Figure 7.5. Percent tribal population in the CPZ

In conclusion, the individual variable analysis for the CPZ has provided indicators to the possible recommendations for the area. Though the mandal level may not be the most appropriate to design details for such a project, it does provide information at a regional scale. In the case of the conservation priority zone, other than conserving the matrix and restoring connectivity, the objectives must include strategies for poverty alleviation and sustainable agricultural practices. The next section deals with identifying the scales of intervention as it is essential to recognize that social factors operate at multiple scales.

7.4 Scales of intervention

The complexity and multiplicity of scale is a well-recognized factor in ecological and geographical studies when dealing with the complex nature of community-based management (Berkes 2004). In the challenges and opportunities (of implementing a biodiversity conservation corridor) discussed by Sanderson et al. (2006), the authors refer to governance, property rights, and community values as the focus areas. These include the larger issues, but even at the regional scale, it is important to comprehend the multiplicity of the situation. For this study the scales of intervention are divided into three categories: local communities and institutions, government, and non-state actors like NGOs (non-governmental organizations). The relevance of each of these in the Indian context has been discussed in great detail by researchers and practitioners in the field (Bhagwat et al. 2005; Chettri et al. 2007; Chhatre and Saberwal 2005; Robbins et al. 2009; Sarma and Easa 2006; Shrivastava and Heinen 2007). Linking these different scales of intervention requires what Berkes (2003) calls "cross-scale conservation", which looks at a process of "… linking institutions horizontally (across space) and vertically (across levels of organization)" (626). For the study area, identifying the stakeholders at each level of intervention is necessary to make specific recommendations (Table 7.1.). The linkages between each scale will have to be drawn and worked upon at the field level, rather than on the basis of a hypothetical understanding.

Table 7.1. Different scales of intervention for a conservation plan

Scale of intervention	**Key stakeholders**
Local communities	Farmers, shepherds, women, resource dependent communities & non-timber forest products (NTFP) collectors
Community level institutions	Informal or semi-formal village level institutions for common property resource management, women self help groups[23] (SHGs) & village forest committees[24] (VFCs)
Local government	Panchayat members (elected village level governing body)
Mandal & District level	Key officials dealing with resource management plans and budgetary allocations
Forest department	District Forest Officer & Forest Beat officials at the lower level
Non-state actors	NGOs working on natural resource management, agriculture, biodiversity conservation, alternate livelihoods, and capacity building
	Individuals or groups who have conducted wildlife based research in the study area

a) Local communities: With respect to the term ‘community’ it is important to mention that it is not a static concept, and it consists of people with homogenous interests (Berkes 2003). Communities are always evolving as are the (locally-based) management institutions they function within. Thus, conservation recommendations should incorporate the requirements of the key stakeholders identified under the community level in Table 7.1. Locally managed institutions are often influential in the village, and play an important role in managing common property resources. Assessing the presence, influence and representation of the vulnerable groups in these institutions will have to be a prerequisite to involving them in the process.

[23] SHGs are women groups organized by both the state and NGOs in villages, with multiple objectives often beginning with saving and credit mechanisms, capacity building and other significant issues.
[24] VFCs are village level committees organized by the forest department under the JFM (Joint Forest Management Program).

b) Government: The government is important not only for the required permissions to implement such a project, but also to ensure participation from local leaders and government officials, which in turn affects the implementation stage. Additionally, government resources can help fund projects. For this purpose, it will also be useful to identify existing conservation-related laws within which a biodiversity conservation corridor can be implemented. Since this research does not focus on the details of the legal framework or the politics of the conservation discourse in India, further investigation into relevant laws (Table 7.2) is required to pin point where and how they can be used.

Table 7.2. Potential laws and possible interventions to establish the biodiversity conservation corridor

Legal framework	**Possible interventions**
Indian Forest Act, 1927	To declare the area as a Reserved Forest or a Protected Forest
Wildlife (Protection) Act, 1972	To include the corridor (linkages) as a Protected Area based on the endangered and endemic species present or declaring the area as a Community Conserved Area
The Environment Protection Act, 1986	To declare the conservation priority zone as ecologically sensitive
The Biological Diversity Act, 2002	To streamline benefit sharing from biological resources (high value NTFPs-non-timber forest products) and ensure sustainable extraction
Forest Rights Act, 2006	Recognition of rights to traditional forest dwellers and scheduled tribes
Source: Ministry of Environment and Forests (MoEF) online portal, 2012	

Since there is no template regarding which laws can be used to demarcate a wildlife corridor in India, there is a need for flexibility in the approach. The process of establishing elephant corridors in India is still in the planning stage for most of the proposed corridors, and the few that have been recognized use different aspects of the law based on the land use in the area (Menon et al. 2005). This implies that interventions using the legal framework will also be context-specific.

c) Non-state actors: Non-government organizations or NGOs play a significant role in global environmental governance (Gemmill and Bamidele-Izu 2002). This is true for Chittoor district too, as there are a number of organizations working on issues related to common property resource management, forests, water and sustainable livelihoods. NGOs and other civil society forums are perfect platforms to initiate new concepts, generate awareness, gain local support and mobilize community participation. The involvement of local NGOs as stakeholders may be an advantage in the process of building rapport with villagers for the biodiversity conservation corridor. In addition, working with academics and independent researchers who are conducting research related to biodiversity conservation and socioeconomic dynamics in Chittoor district will be very helpful.

7.5 Recommendations

Based on the discussion so far, recommendations are provided for the proposed biodiversity conservation corridor in Chittoor district. These consider the biodiversity conservation perspective, socioeconomic situation, and the institutional linkages needed to implement this proposal.

7.5.1 Recommendations for conservation of biodiversity in Chittoor district

a) Assess the migratory status of species (specifically those which are known to migrate on a regular basis), routes used, human-animal conflicts, road kills, and the ecological history of the area: Since the biodiversity conservation corridor is primarily for conservation of species outside Protected Areas, conducting an assessment to gauge the level of species movement, the routes used and potential issues which may hamper movement needs to be studied. This will allow for a more scientific analysis with regard to species dispersal. Species level data can be collected through independent researchers, conservation based NGOs, and the Forest Department either through existing databases or surveys. The Forest Department maintains a record of human-animal conflicts, which can be accessed for the areas that fall under the CPZ. This information can be supplemented through discussions with village representatives to assess the situation.

   Along with this, identification of the forest classification (by the Forest Department) in the linkages will determine the scope of conservation. As discussed earlier, forests are categorized into reserved, protected, and unclassed forests, and each of these have varying levels of protection and hence varying degrees of resource extraction.

b) Organize workshops with local stakeholders to assess the credibility of the conservation priority zone and the linkages identified: Despite the fact that the conservation priority zone has been based on the land use and selected socioeconomic variables, it is essential to validate these findings with local communities, representatives of the Forest Department and local NGOs. Since dealing with all the stakeholders at an individual level will be difficult, organizing a workshop will help bring everyone to the table thus allowing a discussion and debate on the efficacy of the area selected.

In addition, consulting researchers who have conducted research in the area will be of immense value as they may have more insight into the dispersal dynamics of species in the area. For example, Manakadan et al. (2010) track the history of colonization of elephants in the area over two decades, analyze conservation issues which led to this migration, and assess the scope of long term survival of these populations based on current population estimates, habitat suitability, frequency of fires, and water availability. The migratory route taken by elephants in the late 1980s has been documented (Figure 7.6), which corresponds with the linkages proposed in this study to some extent.

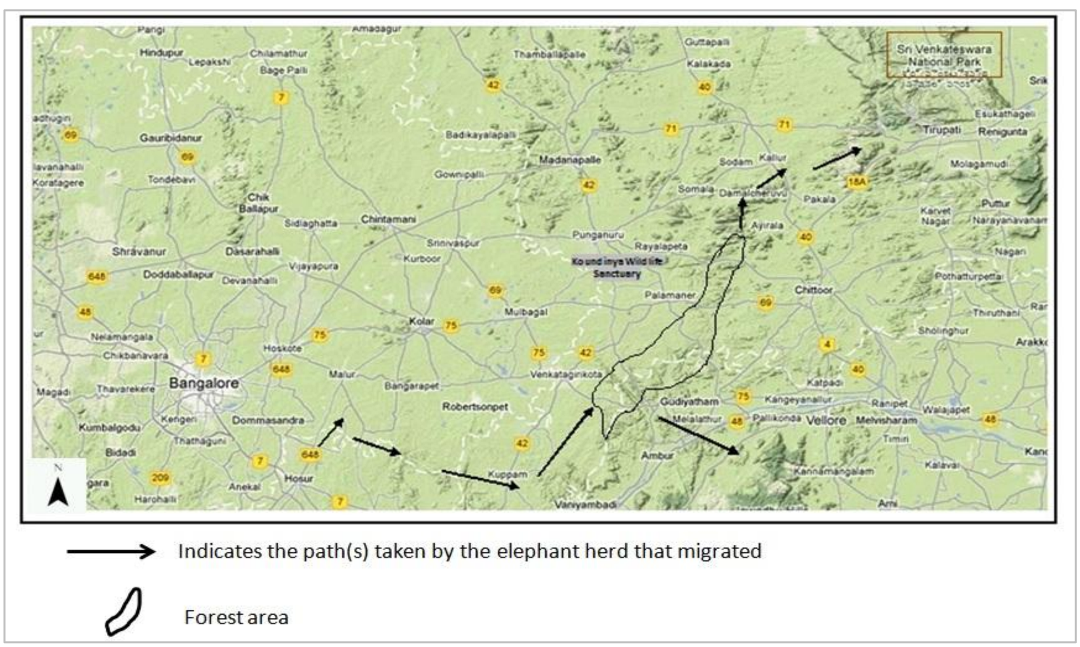

Figure 7.6. Dispersal route of elephants from the Western to the Eastern Ghats (Source: Adapted from Manakadan et al. 2010, 17)

c) Assess land use at the village level for the linkages identified to propose specific interventions: This will provide an opportunity to make precise recommendations based on the agricultural practices, taking into account currently used soil and water conservation methods being practiced and thus design interventions targeted at restoring the matrix.

d) Document the biodiversity in the forests selected as part of the linkage: A study of flora and fauna in the areas selected for creation of the biodiversity conservation corridor will help in assessing the present status of these forests which will in turn provide indicators for targeted conservation activities.

e) Compute landscape metrics at a finer scale: Once the area selected has been validated at the field level, landscape metrics such as the size of each patch, the core area, edge density, and patch density will provide details that will help in the design of the proposed linkages.

f) Assess change in forest cover: A change analysis will determine the effects on forest cover over the last decade and will also identify areas where habitat loss and fragmentation exist. This can be used to provide evidence for the need to conserve the existing forests in the district.

7.5.2. Recommendations for addressing socioeconomic realities in Chittoor district

a) Agriculture: Considering that agriculture is the predominant land use in the area, a focus on strategies to conserve the matrix will be required to ensure minimal resistance for species dispersal. Potential approaches can include promotion of agroforestry[25] and live fencing[26], which will not only provide alternatives for fuel wood and fodder but also reduce pressure on forests, and simultaneously augment farm income through harvest of non-timber forest products (NTFPs). Agroforestry techniques have also been shown to provide benefits to soil and water in agricultural fields. Most importantly, "agroforestry has benefits for biodiversity by providing structurally similar habitat for forest species, serving as biological corridors…" (Leisher et al. 2010, 39). The key component for agroforestry to benefit both biodiversity and people will be to maximize plantation of native trees and shrubs with a focus on those species that meet the biomass requirements of the landowners and provide an added income source. Soil and water conservation methods that help the farmers as well as the overall health of the landscape can also be undertaken on agricultural lands to promote better yields, especially in the more drought prone and poorer areas of the district.

b) Resource dependent communities: Identify resource-dependent groups and develop strategies to involve them in the process of conservation. Among the previously identified stakeholders (Table 7.1), demarcation of resource-dependent communities is of paramount importance for two reasons: first, to meet the needs of these communities in an equitable and sustainable manner and second, for data collection as individuals from these groups can provide vital information on animal dispersal and the location and status of non-timber forest products (NTFP) in the forests. Working with these communities will also provide insight into NTFP collection in terms of the supply chain and the levels of extraction.

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[25] The practice of integrating trees into agricultural landscapes (CBD 2010), essentially combining agriculture and forestry to benefit both sectors.

[26] A traditional form of agroforestry where a line of trees or shrubs were planted with little space between them practiced in tribal dominated areas of the Eastern Ghats (Choudhury et al. 2004).

Resource-dependent communities are landless, or have historically depended upon forest resources for their sustenance. Given the present scenario, one can assume that resource-dependent communities are the most vulnerable and poor groups in the area. A conservation plan will have to include strategies like capacity building and alternate livelihood options for these groups.

Further, conservation strategies must also include women in the planning and implementation process. In the study area women are most often responsible for collecting fuel wood from the forests, thus potential activities aimed at reducing pressure on forest resources must include their participation at every stage.

c) Livestock: Another complicated issue that must be dealt with is livestock. Livestock rearing has multiple benefits especially for poor households; it is a form of nutrition for the home, it aids in crop production (for plowing the fields and organic manure) and it is often used as an "adaptive strategy" (Akter et al. 2008). Livestock are assets and help to combat family emergencies, especially in severe drought years and other times of crisis. A consequence of this has been the distribution of sheep, cattle, and goats by both the government and the NGOs to vulnerable communities (Jones 2012). Unfortunately, this technique to combat poverty has not been successful or even viable for several reasons that include: lack of grazing land, lack of resources to buy fodder, consecutive drought years, and the fact that rearing livestock has not been historically practiced by many tribal communities.

In this context, whether to promote livestock in the study area or not will have to depend upon a field-based assessment of the livestock population and fodder availability. Moreover, strategies like rotational grazing and development of wastelands around settlements need to be implemented (to deal with the existing livestock population) so that community participation works in tandem with government programs.

Though not all-encompassing, the above recommendations highlight critical areas that need to be addressed before the establishment of a biodiversity conservation corridor in Chittoor district. Along with these, identifying key stakeholders, making linkages between the different scales of intervention and analyzing legal provisions is crucial.

CHAPTER VIII

CONCLUSION

8.1 Introduction

This study began with the aim of assessing the feasibility of establishing a wildlife corridor between the Rayala Elephant Reserve and S.V. National Park in Chittoor district, Andhra Pradesh, India. The likelihood of establishing a wildlife corridor depends both on ecological and socioeconomic factors. This is further complicated by administrative hurdles and logistics required to establish and maintain such a corridor. This research takes into account the structural configuration and composition of the landscape, socioeconomic factors affecting forest area in Chittoor district, and the practical aspects to consider before proposing a wildlife corridor. More specifically, this study set out to identify socioeconomic factors that contributed to forest area in Chittoor district and determine their relative contribution towards a corridor design. Additionally, it aimed at proposing a potential corridor between the Rayala Elephant Reserve and Sri Venkateswara National Park based on both social and biogeographic factors. Ultimately, the scope of this research was to make conservation recommendations centered on the potential corridor(s) identified by this study.

8.2 Discussion of results

A biodiversity conservation corridor attempts to strike a balance between the sustenance of resource-dependent communities and biodiversity within a region. In a human-dominated landscape, which is the case in this study, balancing the needs of communities and biodiversity is difficult. In designing such a corridor, appropriate planning, adequate resources, involvement of the stakeholders, and a multi-objective design needs to be taken into consideration.

Thus, the need for a biodiversity conservation corridor in Chittoor district that potentially connects the Rayala Elephant Reserve and Sri Venkateswara (S.V.) National Park was established through an analysis of the various contributing factors. Forests cover 30% of the geographic area in the district, and with only three protected areas (comprising 0.27% of the forest area) there is an urgent need to conserve the remaining forests. The computed landscape metrics indicated the prevalence of a highly fragmented landscape. On the other hand, the contagion index showed contiguity within the different land use/land cover categories suggesting a scope for conservation and/or restoration of the landscape. The land use/land cover also provided evidence of a high percentage of land use for agriculture, which has the potential to supplement the existing forest network to enhance connectivity. In terms of the socioeconomic dynamics, Chittoor district has high rates of poverty that will inevitably affect conservation efforts because of the hypothesis that the poor often depend on forests for their livelihood and fuel wood requirements. The OLS regression model used to assess the contribution of selected socioeconomic variables such as agricultural area, non-agricultural area, tribal population, poverty, and population of cattle and goats on forest area explained 75 percent of the variation in forest area in the district.

The next step was to identify a conservation priority zone (CPZ) based on the criteria for a biodiversity conservation corridor between the S.V. National Park and the Rayala Elephant Reserve. Apart from using the results obtained from the socioeconomic and landscape analyses, transportation networks, and the presence of water was taken in to consideration in the CPZ. Finally, two linkages were proposed and compared using a weighted matrix that employed different criteria to numerically assess the permeability for each linkage.

Finally, conservation recommendations for the CPZ were provided based on both biodiversity considerations and the socioeconomic realities. This section of the study identified different scales of intervention, which included resource dependent communities, state and non-state actors. The potential biodiversity conservation corridor was also analyzed within the context of the legal frameworks existing in India to show that a case-by-case application of the law is necessary.

8.3 Limitations

Each chapter addresses specific limitations implicitly, thus putting potential shortcomings into context. Some of these are the lack of field surveys that point towards a disparity between theoretical potential and ground realities. This study continuously acknowledges that the data provided and analyzed, the methods used, and the recommendations supplied are only the first step in the conception of a biodiversity conservation corridor. Second, the unavailability of data in specific formats led to several constraints. For example, lack of appropriate data was the primary reason for not using graph theory, or other modeling techniques in GIS to assess the linkages. Third, the scope and timeframe of this study prevented further research into what now seems like a very complex problem.

8.4 Suggestions for future research

Drawing from the first limitation mentioned in the previous section, the primary objective of future research would be fieldwork. This will help validate the findings and the proposed linkages, which can create awareness among stakeholders. Examining the biogeographic and socioeconomic factors contributing to forest fragmentation at a finer scale will also be essential. Finally, interactions with resource dependent communities and relevant stakeholders at the state level will put this research into perspective and provide further direction. Overall, the scope for further research in the area is immense and can have a wide-ranging impact. This study provides a basis to build, restore, and conserve the biodiversity in Chittoor district and simultaneously work towards the needs of specific communities.

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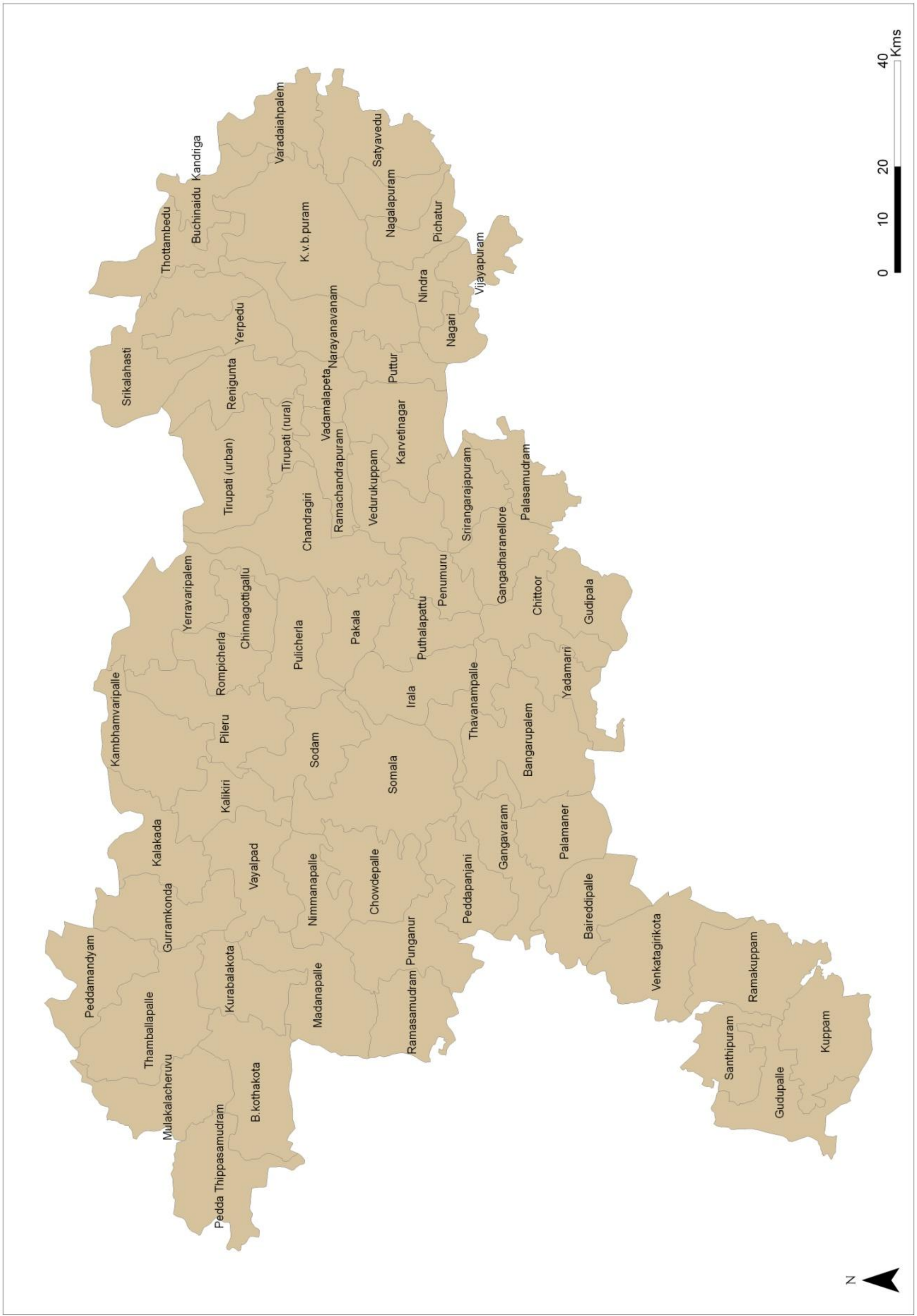
APPPENDICES

A.1: Metadata for the OLS regression analysis

Field	**Data**
Mandal	Name of mandal (administrative division)
Total Geographic Area	Area in square kilometers
Pct. Forest Area*	Percent forest cover
Pct. Agricultural Area	Percent agricultural area
Pct. Non-agri.area	Percent non-agricultural area (Lands put to uses other than agriculture)
Pct. Poverty	Percent of population living under poverty
Pct. Tribal Population	Percent tribal population (based on total tribal population)
Goats per km^2	Goats per square kilometer of forest area
Cattle per km^2	Cattle per square kilometer of forest area
Source: Handbook of Statistics for Chittoor District, 2010 *The State of Forests Report, 2010	

A.2: Mandal map for Chittoor district



Srikalahasti
Thottambedu
Buchinaidu Kandriga
Varadaiahpalem
Satyavedu
K.v.b.puram
Nagalapuram
Pichatur
Vijayapuram
Nindra
Nagari
Yerpedu
Renigunta
Narayanavanam
Vadamalapeta
Puttur
Tirupati (urban)
Tirupati (rural)
Ramachandrapuram
Karvetinagar
Vedurukuppam
Chandragiri
Srirangarajapuram
Palasamudram
Gangadharanellore
Yerravaripalem
Chinnagottigallu
Rompicherla
Pulicherla
Pakala
Puthalapattu
Penumuru
Chittoor
Gudipala
Kambhamvaripalle
Pileru
Irala
Thavanampalle
Yadamarri
Bangarupalem
Sodam
Somala
Kalikiri
Kalakada
Vayalpad
Nimmanapalle
Chowdepalle
Peddapanjani
Gangavaram
Palamaner
Gurramkonda
Peddamandyam
Thamballapalle
Kurabalakota
Madanapalle
Punganur
Ramasamudram
Baireddipalle
Venkatagirikota
Ramakuppam
Kuppam
Santhipuram
Gudupalle
Mulakalacheruvu
B.kothakota
Pedda Thippasamudram
0
10
20
40
Kms
N

A.3: Mandal-wise population and tribal population

No.	Mandal	Total Population	Population Density	Tribal Population	Pct. Tribal Population
1	B.kothakota	54,688	189.89	1677	3.07
2	Baireddipalle	50,094	166.43	1333	2.66
3	Bangarupalem	69,253	175.77	2787	4.02
4	Buchinaidu Kandriga	30,885	120.18	4002	12.96
5	Chandragiri	53,051	116.34	2851	5.37
6	Chinnagottigallu	24,910	138.39	656	2.63
7	Chittoor	207,419	934.32	2302	1.11
8	Chowdepalle	40,410	172.69	470	1.16
9	Gangadharanellore	64,831	319.36	562	0.87
10	Gangavaram	48,879	216.28	804	1.64
11	Gudipala	42,387	250.81	719	1.70
12	Gudupalle	38,480	229.05	306	0.80
13	Gurramkonda	41,769	163.16	806	1.93
14	Irala	48,891	227.40	1424	2.91
15	K.v.b.puram	39,432	101.11	3379	8.57
16	Kalakada	34,279	142.83	1403	4.09
17	Kalikiri	46,413	241.73	624	1.34
18	Kambhamvaripalle	43,353	130.58	2202	5.08
19	Karvetinagar	44,735	178.23	1790	4.00
20	Kuppam	102,947	239.41	1018	0.99
21	Kurabalakota	37,686	184.74	602	1.60
22	Madanapalle	190,512	577.31	5382	2.83

No.	Mandal	Total Population	Population Density	Tribal Population	Pct. Tribal Population
23	Mulakalacheruvu	41,711	170.95	951	2.28
24	Nagalapuram	33,886	176.49	2053	6.06
25	Nagari	89,655	640.39	2689	3.00
26	Narayanavanam	35,677	312.96	1794	5.03
27	Nimmanapalle	31,166	160.65	296	0.95
28	Nindra	27,905	281.87	1851	6.63
29	Pakala	56,802	312.10	1172	2.06
30	Palamaner	71,545	305.75	2325	3.25
31	Palasamudram	20,948	213.76	292	1.39
32	Pedda Thippasamudram	51,040	180.99	590	1.16
33	Peddamandyam	34,453	133.02	3256	9.45
34	Peddapanjani	52,371	178.13	703	1.34
35	Penumuru	38,912	288.24	804	2.07
36	Pichatur	31,389	207.87	1600	5.10
37	Pileru	61,824	317.05	2788	4.51
38	Pulicherla	38,554	179.32	750	1.95
39	Punganur	94,784	319.14	3145	3.32
40	Puthalapattu	44,676	238.91	998	2.23
41	Puttur	68,256	361.14	3945	5.78
42	Ramachandrapuram	30,533	213.52	1261	4.13
43	Ramakuppam	50,874	175.43	4803	9.44
44	Ramasamudram	45,078	268.32	300	0.67
45	Renigunta	66,563	286.91	3419	5.14

No.	Mandal	Total Population	Population Density	Tribal Population	Pct. Tribal Population
46	Rompicherla	27,359	189.99	431	1.58
47	Santhipuram	50,952	312.59	331	0.65
48	Satyavedu	48,992	195.97	3059	6.24
49	Sodam	33,771	146.83	754	2.23
50	Somala	42,987	117.77	1014	2.36
51	Srikalahasti	124,918	397.83	8135	6.51
52	Srirangarajapuram	33,762	259.71	886	2.62
53	Thamballapalle	38,693	110.87	2623	6.78
54	Thavanampalle	51,927	270.45	1263	2.43
55	Thottambedu	41,290	212.84	4339	10.51
56	Tirupati (rural)	73,478	656.05	1881	2.56
57	Tirupati (urban)	309,435	1419.43	6328	2.05
58	Vadamalapeta	31,291	188.50	2470	7.89
59	Varadaiahpalem	41,547	183.03	4105	9.88
60	Vayalpad	44,725	154.76	354	0.79
61	Vedurukuppam	44,995	166.03	1010	2.24
62	Venkatagirikota	74,919	334.46	2205	2.94
63	Vijayapuram	29,317	162.87	1512	5.16
64	Yadamarri	49,437	321.02	608	1.23
65	Yerpedu	53,001	203.85	4567	8.62
66	Yerravaripalem	25,173	102.33	1326	5.27

A.4: Parameters used to calculate landscape metrics using Fragstats

For the study area	
File format	ASCII
Cell size (in meters)	30
No. of rows	5532
No. of columns	8048
Analysis type	Standard
Cell rule	4 Cell Rule

For the Conservation Priority Zone (CPZ)	
File format	ASCII
Cell size (in meters)	30
No. of rows	1249
No. of columns	1471
Analysis type	Standard
Cell rule	4 Cell Rule

A.5: Scores calculated for each segment of Linkage 2 (L2)

Weighted matrix for L2 : Scores for each segment (i.e. a-f)					
Criteria	**L2**	**a**	**Scores**	**Weight**	**Geometric Mean**
Distance		90	90	20%	2.46
Presence of NH		100			
Presence of SH		100	100	20%	2.51
Presence of railways		100			
Presence of streams		0	50	40%	4.78
Presence of tanks		100			
Presence of settlements		100	100	20%	2.51
Final Score					74.21
	L2	**b**	**Scores**	**Weight**	**Geometric Mean**
Distance		90	90	20%	2.46
Presence of NH		100			
Presence of SH		80	90	20%	2.46
Presence of railways		90			

Presence of streams		100	50	40%	4.78
Presence of tanks		0			
Presence of settlements		100	100	20%	2.51
Final Score					72.66
	L2	**c**	**Scores**	**Weight**	**Geometric Mean**
Distance		80	80	20%	2.40
Presence of NH		100			
Presence of SH		100	100	20%	2.51
Presence of railways		100			
Presence of streams		100	50	40%	4.78
Presence of tanks		0			
Presence of settlements		100	100	20%	2.51
Final Score					72.48
	L2	**d**	**Scores**	**Weight**	**Geometric Mean**
Distance		80	80	20%	2.40
Presence of NH		100			
Presence of SH		80	90	20%	2.46
Presence of railways		90			
Presence of streams		0	50	40%	4.78
Presence of tanks		100			
Presence of settlements		100	100	20%	2.51
Final Score					70.97

	L2	e	Scores	Weight	Geometric Mean
Distance		90	80	20%	2.40
Presence of NH		100			
Presence of SH		100	96.67	20%	2.49
Presence of railways		90			
Presence of streams		0	0	40%	0.00
Presence of tanks		0			
Presence of settlements		100	100	20%	2.51
Final Score					15.05*
* has excluded the 0 value					
	L2	**f**	**Scores**	**Weight**	**Geometric Mean**
Distance		90	90	20%	2.46
Presence of NH		90			
Presence of SH		100	96.67	20%	2.49
Presence of railways		100			
Presence of streams		100	50	40%	4.78
Presence of tanks		0			
Presence of settlements		90	90	20%	2.46
Final Score					72.17

VITA

Diya Paul

Candidate for the Degree of

Master of Science

Thesis: CONSERVING BIODIVERSITY OUTSIDE PROTECTED AREAS: ANALYSIS OF A POTENTIAL WILDLIFE CORRIDOR IN CHITTOOR DISTRICT, ANDHRA PRADESH, INDIA

Major Field: Geography

Biographical:

Education:

Completed the requirements for the Master of Science in Geography at Oklahoma State University, Stillwater, Oklahoma in July, 2012.

Completed the requirements for the Master of Arts in Social Work at Delhi University, India in 2002.

Professional Memberships: Association of American Geographers and Gamma Theta Upsilon

Name: Diya Paul Date of Degree: July, 2012

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: CONSERVING BIODIVERSITY OUTSIDE PROTECTED AREAS: ANALYSIS OF A POTENTIAL WILDLIFE CORRIDOR IN CHITTOOR DISTRICT, ANDHRA PRADESH, INDIA

Pages in Study: 144 Candidate for the Degree of Master of Science

Major Field: Geography

Scope and Method of Study:

This study analyzes the potential of establishing a biodiversity conservation corridor in Chittoor district, Andhra Pradesh, located in southern India. More specifically, the focus is on the area between the Rayala Elephant Reserve and the S. V. National Park. Using a combination of methods to assess the feasibility of conservation in this portion of the Eastern Ghats, the study focuses on biogeographic and socioeconomic factors. The study specifically analyzes the spatial configuration of land use/land cover through the calculation of landscape metrics using Fragstats. The interplay of socioeconomic variables influencing forest cover in the district is analyzed using an OLS regression model. Thus, based on the identification of different scales of intervention and legal frameworks, the study provides conservation recommendations for a biodiversity conservation corridor in Chittoor district.

Findings and Conclusions:

The OLS regression model explains 75% of the variation in area covered by forests in Chittoor district. While the landscape metrics calculated, show a fragmented landscape albeit one that is contiguous across the various forest classes in the district. Thus, it is possible to infer that the land use /land cover is at a stage where conservation efforts are essential to restore the habitat for species affected by fragmentation. Based on these findings and the criteria for biodiversity conservation corridors a conversation priority zone was selected between the Rayala Elephant Reserve and SV National Park. Two potential linkages are identified within this zone and assessed using multiple criteria. Consequently, the study provides conservation recommendations based on both biodiversity considerations and socioeconomic conditions in the district.

ADVISER’S APPROVAL: Dr. Dale Lightfoot