Evaluation of Impact of Landscape Changes on Large Mammal Habitats in Pench Tiger Reserve, Madhya Pradesh, India.

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Executive Summary

Wildlife conservation planning *inter-alia* requires basic information on distribution and abundance of natural resources. Knowledge of presence or absence of wildlife species and their distribution across a landscape is critical for making sound wildlife management decisions. Carnivore and herbivore species play a pivotal role in maintenance of forest ecosystem equilibrium, as they help in shaping its structure, composition and also directly or indirectly affect other animals. However, efforts towards conservation and management of wildlife are often hampered due to non-availability of good quality data on species, habitats and sustainability of the habitats for different species. *In-situ* conservation of biodiversity requires multidisciplinary approaches sustained by a foundation of sound scientific and technological information. With this background, the study aimed to map land use/land cover patterns and to assess spatial structure and configuration of landscape; structure and composition of vegetation types in landscape; spatial and ecological distribution of major carnivore and herbivore species.

The present study was carried out in Pench Tiger Reserve (PTR), Madhya Pradesh. The extent of the total area of PTR is 757.85 km^2 out of which Pench National Park (PNP) comprises 292.85 km^2 while Pench Mougli Sanctuary (PMS) covers 183 km^2 and surrounding reserved forest covers 229 Km^2, which are the parts of South Seoni forest division, South and East Chhindwara forest divisions. PNP and PMS forms the core of PTR while the reserved forest forms buffer. The Vegetation falls under Tropical dry deciduous and Tropical moist deciduous category.

Field work was carried out between April 2007 and June 2009. A total of 460 circular plots were sampled for vegetation quantification. The area was sampled using systematic stratified sampling approach. Stratification was done using administrative unit *i.e.* a forest beat. A total of 43 line transects of 2 km length were laid in all 43 beats of PTR covering all vegetation types of the study area. On these transects 215 circular plots were laid for vegetation quantification, equidistant at 400 m interval, while 245 plots were also laid randomly. Landsat TM data was used for land use/land cover mapping and canopy density mapping of PTR. Spatial structure of PTR landscape was described using software package FRAGSTATS. Data from vegetation plots was used to quantify structure and composition of six major vegetation communities by Two Way Indicator Species Analysis (TWINSPAN). Community-wise diversity, richness and evenness of tree species were calculated. Satellite data was mapped with seven vegetation type and four land use categories. *Chloroxylon swetenia*, *Zizyphus oenoplia-Lannea corromendalica-Tectona* grandis community and *Tectona grandis- diospiros melanoxylon- Grewia taeliafolia- Gardenia latifolia* community found to be most diverse while the later also registered highest species richness. Misecllaneous Forest occupied the maximum proportion of study area (38.9%) while the *Cliestanthus colinus* forest occupied the least (0.05%). Based on canopy density, the forests were sub grouped into four canopy density classes. The structural analysis of PTR landscape revealed its heterogeneous nature with large variations in patch size, but with high density, high evenness and intermediate interspersion of forest types.

Village level information on population density, sex ratios, literacy, fertile land holding, employment structure and live stock holding were collected from all the 99 villages present around 5 Km buffer of PTR. These villages were distributed in five ranges (Khawasa, Kurai, Rukhad, Gumtara and Bichua). A detailed data collection was done from February to June 2009. All the villages of each range were finally classified into three different distance categories as Category-I (within 1 Km), Category II (1 Km-2 km) and Category III- (2 km-5 Km) and the smallest and largest village in all categories in each ranges were chosen for household sampling. A close-ended questionnaire survey was administered to 1926 (98.7%) households of category-I sampling villages, 1324 (96.2%) households of category II sampling villages and 1471 (95.6%) households of Category-III sampling villages.

The villagers mostly belonged to Gond tribe (Scheduled Tribe). The average sex ratio amongst all the sampled households was found to be 98 females per 100 males, which is quite higher than the national average i.e. 93 females per 100 males. The child to adult female ratio of 183:100 revealed high growth in population. The overall reported literacy rate of the 99 villages was about 55.1 %. Among all the villages, the estimated average child literate to adult literate is 1.58:1 i.e. 158 child literate per 100 adult literate. The total number of livestock was estimated as 36143 with 9035 cows, 3130 buffaloes, 14299 oxes and 9679 goats. The villagers mainly grow paddy, wheat, corn, sugarcane, soyabean, pulses and gram largely for their own consumption.

In this study, data from 30 villages were presented which were selected for household sampling. The major tree species exploited as fuel wood in PTR are *Phyllanthus emblica*, *Boswellia serrata*, *Anogeissus latifolia*, *Butea monosperma*, *Terminalia tomentosa*, *Diospyros melanoxylon* and *Madhuca indica.* The NTFP collection was restricted to the collection of Tendu (*Diospyros melanoxylon*) leaves, flower and seeds of Mahua (*Madhuca indica*), fruits of Aonla (*Phyllanthus emblica*), fruits of Chiranji (*Buchnania lanzan*)**.** It was estimated that a total of 2265 headloads of fuelwood per day is extracted by all the 10 villages in Category I. The average head load each weighing about 30 kilograms, the total weight of the harvested fuel wood comes to 67950 kg per day combined for the 10 villages. Similarly, for the villages in Category II fuel wood exploitation is estimated to be 59850 kg per day and 49020 kg per day for the villages located in Category III. Amount of NTFP collected was highest among Category I villages and lowest in Category III villages. These villages have varied land holding, income movable property, mostly dependant on village size, location and connectivity with other areas. It was clearly evident that a large human population, residing around the Pench Tiger Reserve, is almost entirely dependent on the forest resources of the Reserve for the sustenance of its livelihood.

In recent years, a critical approach to environmental sustainability has resulted in greater importance being given to scientific research into the causes and effects of land use and land cover changes. Direct causes of deforestation can be divided into three main groups: a) infrastructure extension, b) agricultural expansion and c) wood extraction. This study highlighted some key impact of landscape change due to different anthropogenic activities like dam construction, cattle grazing, wood extraction and by different demographic, economic and policy attributes. Landsat Satellite imageries of 1977, 1989, 1999 and 2009 were used for Land use/ land cover change (LULCC) analysis. The trajectory images from the four dates with 5 land cover classes for each date resulted into 1) Stable miscellaneous forest, 2) Stable teak-associated forest, 3) Stable open forest, 4) Stable water, 5) Stable Non-forest, 6) Teak to Miscellaneous, 7) Deforestation, 8)

Reforestation, 9) Degradation, 11) Up-gradation. A series of non-redundant landscape metrics was applied to the present and historical classified land use/cover maps.

The overall trend corresponded to an absolute decrease in forest cover of about 11.1% of the forest surface present in 1977. This was due to the creation of hydroelectric dam in 1987 (impact of dam was discussed later in details) and deforestation. The forest surface showed a pronounced fragmentation in 1977 with a high number of patches and this fragmentation dramatically decreased in 2009, with a little exception of Miscellaneous forest which showed some increase in number of patches in last 10 years. Creation of Totladoh hydroelectric dam in 1987 had caused a loss of 76.7 km^2 area of the landscape. Between the year 1999 and 2009, the observed deforestation and degradation rates were very low in the core area which might be because of the protection measures taken by the forest department. In the Middle area (within PA and within collection/extraction distance), though the deforestation rates went down in the last 10 years, an increase in degradation was observed in this category. In the Outside area, both deforestation and degradation were almost same over the years. The present study provides a direct comparison of the effects of strict protection on forest and land-cover changes and thus contributes to the forest management literature. The study area exemplifies a typical case of contrasting management regimes in an area protected for wildlife. This condition enabled me to examine the role of different protective management approaches in preserving forest cover. Due to very little forest management intervention for more than 30 years, most of the one or two tree species dominated forest stands (like Teak-associated forests) were converted into mixed forest as shown by the increase in patch area but decrease in number of patches.

Uncontrolled extraction of forest resources in terms of fuel wood, fodder, NTFPs, agricultural expansions and utilization of forested lands for grazing left very less forested patch outside PTR where forests were heavily managed for harvesting of timber. While two date change trajectories showed decadal changes in forest covers as a result of changing forest policies, the overall change trajectory drew an overall change scenario experienced in the study area in the last 30 years. There were 50 tourism resorts that had come up after 1999 around the park. In the villages with these tourist resorts, degradation of forest had gone down between 1989 and 1999 but again increased after 1999. The opposite trend was found in deforestation. Most of these resorts maintained the theme to be a wildlife resort, so these resorts actually promoted to keep a forest cover to give the tourists wilderness feelings.

This study contributed to the land/forest cover change and socio-economic, biophysical and proximity factors affecting it. It was the first large scale forest cover change study in India for the entire Tiger Reserve and surrounding areas that investigated forest cover change and spatial variation within determinants by applying GWR. This study showed the importance of studying local spatial variation of forest cover in a protected area gathering information at village level with a set of demographic, biophysical and proximity determinants. Finally, this study demonstrated the importance of GWR as a tool for exploring local spatial variation of forest cover change and reducing spatial autocorrelation. This instrument could be used for studies with focus on natural resources in human-dominated landscapes managed for wildlife to reveal information at local level, which could be otherwise neglected. It is suggested that a GWR study should investigate whether local spatial variation was due to the influence of determinants to a response variable, a step which was not often in use though I found it valuable and meaningful. GRW analysis explored the behavior of variables at a local level and revealed significant spatial variability among some of them. This represented a clear enhancement of the understanding offered by a global analysis, rather than obtaining an average coefficient for the entire area, an estimated coefficient for each point analysed was obtained. Furthermore, this method revealed certain aspects of the inter-relationships which did not emerge with traditional global specifications. This implied that the parameter estimates for this regression varied according to geographical location. Therefore, the application of this method made it possible to study the spatial stability of the global model coefficients. It was found that the coefficients of many variables were spatially non-stationary and that the models produced using GWR describe the data significantly better than the global model (OLS). For both deforestation and degradation models in Geographically Weighted Regression, variation in number of households, variations in ST polulation, variation in literate population, variation in total irrigated land, distance from road and protectedness were selected.

The land use land cover prediction map by cellular automata markov model of 2019 had resulted in five classes i.e. Miscellaneous forest, Teak Associated forest, Open forest, Water and Agri-habitation. Miscellaneous forest had turned out to be the largest class.

Competition between human activities and wildlife is becoming more intense due to habitat destruction, leading to the decline of wildlife species. Effective wildlife conservation needs to reduce the friction between human and wildlife activities by identifying areas suitable for wildlife, and by reducing human intervention in these areas. For this purpose, mapping of suitable habitat is very important for wildlife conservation and ecosystem management. The actual geographical distribution of species as Habitat Suitability (HS) map is the result of the analysis of species–environment relationships. Species distribution lies well within the optimal range of environmental factors. It is, therefore, useful for ecological modelers to design a methodological algorithm to compute HS by incorporating most of the environmental factors with presence–absence data or only with presence data to develop a more precise estimate. In the present study, chital (*Axis axis*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*) among the wild ungulate species and among large carnivores, tiger (*Panthera tigris*), leopard (*Panthera pardus*) and wild dog (*Cuon alpinus*) were chosen for large mammal habitat suitability (HS) modeling.

In the present study, high positive marginality of chital, sambar and wild pig were found with tiger, leopard and wild dog. In spite of similar densities, carnivores like tiger, leopard and wild dog may co-exist since the ecological factors, such as adequate availability of appropriate-sized prey, dense cover and high tree densities may be the primary factors in structuring the predator communities of tropical deciduous forests. In the present study, the observed low marginalities among the carnivores showed less competition/affinity. The presence of all the study species (prey/predator) were negatively correlated with major human disturbance indicators such as lopping, cattle dung and wood cutting. This suggested that all these species avoided disturbed areas and preferred areas far from roads and villages. The extent of human presence could be attributed by the presence of 99 villages within 5 Km buffer of PTR. These villages exert immense pressure on forests as people here are mostly dependent on forest for fuel wood collection and grazing of livestock. Due to adequate protection and support from field staffs, the overall specialisation of the human disturbance models of the carnivore species turned out to be the highest, which can be attributed as the conditions of human disturbances in PTR for carnivores are better than species interaction and resource-geographical conditions. As predator distributions are guided by prey distributions, similarly presence of chital, sambar and wild pig distribution are influenced by forest canopies as observed in the present study. Miscellaneous and teak associated forests dominate in PTR. These forest types had shown greater association with all the study species. Water being one of the essential life support factor, contributed equally in all the HS models of the study species.

Though future predictions of HS are modeled only with few habitat classes, still they are powerful enough to enlighten future scenarios. In the given circumstance these predictions are over estimated as same species presence data sets of present day was used for the future scenarios. These results left enough space for validation or contradiction through many similar studies in future. All the study species showed decrease in suitable habitat.

The HS models provide a tool for the conservation and management planning of major carnivore and wild ungulate species in and around PTR. These models predicted the distribution and the extent of favorable species-specific habitats in the study area. This study provided not only factors governing species presence in PTR but also gave a clear idea of areas which needed urgent management interventions. Utmost care should be taken before any management intervention is planned in highly or moderately suitable areas as few of them may alter habitat quality for the study species. This study also provided good insight for future landscape changes which will help the managers to set priority areas for habitat improvement or restrict areas to deteriorate any further.

Introduction

1.1 Tropical Landscape Change and human:

Natural landscapes, i.e. those unaffected or hardly affected by human activities, are being transformed into cultural landscapes throughout the world (Feranec et al. 2010, Foley et al. 2005, Lopez and Sierra 2010). This transformation trades off the biodiversity and ecosystem services which are characteristic of both types of landscapes, e.g. higher levels of biodiversity and supporting and regulating services in natural landscapes vs. higher levels of provisioning services such as crop and timber production in cultural landscapes (Millennium Ecosystem Assessment 2005, Rey Benayas 2009). As the characteristics of land cover have important impacts on climate, biogeochemistry, hydrology and species diversity, land cover change has been indicated as one of the high priority concerns for research and for the development of strategies for sustainable management (Turner et al. 1993, Vitousek 1994). In recent years, special attention has been given to land-use changes and dryland degradation (Reynolds et al. 2007). Vegetation cover in these ecosystems with limited primary productivity plays a crucial role in providing services such as climate and water regulation (Millennium Ecosystem Assessment 2005).

The synoptic nature of satellite-based earth observation data enables the consistent characterization of forest cover across space and over time. Changes in land cover (biophysical attributes of the earth's surface) and land use (human purpose or intent applied to these attributes) are among the most important discussions among scientists for last two decades (Turner et al. 1990, Lambin et al. 1999). Direct impacts of these changes are not only on biotic diversity worldwide (Sala et al. 2000) but also affect the ability of biological systems to support human needs (Vitousek et al. 1997). According to the recent estimates by Hansen et al. (2010), dry tropics, which is highest in terms of biodiversity, has the third highest estimated area of global forest cover loss in the biome category and Asia is the second among continents with one quarter of the global total.

High rates of deforestation within a country are most commonly linked to population growth, poverty and shifting cultivation in large forest tracks (Mather and Needle 2000). Results of careful surveys of tropical deforestation support the view that population growth is never the sole and often not even the major underlying cause of forest cover change (Angelsen and Kaimowitz 1999, Geist and Lambin 2001). The crucial point, however, is that tropical deforestation is driven largely by changing economic opportunities with social political and infrastructural changes (Hecht 1985).

1.2 Changes in wildlife Habitat:

Unlike Africa, Latin America or South-East Asia, forest boundaries in India appear to have stabilized while forest quality continues to deteriorate due to resource extraction (Ghimire 1979, Gunatilake and Chakravarty 2000, Lele et al. 2000). In the past 50 years, human has changed these landscapes to meet the growing demand for food, fodder, timber, fiber, and fuel (Millennium Ecosystem Assessment 2005) more rapidly and extensively than in any comparable period of time, to meet the challenges of increasing demand for resources by an ever growing human population. There is a need for a holistic landscape approach which can look in depth the anthropogenic driving forces of this changing landscape spatially as well as temporally to come up with proper conservation planning for wildlife in these human dominated landscapes.

Present day regional landscapes have been formed through dynamic interactions over time between the biophysical characteristics of the location (eg. soil, topography, vegetation and climate), natural disturbances (eg. fire) and human modifications (Naveh 1995; Wu and Hobbs 2002). Over the past 200-300 years, humans have been the dominant drivers of landscape transformations, in order to meet their need and aspirations (Vitousek et al. 1997). Study of the causes and effects of landscape change has increased markedly over past decades, primarily resulting from global concerns about environmental degradations, loss of biodiversity, climate change and increasing social awareness of the need for sustainable use of the Earth’s resources (Turner 1997, Burgi et al. 2004).

1.3 Emerging Science: Landscape Ecology to Study Landscape Change:

Landscape being the prime sphere, combined effects of society and nature become visible. As societies and nature are dynamic, change is an inherent characteristic of landscapes. Indeed, Forman and Godron (1986) offered a scientific framework of Landscape Ecology based on the three qualities; structure (spatial relationship), function (flow), and change (dynamics). Interest in models of landscape change started early (Baker 1989) and such models became widespread with the recognition that land-use change is one of the major factors affecting global environmental change (Dale et al. 1993, McDonnell and Pickett 1993, Meyer and Turner 1994). Landscape change has primarily been studied in cases where it leads to severe environmental problems. There is for example a long tradition of interdisciplinary work about the causes of land degradation and soil erosion (Blaikie 1985; Blaikie and Brookfield 1987, Adams 1990). Today, the study of causes, processes, and consequences of land-use and land-cover change is one of the main research topics of landscape ecology (Wu and Hobbs 2002), and is also relevant for ecology (Dale et al. 2000). As today's landscapes are the result of many layers of past natural processes and human interventions, a historical perspective is needed (Russell 1997). Such a landscape history provides valuable information for managing cultural landscapes (Blaikie and Brookfield 1987, Cronon 2000, Russell 1994, Tress et al. 2001), for land-use planning (Berger 1987; Hersperger 1994, Marcucci 2000), and for restoration ecology (Egan and Howell 2001, Burgi et al. 2004).

To generalize simplifications are needed, but these simplifications are often sufficient to explain general trends of ecosystem change. Many of these approaches immerge from disciplinary perspectives, such as spatial agro-economic models of land use change (Alcamo et al. 1998; Nelson and Geoghegan 2002). Others use generalizing schemes on a highly aggregated basis like the IPAT approach, where environmental impact is seen as the product of population, affluence, and technology (Ehrlich and Holden 1971; Ehrlich and Daily 1993; Waggoner and Asubel 2002). Others analyze case studies in order to identify common threads and processes (Scherr 1997, Geist and Lambin 2002), sometimes attempting to identify trajectories of environmental criticality (Kasperson et al. 1995) or to formulate qualitative models (Petschel-Held et al. 1999, Petschel-Held and Matthias 2001).

1.4 Study background, Aim, Research Questions and Objectives:

1.4.1 Study background and Aim:

In India, forests and people are inextricably linked since millions of people live adjacent to or within protected areas and harvest forest products (Kothari et al., 1989). However, often the human pressure on forests is not sustainable and can cause forest loss and degradation (Ganesan 1993, Maikhuri et al. 2001, Puyravaud and Garrigues 2002, Sagar and Singh 2004, Arjunan et al. 2005), and together with intensive livestock grazing and biomass extraction can reduce carrying capacity, i.e. the net primary productivity available for herbivores in a year as well as forest cover (Ganesan 1993, Silori and Mishra 2001, Sagar and Singh 2004, Madhusudan 2004 and 2005, Barbier et al. 2006, Sahabuddin and Kumar 2007, Mehta et al. 2008, Sahabuddin and Rao 2010). In the recent past, a number of studies in India have focused on the impacts of human settlements on protected areas (PAs). These studies fall into two categories, those based primarily on ground measurements of vegetation across a human-use gradient (Barve et al. 2005, Karanth et al. 2006, Kumar and Shahabuddin 2005, Shahabuddin and Kumar 2006 and 2007) and others that rely on some remotely sensed data from one, two or three date satellite data to assess changes over space and/or time (Barve et al. 2005, Nagendra et al. 2006, Ostrom and Nagendra 2006, Robbins et al. 2007). The remote senseing based approach typically underestimates the loss in conservation values over time as it does not account for livestock-grazing, collection of Non-Timber Forest Products (NTFP), habitat degradation and other human pressures that operate under the canopy at very small patch sizes and directly contribute to species loss (Hansen and DeFries 2007). More importantly, attributing all observed vegetation changes to either human influence or bio-physical processes leads to a simplistic view of complex patterns and dynamics in landscapes that change over time. Except study by Vaidhanathan et al. (2010), no other study really addressed the gap between the impacts of both bio-climatic and human use influences on spatial patterns and dynamics of forests over decadal time-scales in the tropical forest landscape of India.

Tiger (*Panthera tigris*) needs fairly good amount of undisturbed forested habitat for breeding, movement, and dispersal. Existing forest landscapes have varied carrying capacities for tigers depending on their habitat qualities. The spill over population has to disperse to new areas to ensure their future. These ecological facts have encouraged us to take up a landscape level study to ensure long term survival of tigers. Efforts are underway to mainstream the concerns of tiger in the landscape surrounding such protected areas through restorative actions, as well as providing livelihood options to local people to reduce their dependency on forests. But the agony of tiger conservation in India is that in most of these TRs, park managers have little authority over the surrounding landscape which results in rapid land use changes and infrastructure development causing major impacts on the integrity of a tiger reserve. As of now, most of these TRs still continue to hold the source tiger populations but the surrounding forests are acting as sink to these populations. Only recently, India lost tigers from two of its TRs due to illegal poaching which led the government to undertake scientific ecological monitoring to inform management in all source sites. However, management of forests outside these protected areas continues to be a challenge, and highlights the need of landscape ecological research for better holistic planning towards conservation of this charismatic big cat.

1.4.2 Objectives:

The objectives of the present study are

1) Evaluate patterns of Land use/ land cover for the study area
2) Evaluate anthropogenic factors operating in the landscape.
3) Evaluate correlation between landscape change and anthropogenic factors.
4) Generate habitat occupancy models for conservation of large mammals.

1.4.3 Research Question:

Keeping in view the above background, the following questions were set forth in context of present study in Pench Tiger Reserve (PTR):

- What is the present pattern of landuse/landcover in PTR?
- What is the pattern in the landscape heterogeneity?

- What is the present condition of different anthropogenic factors operating in and around PTR?
- Are the patterns of changes in landscape heterogeneity correlated with patterns of anthropogenic factors?
- Is spatial heterogeneity is reflected in the distribution of large mammals?

1.5 Organisation of the Thesis:

The thesis is organized in six Chapters. Chapters 1 and 2 deal with the introduction and study area respectively. Rest of the four Chapters (1,2,3,4) are based on above four objectives. Each of these chapters includes a brief introduction with review of literature followed by methodology, results and discussion. The Chapter 1 provides general introduction and explains the background of the present study. It further explains the significance of the study, includes the relevant research questions and objectives. Chapter two deals with the study area, its physical environment, socio-economic environment, unique biodiversity and the previous studies carried out in PTR. Chapter Three deals with land use /land cover characterisation of PTR and the assessment of the spatial heterogeneity of the landscape. Chapter Four explains current demographic pattern in the villages around 5 Km buffer of PTR with their dependency on forest. Chapter Five deals with the changes in the landscape for nearly forty years. Patterns of landscape change in last ten years were compared with the changes in the pattern of demographic factors. Chapter Six deals with habitat suitability modeling of major large mammals using ecological niche factor modeling.

Chapter 2: Study Area

2.1 General

This study has been carried out in Pench Tiger Reserve (PTR), Madhya Pradesh which comprises of the Pench National Park, Pench Mougli Sanctuary and surrounding territorial forest. PTR is lying between 78º 55' E to 79º 35' E & 21º 40' N to 21º 57' N in the south-western region of Madhya Pradesh located on the Madhya Pradesh-Maharashtra border (Fig 2.1) and it comes under the biogeographic province 6A Deccan Peninsula- Central highlands (Fig 2.2) (Rodgers and Panwar 1988). It has a total area of 757.85 Km^2, which includes Pench National Park (245.85 Km^2), Pench Mougli sanctuary (183 Km^2) and surrounding reserved forest (229 Km^2), which are the parts of South Seoni forest division, South and East Chhindwara forest divisions. Pench river divides PTR into two blocks in east Seoni district and west Chhindwara district. It has 12 circles (Fig. 2.3) and 46 beats (Fig. 2.4) in total as its administrative layout. The State Government declared Pench Game Sanctuary (449.39 Km^2)in 1977. In March 1983, the Government of Madhya Pradesh notified its intention to constitute an area of 292.85 Km^2 as Pench National Park, to be carved out of the pre-existing Pench Sanctuary area. The present Pench Tiger Reserve was included into the stream of the Tiger Reserves in 1992 as the 19th Tiger Reserve of India. The Pench River, from which the reserve derives its name, is the main source of water for PTR. On the southern end of Pench River a dam was constructed in 1987 to generate electricity and for irrigation purpose, resulting 54 Km^2 of submergence area in Madhya Pradesh side (Fig. 2.2).

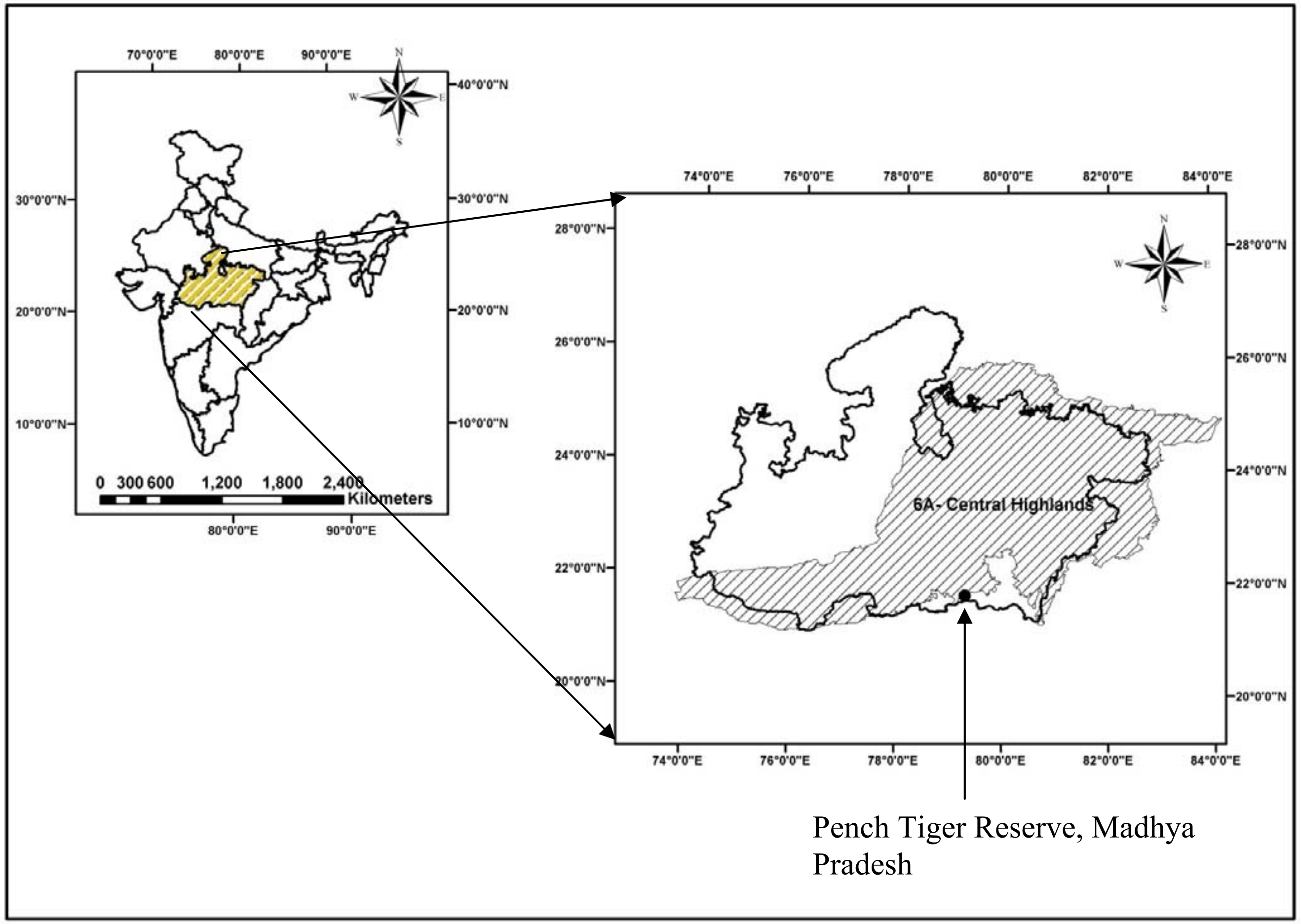


Fig 2.1 Location of Pench Tiger Reserve, Madhya Pradesh

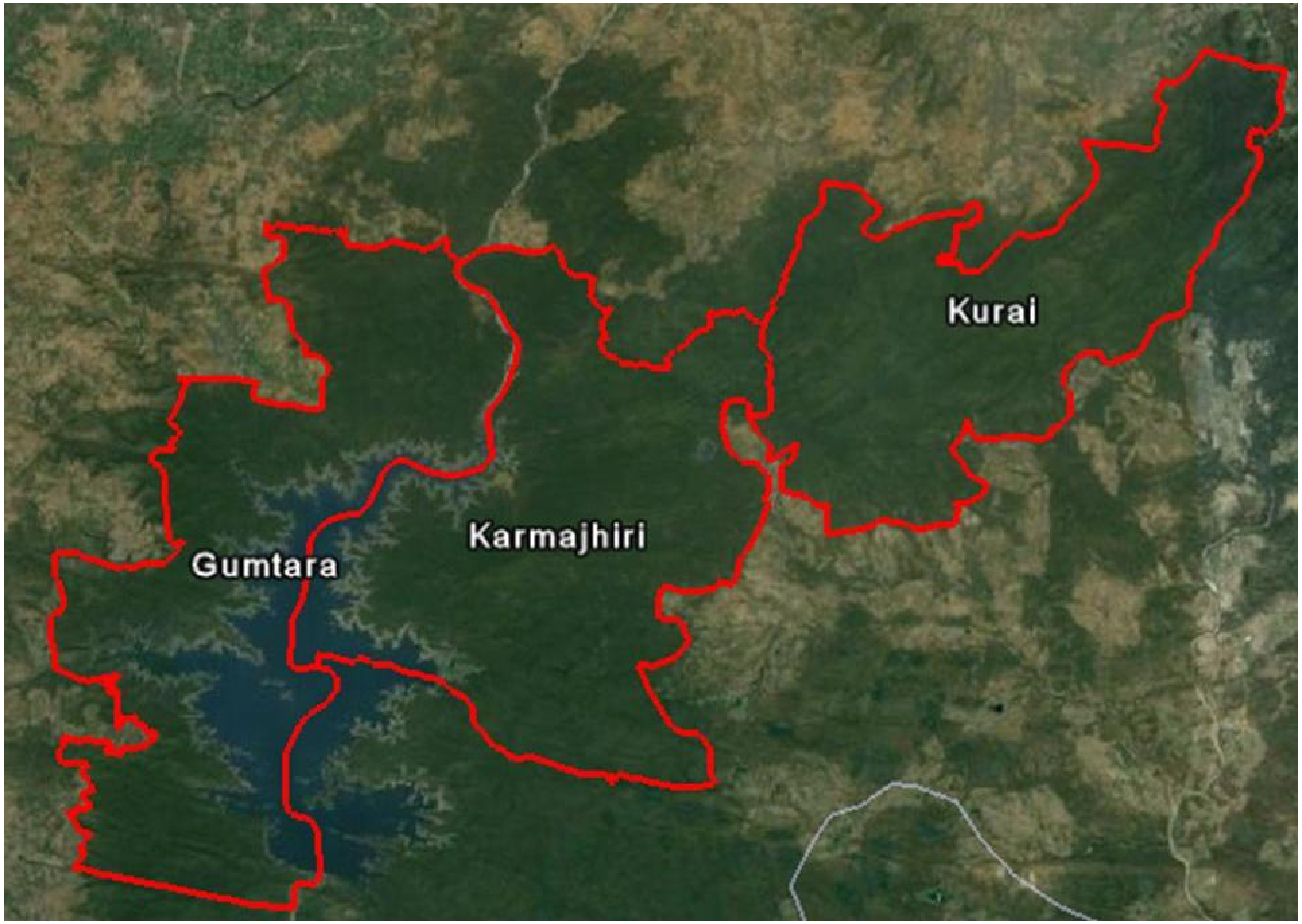


Fig 2.2 Forest ranges of Pench Tiger Reserve on Google earth image.

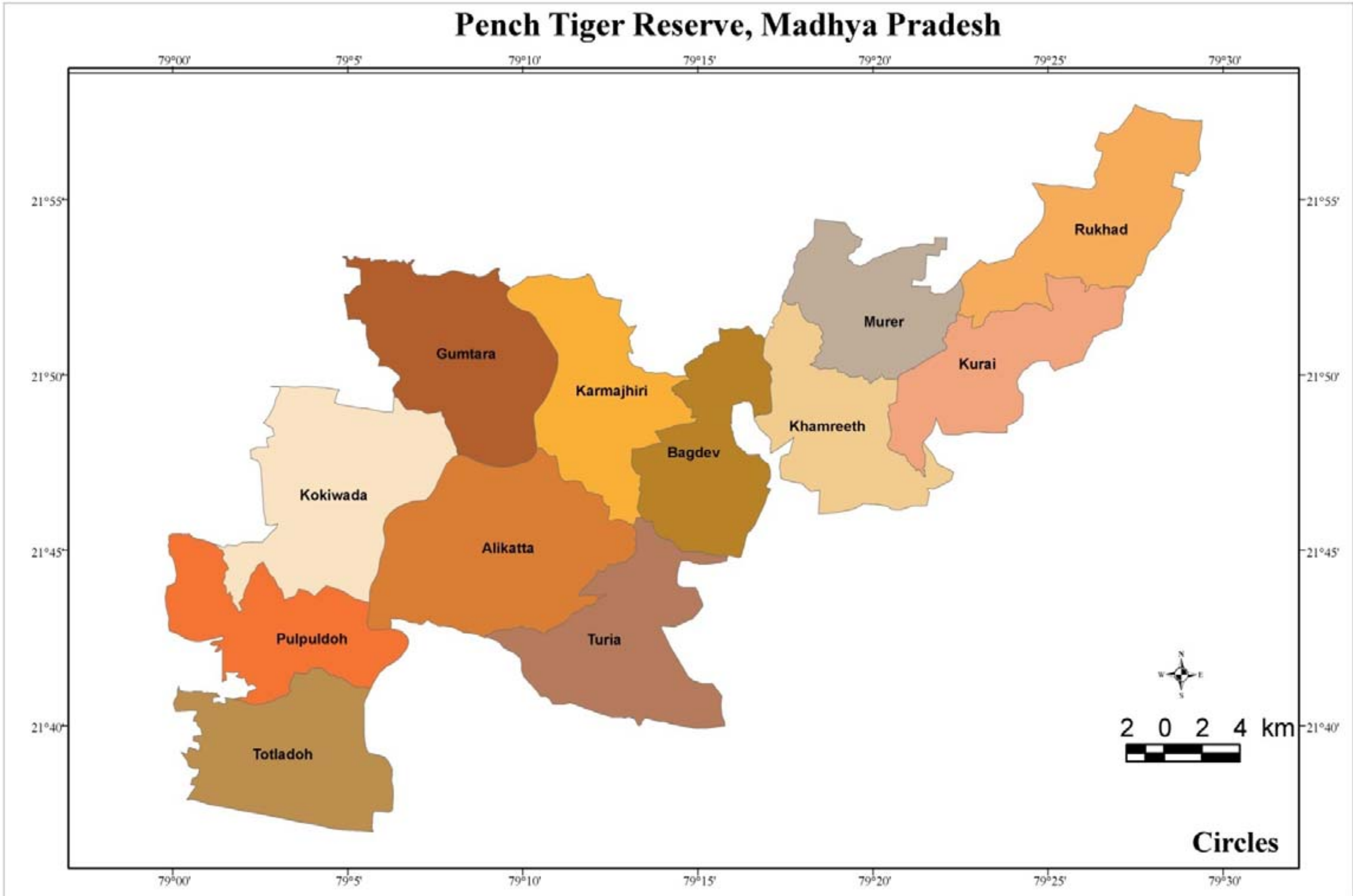


Fig 2.3 Forest circles of Pench Tiger Reserve

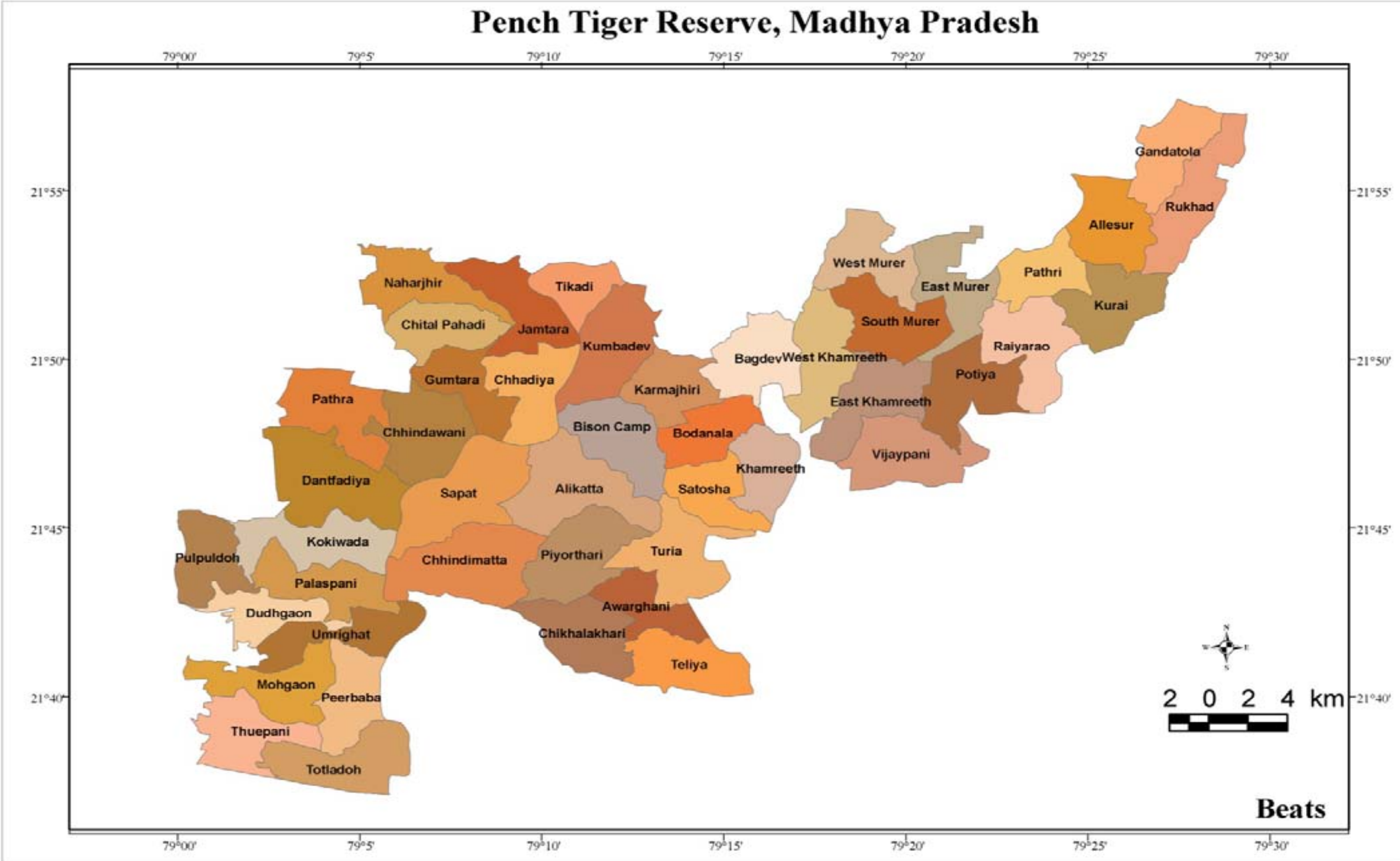


Fig 2.4 Forest beats of Pench Tiger Reserve

2.2 Background Information and Attribute

2.2.1 Terrain: Terrain is gently undulating and criss-crossed by seasonal streams and nullahs. The general slope of the area is from Southwest to Northeast. The mean altitude above mean sea level is 550 m. Among the hills or "matta" (hill in Local Gondi dialect) present in this area, Kalapahar is the highest with an altitude of 625 m. The hills have gradual to steep slopes with almost flat tops. Fig. 2.5 depicts details terrain outlay of PTR.

2.2.2 Soil: Sandy loam soil is the dominant soil type in all the gentle slopes and valleys of PTR resulted from the weathering of Granitic gneisses. Red soil is found in all elevated areas. Foothills with less tree cover and forest gap contains Kankar and saline soil. Alluvial soil is confined to the banks of the stream and Pench River. But according to the National Bureau of Soil Survey, Nagpur, there are 10 different soil types as shown in the table (Fig. 2.6) (Sankar et al. 2001).

Table. 2.1 Soil types and their percentage in Pench Tiger Reserve

Soil Type	Percentage
1. Loamy, mixed, isohyperthermic, Lithic Ustorthents, & Loamy, mixed, isohyperthermic, Lithic Ustropepts (6)	14.21
2. Fine, montmorillonitic, hyperthermic, Typic Haplusterts, & Loamy, mixed, hyperthermic, Typic Ustochrepts (48)	1
3. Loamy, mixed, hyperthermic, Typic Ustorthents & Clayey, mixed, hyperthermic, Lithic Ustothents (50)	29.82
4. Fine, montmorillonitic, hyperthermic, Vertic Ustochrepts & Clayey, mixed, hyperthermic, Typic Ustochrepts (79)	10.62
5. Fine, montmorillonitic, (Cal.), isohyperthermic, Typic Ustropepts & Fine, montmorillonitic, (Cal.), isohyperthermic,	0.00013
6. Loamy-skeletal, kaolinitic, isohyperthermic, Typic Ustropepts & Loamy, kaolinitic, isohyperthermic, Lithic Ustropepts (91)	17.4
7. Loamy, kaolinitic, isohyperthermic, Typic Ustropepts & Loamy kaolinitic, isohyperthermic, Lithic Ustropepts (107)	7.81
8. Fine, mixed, isohyperthermic, Typic Haplusterts & Fine, mixed, isohyperthermic, Typic Ustropepts (108)	0.61
9. Fine - loamy, kaolinitic, hyperthermic, Typic Ustochrepts & Fine, mixed, hyperthermic, Vertic Ustochrepts (113)	6.96
10. Loamy, kaolinitic, hyperthermic, Typic Ustorthernts & Loamy, kaolinitic, hyperthermic, Typic Ustochrepts (137) :	10.13

__2.2.3 Climate:__ There are four distinct seasons as follows:

Winter	-	November to February
Summer	-	March to June
Monsoon	-	July to August
Post-monsoon	-	September to October

- **Rainfall**: The monsoon generally begins in the middle of June and last up to September. The average annual rainfall ranged from 1300 mm to 1400 mm (Sankar et al. 2001). This period accounts for about 90% of total annual rainfall. Pench experiences pre-monsoon showers in the month of April and May and Post-monsoon showers during month of September to November leaving the months December to March with no precipitation.
- **Temperature**: The temperature ranges between minimum of 9.1°C (average) in winter to maximum of up to 40°-45°C in peak summer. Recorded minimum and maximum temperatures are 2.8^0C and 45^0C respectively (Sankar et al. 2001).

2.2.4 Geology and geomorphology:

Geo-morphologically PTR falls in the peninsular foreland of the peninsular division. The peninsula is Archean and Pre-Cambrian in formation (Mani 1974). This area is an extension of Satpura-Mahadeo-Maikal scraps. Nine different geological zones are found in PTR (Sankar et al. 2001), viz. Gnisses (72.54%), Amphibolites (0.12%), Basalt (20.73%), Chorboali formation (1.82%), Lameta formation (1.7%), Lohangi formation (0.82%), Laterite (0.7%) and Manganese ore (0.17%) (Fig. 2.7 & Fig. 2.8)

2.2.5 Drainage

Most of the streams and nullahs in PTR are seasonal. The Pench river, lifeline for the area dries out in the month of April forms several puddles locally called "Kassa". In 1990, 54.51 Km^2 area was submerged due to the formation a reservoir which till date acts as the main water source of PTR. There are two small irrigation tanks namely Bodanala and Dudhgaon tank. As most of the areas are devoid of water in the peak summer months, the PTR management constructed several small ponds and artificial waterholes for wildlife.

2.3 Forest Types

Floristically, according to Champion and Seth (1968), the tiger reserve can be classified as

I) Tropical Moist deciduous Forest:

i) TYPE 3B/C_{1c} Slightly moist teak forest

II) Tropical dry deciduous forests:

i) TYPE 5A/C_{1b} Dry teak forest

ii) TYPE 5A/C_3 Southern dry mixed deciduous forest

Fig 2.5 Digital elevation model of Pench Tiger Reserve

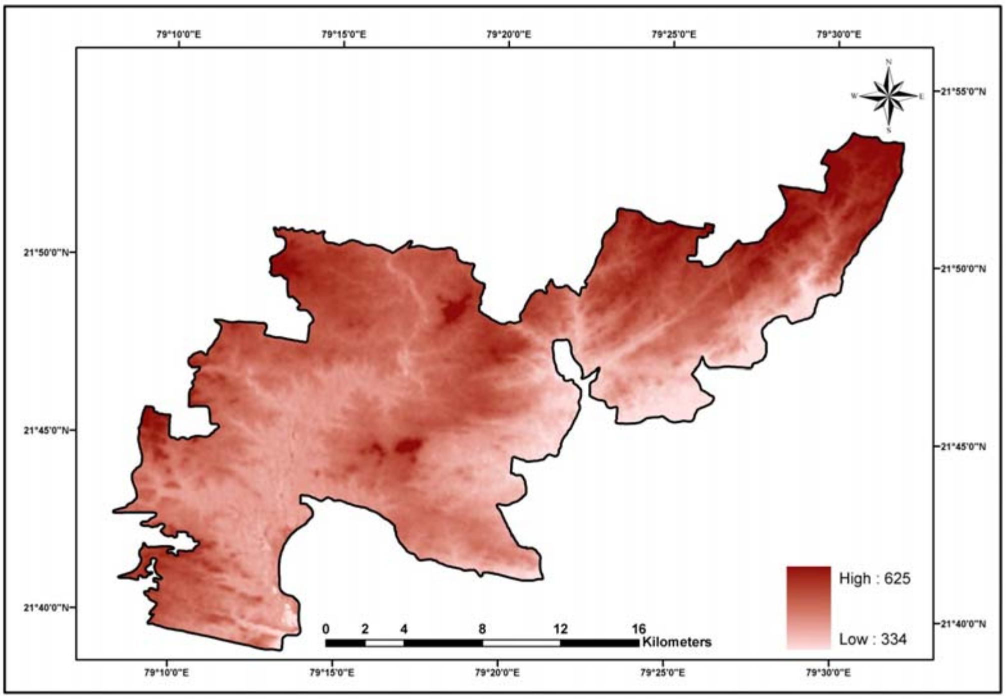
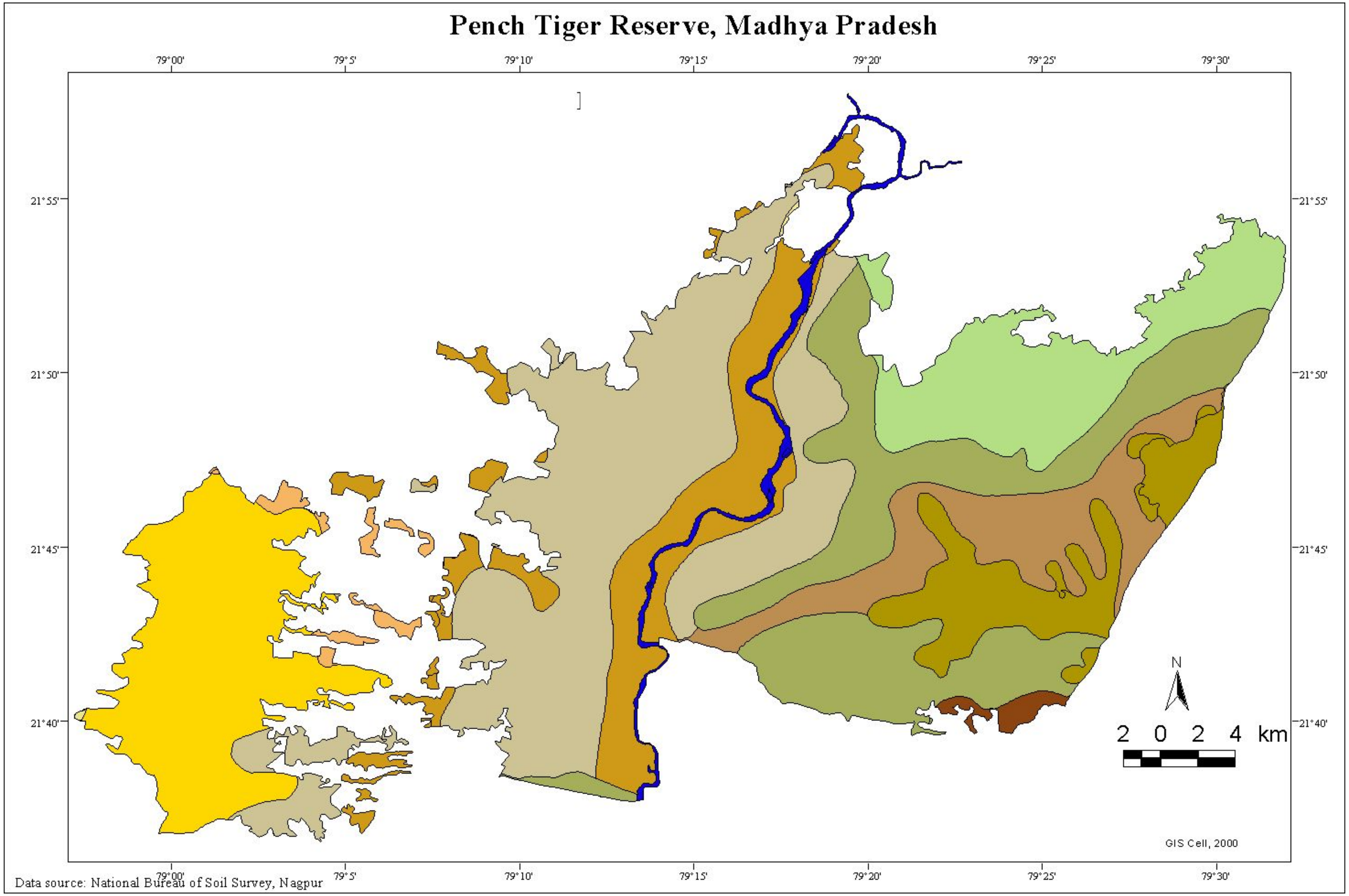


Fig 2.5 Fig 2.6 Soil types of Pench Tiger Reserve (Sankar et al. 2001)



Legend: Soil

6	Loamy, mixed, isohyperthermic, Lithic Ustorthents & Loamy, mixed, isohyperthermic Lithic Ustropepts
48	Fine,montmorillionitic,hyperthermic,Typic Haplusterts & Loamy, mixed, hyperthermic Typic Ustochrepts
50	Loamy, mixed ,hyperthermic, Typic Ustorthents & Clayey, mixed, hyperthermic Lithic Ustorthents
79	Fine, montmorillonitic, hyperthermic,Vertic Ustochrepts & Clayey, mixed, hyperthermic Typic Ustochrepts
83	Fine, montmorillonitic, (Cal.), isohyperthermic,Typic Ustropepts & Fine, montmorillonitic, (Cal.), isohyperthermic,Typic Haplusterts
91	Loamy-skeletal, kaolinitic, isohyperthermic, Typic Ustropepts & Loamy, kaolinitic, isohyperthermic, Lithic Ustropepts
107	Loamy-kaolinitic, isohyperthermic,Typic Ustropepts & Loamy, kaolinitic, isohyperthermic, Lithic Ustropepts
108	Fine, mixed, isohyperthermic,Typic Haplusterts & Fine, mixed, isohyperthermic,Typic Ustropepts
113	Fine -loamy, kaolinitic, hyperthermic,Typic Ustochrepts & Fine,mixed, hyperthermic,Vertic Ustochrepts
137	Loamy, kaolinitic, hyperthermic,Typic Ustorthents & Loamy, kaolinitic, hyperthermic,Typic Ustochrepts
10	Pench River

Fig 2.7 Geological types of Pench Tiger Reserve (Sankar et al. 2001)

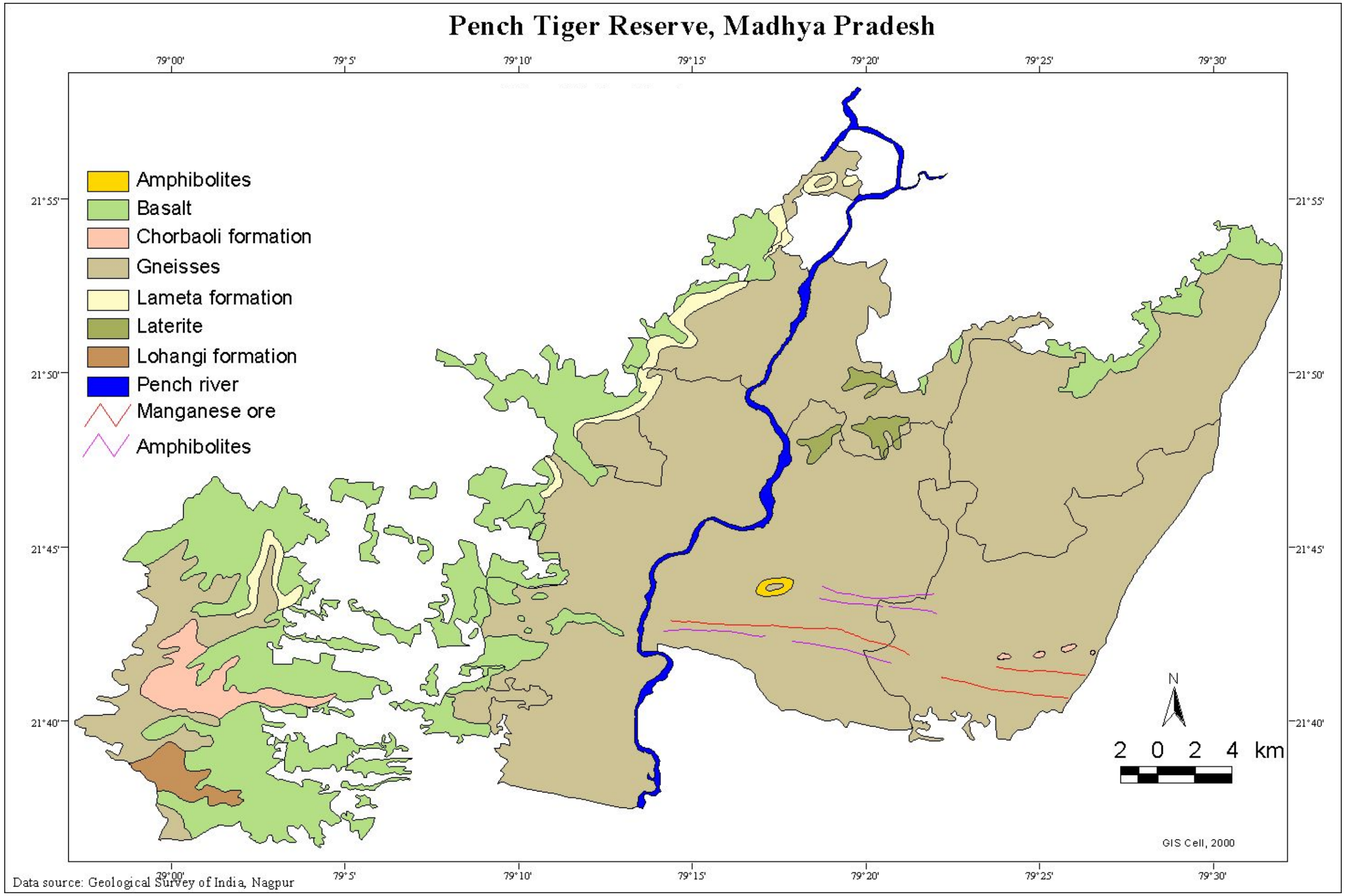
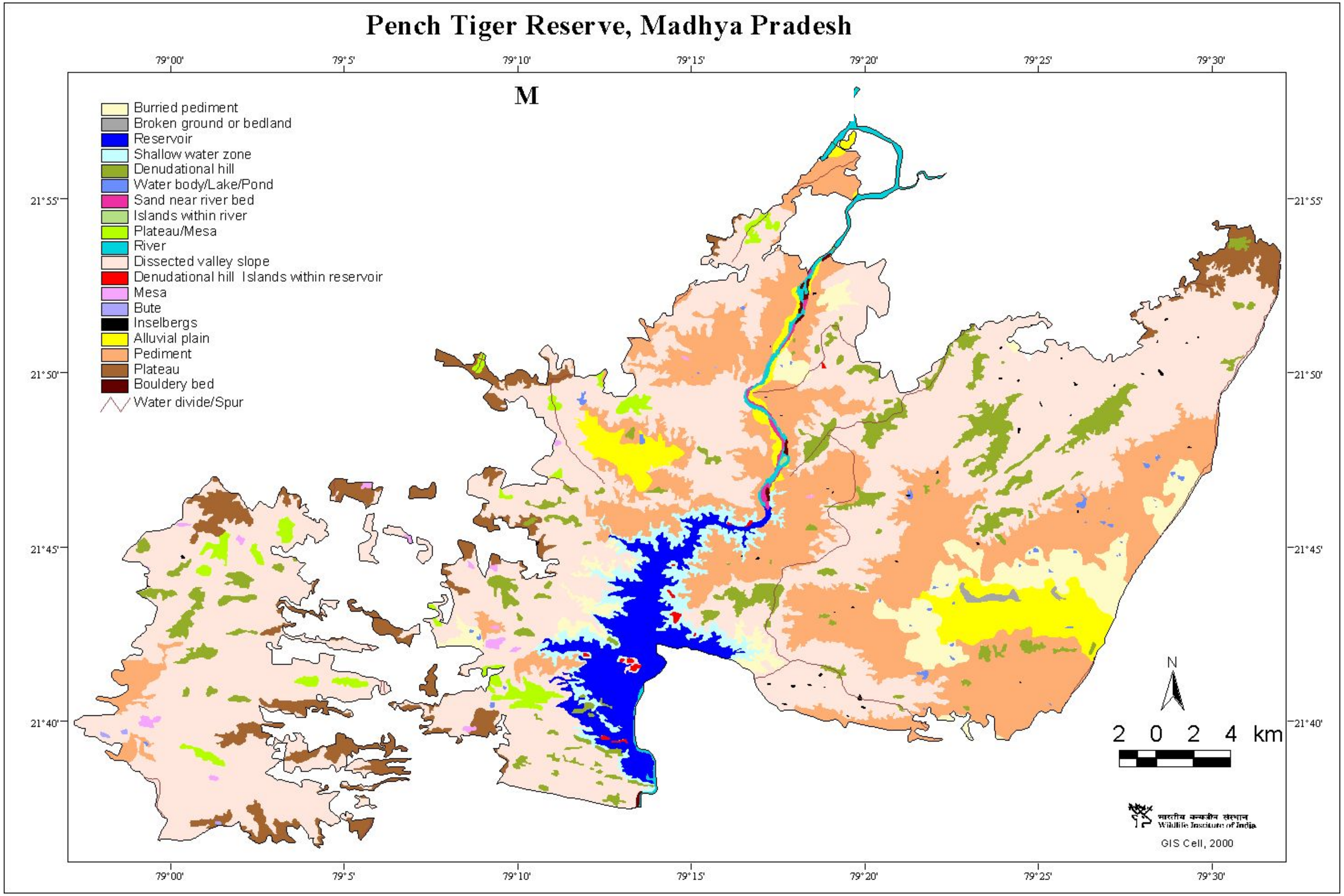


Fig 2.8 Geo-morphological types of Pench Tiger Reserve (Sankar et al. 2001)



2.4 Flora:

Teak (*Tectona grandis*) associated with *Madhuca indica*, *Diospyros melanoxylon*, *Terminalia tomentosa, Buchanania lanzan, Lagerostroemia parviflora, Ougeinia dalbergoides, Miliusa velutina* and *Lannea coromandelica* occur in more or less flat terrain. The undulating terrain and hill slopes have patches of mixed forest dominated by *Boswellia serrata* and *Anogeissus latifolia*. Species like *Sterculia urens* and *Gardenia latifolia* are found scattered on rocky slopes. Bamboo (*Dendrocalamus strictus*) patches occur in the hill slopes and along the streams. Some of the open patches of the park are covered with tall grasses interspersed with *Butea monosperma* and *Ziziphus mauritiana*. Evergreen tree species like *Terminalia arjuna, Syzygium cumini* and *Ixora parviflora* are found in riparian vegetation along the nullahs and river banks. *Cleistanthus collinus* occurs as dense dominant patches in some parts. The major shrub found in this area is *Lantana camara*. Dominant climber species are *Bauhinia vahlii* and *Butea superba*.

2.5 Fauna

Chital (*Axis axis*), sambar (*Rusa unicolor*), gaur (*Bos gaurus*), Nilgai (*Boselaphus tragocamelus*), chowsingha (*Tetraceros quadricornis*), barking deer (*Muntiacus muntjac*) and wild pig (*Sus scrofa*) are the ungulate species found in the study area. Among carnivores tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*), Jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), jackal (*Canis aureus*), small indian civet (*Viverricula indica*), common palm civet (*Paradoxurus hermaphroditus*), Indian grey mongoose (*Herpestes edwardsii*) and ruddy mongoose (*Herpestes smithii*) are found. Common langur (*Semnopithecus entellus*) and rhesus macaque (*Macaca mulatta*) represent the primate fauna of the area. PTR harbors a good population of peafowl (*Pavo cristatus*) (Sankar et al. 2001).

2.6 Fire

PTR, being a dry deciduous habitat experiences below canopy fires. These fires largely restricted to the shrub layer and result in the depletion of the ground layer and possess serious threat to the ground dwelling fauna. Park management burns roadsides as a control measure to accidental fire outbreak.

2.7 People and Protected Area

Mostly Gonds are the most prominent tribe in this part of the Central highlands. In early 17th century the Gonds are politically very active and ruled much of this tract (Rangarajan 1996). The lingual similarity between gonds and tamil folks of southern India bear the testimony that the gonds are a part of the same lineage as the Dravidians of the south India (Forsyth 1871). In the past, gonds inhabiting the interiors of the forest and hills are largely hunter gatherers while those in the fringes of the forest and in the foothills took to agriculture.

The principal tribe of the Dravidian family, the Gonds stand out among the various tribes of India, by their number, vast expanse and their historical importance. Although spread over Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Jharkhand, Maharashtra, Orissa and some parts of Assam, Tamil Nadu and Uttar Pradesh (Census of India 2011), the majority of Gonds are found today in Madhya Pradesh and Chhattisgarh. In Madhya Pradesh, Gonds are concentrated in Satpura plateau (districts like Chhindwara, Betul, Seoni, Hoshangabad, Narsinghpur) and in Mandla district (Census of India 2011).

The Gonds are mainly agro-silvicultural community. While their forest dependence is high, the Gonds are mainly engaged in agriculture and a majorily of them are either farm workers or daily wage laborers. In the hilly tracts most of the Gonds are landowners and cultivate their own land (Table 2.2).

Table 2.2 Occupational pattern of gonds in Madhya Pradesh

Total Worker	46.39
Cultivators	37.22
Agricultural Laborers	11.45
Agri-allied	4.94

(Source: Primary Census abstract, Census of India, 2001)

Of the various tribes of Madhya Pradesh, the Gonds are among the most educated, but still their literacy level was very low compared to other community. Literacy rates for male and female are 32.16 % and 10.73 % respectively with total literacy rate of 21.54 % (Primary Census abstract, Census of India 2001).

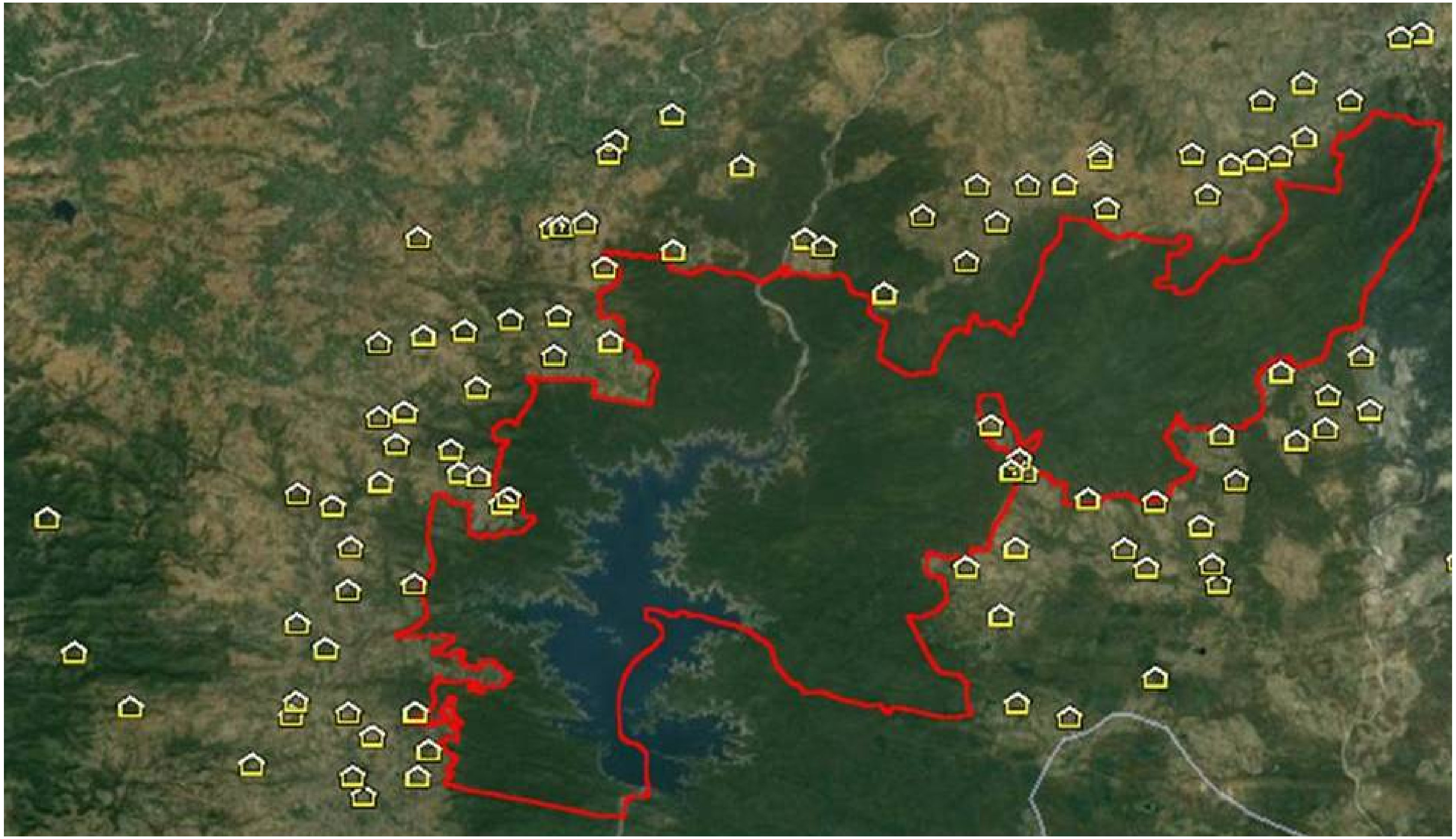
At present, there are 99 villages within five km radius of the periphery of the Pench Tiger Reserve. The total population of the villages stands to be 61000 with a livestock population of 36000 (present study).

2.8 Major Research conducted in Pench Tiger Reserve

Pench has a long history of research and studies conducted so far include both floral and faunal component of the park. In 1988, Dwivedi and Shukla described some ecological and behavioural aspects of the Indian Bison. Shukla (1990) studied ecological interaction between wild animals and vegetation in Pench Sanctuary and its surroundings. Rice (1991) had reported the distribution status of four horned antelope through a questionnaire survey. Jayapal (1997) carried out an intensive study on interaction between bird community and vegetation. Acharya (1997) carried out research on density of wild ungulates in this area. Shukla and Khare (1997) also studied ungulate population in the same year. Karanth and Nichols (1998) reported 4.1 (SE 1.31) tigers per 100 Km^2 in Pench National Park. Quli (1999) reported a significant decrease in tiger number between 1993 and 1995. Garshelis (1999) reported low encounter of sloth bear in the study area. Sankar et al. (2001) studied gaur ecology in PTR. Ishtiaq and Rahmani (2000) tried to find Forest Owlet *Athene blewitti* in the areas where it was earlier reported but failed because of either due to human disturbance or thick ground vegetation. Pasha et al. (2000) reported 19 species of snakes in this area. Pasha et al. (2001) studied predation of gaur by tiger in PTR. Harshey and Chandra (2001) gave a comprehensive account of mammals during their study in Madhya Pradesh and Chhattisgarh. David (2002) conducted study on protected area management and human wildlife conflict interface around PTR. Biswas and Sankar (2002) revealed that Pench harbours very high prey density and tigers are mostly dependent on the wild ungulates rather than on domestic livestock. In their study they found that chital (47.3%) along with sambar (14.5%) and wild pig (10.9%) constituted the major part of the tiger's diet. Pasha et al. (2002) reported debarking of Teak (*Tectona grandis*) by gaur during summer in Pench Tiger Reserve. Chandra et al. (2002) found 38 species of butterflies belonging to eight families during their study of which 14 species found to be rare. Chandra (2002) studied scarabaeid beetles of Pench Tiger Reserve. Karanth et al. (2004) reported Pench Tiger Reserve had comparatively higher prey density which can support more tigers. Pasha et al. (2004)

reported 262 species of birds in this area. Areendran and Pasha (2004) reported presence of Indian wolf *canis lupus pallipes* in PTR. Gajbe (2004) found 21 genera of spiders in PTR. Cuthbert et al. (2006) reported absence of Egyptian vulture and just two individuals of red-headed vulture but Majumder et al. (2009) reported sightings of nine Egyptian and 12 red-headed vulture in the study area. Bhaskar (2007) carried out research on wild dog ecology in PTR. Bhattacharya and Shanker (2007) reported that the total wildlife Carrying Capacity (CC) of Pench National Park has declined by 18.53% due to the tourism activities. Ghuman (2009) studied vigilance behaviour of chital *Axis axis* and found that the behaviour decreases with increase in group size, decrease in density and increase in visibility. Large groups adult males, fawns and adult females with fawns were found to be significantly more vigilant than females without fawns and yearling males in chital (Ghuman 2009). Chandra et al. (2009) studied species composition and diversity of Orthoptera and recorded 59 species belonging to 51 genera and 9 families. Family Acrididae was represented with 23 species in their study. Mascia and pailler (2010) reported proposed down-gradation of Protected area status of some parts of PTR due to the width expansion of National Highway 7. Pragatheesh (2011) studied the effect of human feeding on road mortality of Rhesus Macaques along 11 Km stretch of National Highway 7, which makes the boundary of Pench Mougli Sanctuary reported 54 road hits. Areendran et al. (2012) tried to evaluate land use land cover patterns between 1977 and 2006.

Fig. 2.9 Village locations within 5 Km radius of Pench Tiger Reserve on Google earth image



Chapter 3: Landscape Characterisation

3.1. Introduction

The management of wildlife and protected areas is aimed at conservation and optimal use of forest incorporating the consequences of spatial heterogeneity. The sensitivity of ecological effects of resource management towards spatial configuration is gaining acceptance worldwide. Since landscape structure is often regarded as an important pre-requisite that governs the distribution and abundance of species, the first step is to understand the landscapes and their dynamics. It is not only important to understand how much there is of a particular component but also how it is arranged (Turner 2001). The underlying premise is that the explicit composition and spatial form of landscape mosaic affect ecological systems in ways that it would be different, if mosaic composition or arrangement were different (Wiens 1995). Moreover, recent studies have demonstrated that land use and landscape changes significantly affect biodiversity (Cousins and Eriksson 2002, Gachet et al..2007 and Miyamoto and Sano 2008). The above studies have been conducted using the comparative analysis of remotely sensed temporal data sets.

3.1.1. Community Structure

Measuring and monitoring biodiversity is the first step towards effective conservation and sustainable development of natural resources. Knowledge of floristic composition and vegetation structure is critical for understanding the dynamics of forest ecosystems and empirical data is needed for planning and sound management. Tropical forests cover approximately 11% of the earth's land surface (Dixon et al.1994), but provide significantly large share of ecosystem services. These forests provide habitat for a diverse assemblage of species and thereby support a considerably large proportion of terrestrial biodiversity. Myriad studies on tree community structure and composition have been conducted throughout the tropics to document and understand patterns of tree species diversity found in earth's tropical forests (Condit 1995, Pitman et al.2001). Fashing and Gathua (2004) compared the distribution and density of tree species in two sites of East African tropical forests. The effect of structure and species composition of tropical forests of Tanzania on species diversity was studied by Huang et al. (2003). Chandrashekra and

Ramakrishnan (1996) studied the dynamics of tropical wet evergreen forest in Western Ghats of Kerala. Studies have concluded that tropical forest tree community structure and composition varies widely between forests of same continent (Steege et al. 2000) and even between different sites within the same forest (Proctor et al. 1983). Dry tropical forest accounts for 46% of the total forest cover in India (Singh and Singh 1988). Dry forests are generally characterized by flora of lower species richness than rain forest (Gentry 1995, Timilsina et al. 2007). Much of the floristic studies have been devoted to moist and wet tropical forests, whilst dry tropical forests in spite of being considered one of the endangered ecosystems (Janzen 1988) have received a little attention. Local species extinction rates appear to be very high in case of tropical species (Farnworth and Golley 1974). Palomino and Alvarez (2005) studied the patterns of tree community in dry tropical forests in Peru. Generally, there is a dearth of literature pertaining to structure, floristic composition and diversity of dry tropical forests in India.

Sukumar et al. (1992) have initiated vegetation monitoring in a tropical dry deciduous forest. Reddy et al. (2008) determined structure and floristic composition tree diversity within three hectare plots in tropical dry deciduous forests of Eastern Ghats of southern Andhra Pradesh.

Pench Tiger Reserve (PTR) represents typical tropical dry deciduous ecosystem in Central India. Earlier attempts at floristic studies and qualitative description of vegetation in PTR include Sankar et al. (2001) and Areendran (2007). Areendran (2007) studied the ecological interactions between vegetation structure and gaur abundance, in which vegetation types of PTR were regarded as most important habitat factors. However, in none of the earlier studies have conducted landscape level analysis of landscape characterisation, based on empirical data along with geospatial analysis of major communities.

3.1.2 Remote Sensing for Vegetation Mapping

Satellite remote sensing plays a crucial role in generating information about forest cover, vegetation types and land use changes (Cherill and McClean, 1995). This echnology has given an impetus to resource mapping and monitoring (Lilesand and Kiefer 2000 and Krishna et al. 2001). Remotely sensed estimates of regional variation in biodiversity can be used in analyzing diversity patterns, monitoring changes and aiding conservation efforts (Stohlgreen et al. 1997, Gould 2000). The land cover classification from remote sensing data is a powerful tool that can provide repetitive and spatial information concerning the landscape (Chust et al. 2004). Justice et al. (1985), Jadhav et al. (1990), Innes and Koch (1998), Skole and Tucker (1993) and Franklin et al.(1994) highlighted the role of remote sensing data from earth observation satellites. It is now convenient to map and monitor short and long term changes in forest cover and land use classes, which would have been far too expensive and time consuming through earlier conventional methods. Broad vegetation type stratification using coarse resolution data like NOAA/AVHRR has been reported in the study conducted by Milanova et al. (1999) and mapping at finer resolution data of Landsat TM has also been reported in several studies (Daniel and Shennan 1987, Miles et al. 1996, Roy et al. 1995, Groom et al. 1996, Guillem et al. 2004).

3.1.3. Landscape Characterisation

It is widely acknowledged that patterns of landscape elements strongly influence the ecological characteristics. Therefore, spatial pattern characterization and quantification of land cover classes to relate pattern and process is a pre-requisite at landscape level (Turner 1987). Quantification of landscape pattern is necessary for understanding the composition and configuration of landscapes. Spatial patterns (structures) have a strong influence on information content of ecosystem components. The concept of landscape unit, also called patch, has a relevant role in the study of habitat selection and habitat fragmentation. Recent landscape ecology studies have sought to define the underlying structure of landscape pattern as quantified by landscape pattern metrics. Spatial tools of remote sensing and GIS have a capacity to quantify land cover patterns and understand spatial heterogeneity (Turner 1990). Analyses of landscape patterns are conducted on land use /land cover map derived from satellite imageries. O'Neill et al. (1988) concluded that methods are needed to quantify aspect of spatial patterns that can be correlated with ecological processes. In a study carried by Ritters et al. (1995) a total of fifty five metrics of landscape patterns and structures were calculated for 85 land use/cover maps. Hulshoff (1995) carried out a study to evaluate the indices of landscape pattern developed in United States of America to describe Dutch landscape. Landscape pattern metrics are the measurements designed to quantify and capture aspects of landscape pattern. A large number of spatial indices are based on patch metrics that quantify the spatial pattern at three different levels of organization: the patch, the land cover and the landscape using the programme FRAGSTATS (McGarigal and Marks 1995). Numerous studies have advocated the authenticity of this spatial pattern analysis programme (Lu et al. 2003, Cushman et al. 2008, Lele et al. 2008, Jhala et al. 2008). Griffith et al. (2000) analysed the landscape structure of Kansas at three scales by calculating the landscape pattern metrics.

Studies conducted previously in the study area (Sankar et al. 2001, Areendran 2007) were restricted to the classification of vegetation using IRS LISS III data of 23.5 m resolution and did not deal with landscape structure. The present study was initiated with the aim to document and map current status of forest in the study area using Landsat TM data of 30 m resolution and to describe the landscape structure of Pench Tiger Reserve at three levels of organization *viz.,* landscape level, class level and patch level.

3.2 METHODOLOGY

3.2.1 Data collection protocols

Data on species composition and structure were collected using circular plots method following Muller-Dombois and Ellenberg (1974). Circular plots are expeditious in allowing accurate area sampling with relatively less effort for plot layout (a single central marker for permanent location) and they reduce the number of edge decisions because they minimize perimeter to area ratio (Mc Cune and Grace 2002). At each sampling point, a circular plot of 10 m radius was laid for enumeration of trees. The individuals with > 30 cm girth at breast height (gbh) and height > 1.37 m with distinct bole were considered as trees (Muller-Dombois and Ellenberg 1974). In each plot parameters like species name, number of trees, gbh and % canopy cover were recorded.

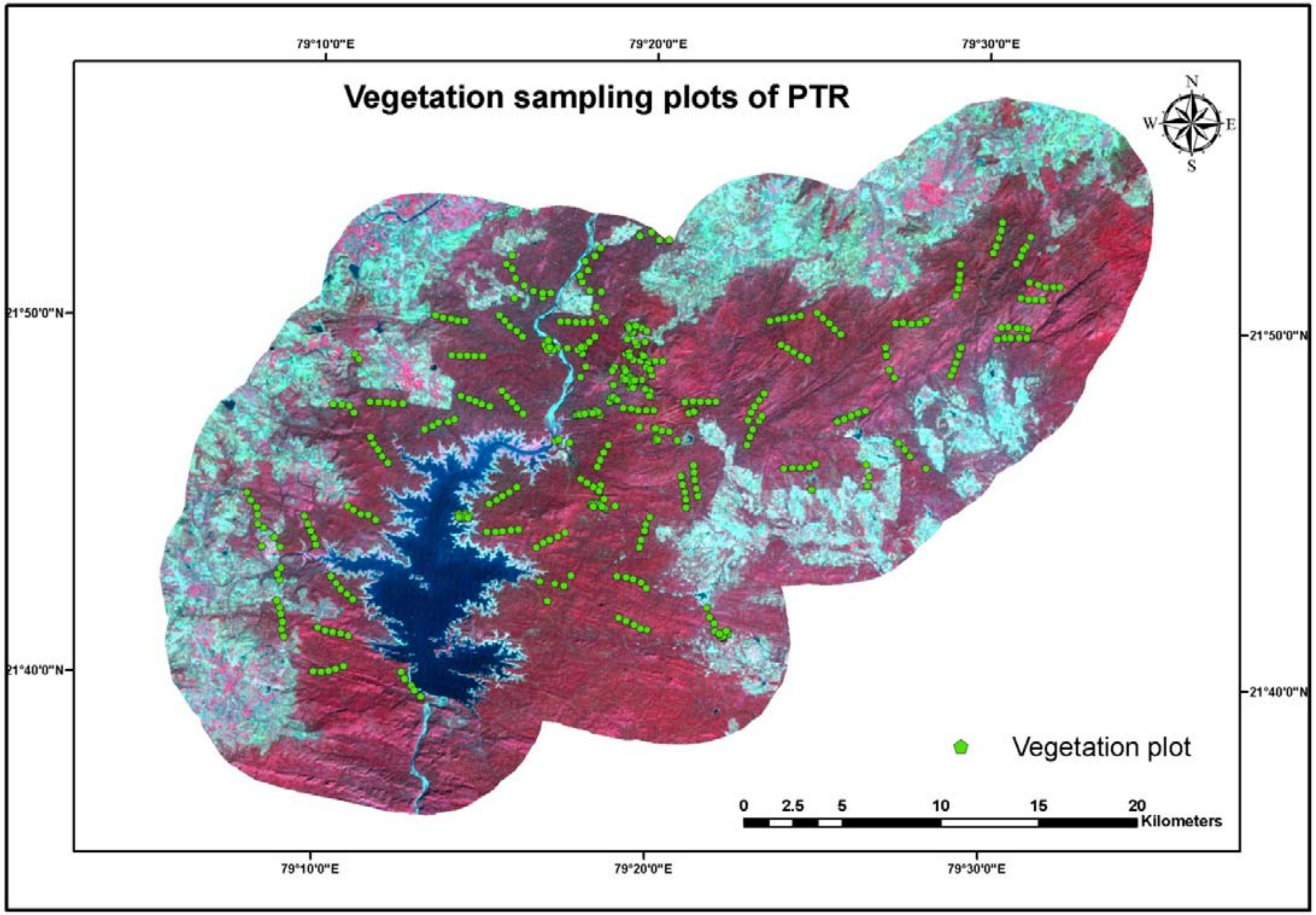
3.2.1.1 Stratification and sampling units

After a preliminary reconnaissance survey of PTR, intensive vegetation sampling was carried from April 2007 to June 2009. This area was sampled using systematic stratified sampling approach. Stratification was done using smallest administrative unit *i.e.* forest beat. A total of 43 transects were laid in all fourty three beats of PTR covering all vegetation types of the study area. On these transects two hundred fifteen circular plots were laid equidistant at 400 m interval, while two hundred fourty five random plots were also laid to cover the entire area (Fig 3.1).

3.2.2 Community classification

One of the most popular hierarchical divisive classification techniques in community ecology is Two-way Indicator Species Analysis (TWINSPAN) (Hill 1973). The TWINSPAN algorithm starts with primary ordination of sites along the first axis of correspondence analysis (Hill 1973, 1974). In the next step, sites are divided into two clusters by splitting the first CA axis near its middle. Then, site classification is refined using a discriminant function that emphasizes species preferential to one or the other half of the dichotomy (Hill and Šmilauer 2005). The process can be repeated, each of the two clusters being repeatedly divided in the same way. Thus, the number of clusters increases in powers of two, and divisions of some fairly homogeneous clusters may be imposed by this simple divisive rule. The software programme PC-ORD (McCune and Mefford 2011) is used to run this analysis.

Fig. 3.1 Distribution and locations of vegetation sampling plots on Landsat TM False colour composite



3.2.3Diversity, Richness and Evenness

Species diversity, richness and evenness were calculated using EstimateS Version 7.5 (Colwell 2005).

3.2.3.1 Species diversity is a product of two components: species richness and evenness (Simpson 1949). Species diversity was estimated using Shannon-Wiener Index (Pielou 1975, Magurran 2004). It is most commonly used index in community ecology. It is a measure of average degree of uncertainty in predicting as to what species an individual chosen at random from a collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even (Magurran 2004). The Shannon's Index can be computed as below:

H′= S pi. log. pi

where,

H′= Shannon-Wiener Diversity Index

S = Number of species in the community

pi = Proportion of ith species in the community.

3.2.3.2 Species Richness is simply the number of species in the unit of study. It was calculated using Menhinick's Index (Magurran 2004)

DMn = S/√N

where,

DMn = Species Richness

S = Number of species in the community

N = Number of individuals of all species in the community.

3.2.3.3 Evenness describes the variability in the species abundance. A community in which all species have approximately equal number of individuals would be rated as extremely even. Conversely, a large disparity in the relative abundances of the species would result in the descriptor "uneven" (Magurran 2004). It was calculated using Shannon Evenness Index.

J= H′/logS

where,

J = Evenness Index

H′ = Shannon-Wiener Diversity Index

S = Total number of species in a community.

3.2.4 Landuse/cover mapping

The different stages are elaborated below:

3.2.4.1 ***Data Used****:* One digital scene of Landsat TM (Path-144 and Row-45) with 30 m resolution was downloaded from USGS- earthexplorer site for the date of 14.12.2009, since during this period the vegetation was in full bloom thus reducing chances of phonological variations and cloud free data could be obtained.

3.2.4.2 ***Ancillary data*****:** Range maps and beat maps were taken from Madhya Pradesh forest Department for planning field data collection.

3.2.4.3 ***Software used:*** ERDAS 9.0 (Leica Geosystems 2005) was used for digital image processing, geo-referencing and digital classification of satellite image. ArcGIS 9.3 (ESRI Inc.) had been used for plotting GPS points on the image.

3.2.4.4. ***Radiometric Corrections:*** Radiometric calibrations and atmospheric correction were carried out to correct the solar drift, differences due to variations in the solar angle and atmospheric effects (Green et al. 2005). This technique assumes that there is a high probability that at least a few pixels within an image should be black (0% reflectance). However, because of atmospheric scattering, the imaging system records a non-zero Digital Number (DN) value at the supposedly dark-shadowed pixel location. Therefore the DN value was subtracted from the data to remove the first- order scattering component.

3.2.4.5. ***Geometric Corrections:*** Images were registered geometrically. Geometric corrections were carried out on imageries of all dates using Survey of India Toposheets at 1:50000 scale (55 O/2, O/5, O/6, O/9, 55K/13 and 55K14) and nearest neighbour algorithm with root mean square error (RMS) less than 0.5 pixels i.e. < 15 m (for MSS 30 m) (Lillesand and Keifer 2000) and the image was resampled by nearest neighborhood method. The desired study area was extracted from the scene using the subset function in ERDAS 9.0 (Leica Geosystems 2005) with a buffer of 5 km around the Tiger Reserve. False colour composite maps ware generated for the study area (Fig 3.1)

3.2.4.6. ***Ground Truthing:*** A reconnaissance survey was conducted from March- June 2007 to have the fair idea of broad vegetation types of study area, Range maps were used to stratify the area for ground survey. Later, the intensive ground validation points were collected and a total of four hundred sixty vegetation plots were collected to capture the variation in spectral signatures of different vegetation types over the entire study area and to achieve higher accuracy of vegetation mapping. GPS points were then plotted on the image and some were left for the accuracy assessment.

3.2.4.7. ***Classification:*** Classification of remotely sensed data involves assigning each pixel on the image a ground class based on its spectral reflectance (Lillesand and Kiefer 2000). Multi-spectral imagery was used to identify the spectral signature of the spectral classes present in the image. Both unsupervised and supervised clustering was used for classifying land use/cover types. Classification was performed using maximum likelihood (Jenson 2005) as it has been proven very efficient for land use/cover mapping. Also hybrid approach was extensively used for deriving the pure class.

3.2.4.7.1 Unsupervised classification: The classification uses ISODATA algorithm for differentiating spectral reflectance of various objects. Principle component analysis (PCA) was done on all the spectral bands except the thermal band to extract three factors. This PCA product was then subjected to 50 clusters with 10 iterations. The fifty classes derived from the iteration were later merged into broad land use/cover classes (Singh 1989, Lillesand and Kiefer 2000).

3.2.4.7.2 Supervised classification: A supervised technique requires ground truth points to derive training sets containing information about the spectral signatures of the land use/cover types that occur in the considered area (Lillesand and Kiefer 2000). Three hundred ground validation points was used to derive land use/cover classes using spectral signature. One hundred sixty points collected during field data collection were used for accuracy assessment.

3.2.4.7.3 Hybrid Classification: Hybrid classification methods were used to overcome the lacunae of their respective techniques and in order to obtain high accuracy and efficiency (Schowengerdt 2007, Bakr et al. 2010). *Cliestanthus collinus* forest was not clearly delineated using both the above techniques. These errors were not due to the error in the pixel but due to the similar spectral reflectance values of the feature classes. Manual recoding was done to resolve this using ground truth points and field sampling information as a parameter. Manual recoding increased classification accuracy.

3.2.4.8. ***Smoothening:*** The pixilated classified output image was obtained. The map was subjected to 5x5 filters and the patches below 0.5 ha were removed so as to avoid errors of misclassification and accurate indices for landscape structures could be determined. Finally, the area was calculated for each class.

3.2.4.9. ***Accuracy Assessment:*** The accuracy of the map was done using those of the ground truth points which were not used during classification. The land cover information of these locations was compared to classified maps. Accuracy was tested using Cohen's Kappa Statistics (Khat coefficient) (Lillesand and Kiefer 2000).

3.2.5 Canopy density mapping

As a part of field work, percent canopy cover for each vegetation plot was recorded using densiometer. An unsupervised classification using nearest neighbour algorithm was performed (Lillesand and Kiefer 2000). Initially the area was classified into 15 classes which were later reduced to four canopy density classes a) canopy >60%, b) canopy 30-60%, c) canopy <30% and d) No-canopy by integrating the field knowledge/data and spectral characteristics of classes.

3.2.6 Landscape Characterisation

For the quantification of the landscape of PTR, statistical measures or indices were used that describe landscape configuration and composition. These indices were calculated by FRAGSTATS (McGarigal and Marks 1995). The FRAGSTATS is a spatial pattern analysis programme for categorical maps. It simply quantifies the areal extent and spatial configuration of patches within landscape. The landscape structure was analyzed at three different scales *viz.,* landscape, class and patch level using 12 set of indices as shown in Table 3.1. Numerous studies have supported the authenticity of these indices (Griffith etal. 2000, Cushman et al. 2008).

Table 3.1 Matrices used for landscape characterization of PTR

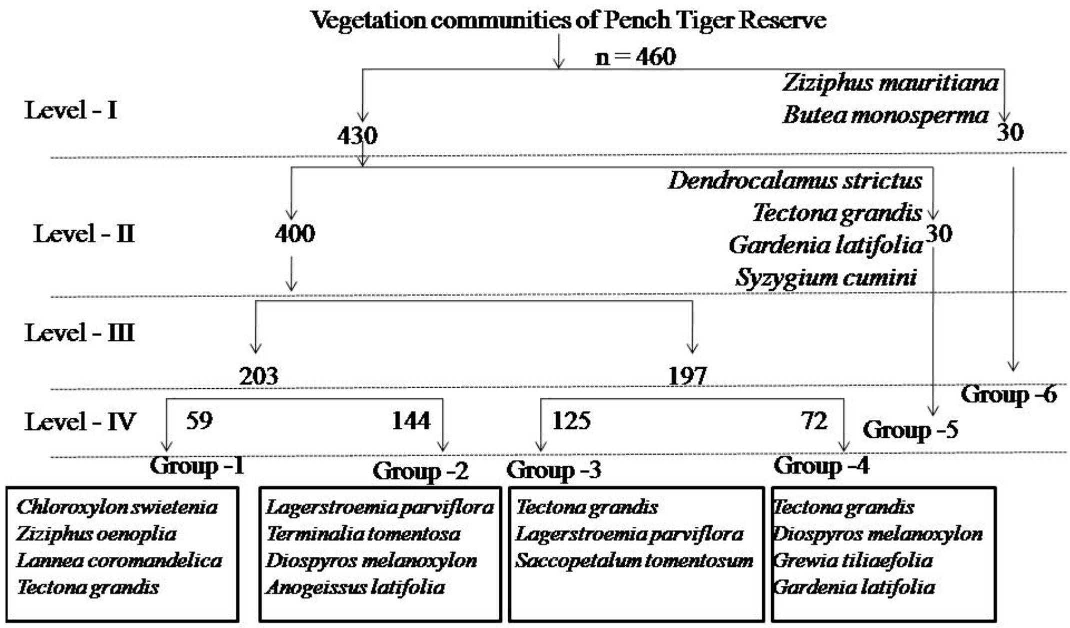
Level	Metrics	Description	Unit
L1 (Landscape)	No. of patches(NP)	No. of patches in a landscape	None
L2 (Landscape)	Patch density (PD)	No. of patches in a landscape divided by landscape area	#/100ha
L3 (Landscape)	Largest patch Index (LPI)	Largest patch area divided by total landscape area	%
L4 (Landscape)	Interspersion and Juxtaposition(IJI)	Adjacency among patches of different class	%
L5 (Landscape)	Simpson diversity index(SIDI)	Diversity of patches in the landscape	None
L6 (Landscape)	Simpson Evenness index (SIEI)	Even distribution of area among patch types	None
C1 (Class)	Percentage of landscape (PLAND)	Percentage of landscape comprised of corresponding class	%
C2 (Class)	No. of patches (NP)	No. of patches of corresponding class	None
C3 (Class)	Patch density (PD)	No. of patches of corresponding class divided by class area	#/100ha
C4 (Class)	Mean patch size (MPS)	Average patch size of the corresponding class	Ha
C5 (Class)	Interspersion and juxtaposition (IJI)	Adjacency among patches of corresponding class	%
P1 (Patch)	Patch area (PA)	Area of the patch	Ha

3.3 RESULTS

3.3.1 Community classification based on TWINSPAN

The results of the TWINSPAN analysis are summarised in Fig. 3.2. Based on floristic composition, the 460 sample plots were classified into six groups. The classification was stopped at the fourth level of division, leaving only groups with a sufficient number of samples to characterise the vegetation communities. The characterization of the identified groups into named community types was based on the concepts of fidelity and constancy. Fidelity refers to the degree to which species are confined to particular groups of plots. Constancy refers to the number of times each species is present in the plots that belong to a specific group. Species with a constancy of 30–75% and a degree of fidelity of 3–5 (on a scale from 1 to 5) (Kent and Coker 1992), were termed ''characteristic species'' and were used to name each community type. Six community types were therefore identified namely i) *Chloroxylon swietenia-Ziziphus oenoplia-Lannea coromandelica-Tectona grandis*, ii) *Lagerstroemia parviflora-Terminalia tomentosa-Diospyros melanoxylon-Anogeissus latifolia*, iii) *Tectona grandis-Lagerstroemia parviflora-Saccopetalum tomentosum*, iv) *Tectona grandis-Diospyros melanoxylon-Grewia tiliaefolia-Gardenia latifolia,* v) *Dendrocalamus strictus-Tectona grandis-Gardenia latifolia-Syzygium cumini* and vi) *Ziziphus mauritiana-Butea monosperma*.

Fig. 3.2 Dendogram derived from the TWINSPAN analysis of the data collected



i) *Chloroxylon swietenia-Ziziphus oenoplia-Lannea coromandelica-Tectona grandis* community: This belongs to miscellaneous forest type mostly found in moist and undulationg terrain with gentle slope area of the reserve. The characteristic species are *Chloroxylon swietenia, Ziziphus oenoplia, Lannea coromandelica* and *Tectona grandis*. The other tree species found in this community are *Boswellia serrata* and *Grewia rothii.*

ii) *Lagerstroemia parviflora - Terminalia tomentosa - Diospyros melanoxylon - Anogeissus latifolia* community: This community also consists of miscellaneous species. This community was found generally in areas with gentle slopes. This association was found more in the drier regime of the tiger reserve. The characteristic species are *Lagerstroemia parviflora, Terminalia tomentosa, Diospyros melanoxylon* and *Anogeissus latifolia.* The other tree species found in this community are *Bauhinia racemosa, Flacourtia indica, Grewia celtidifolia, Saccopetalum tomentosum, Ziziphus xylopyrus.*

iii) *Tectona grandis-Lagerstroemia parviflora-Saccopetalum tomentosum* community: This community is found commonly near the roadside openings and forest edge. The characteristic species are *Tectona grandis, Lagerstroemia parviflora, Saccopetalum tomentosum* and other tree species found in this community are *Butea monosperma, Grewia celtidifolia* and *Lannea coromandelica.*

iv) *Tectona grandis - Diospyros melanoxylon - Grewia tiliaefolia - Gardenia latifolia* community: This community is distributed almost throughout the tiger reserve more in gentle slopes. The characteristic species are *Tectona grandis, Diospiros melanoxylo, Grewia tiliaefolia* and *Gardenia latifolia*. Other tree species found in this community are *Anogeissus latifolia, Cassia fistula, Emblica officinalis* and *Kudiya calcina.*

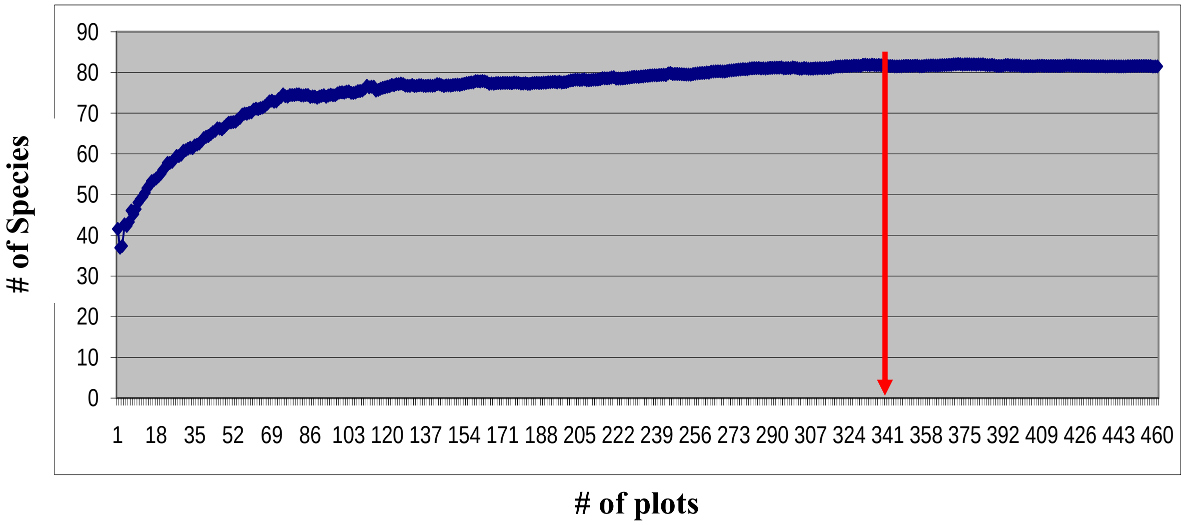
v) *Dendrocalamus strictus - Tectona grandis - Gardenia latifolia - Syzygium cumini* community: This community is distributed patches mainly in the wet and moist areas of the tiger reserve in undulating terrains with moderate to gentle slopes. The characteristic species are *Dendrocalamus strictus, Tectona grandis, Gardenia latifolia* and *Syzygium cumini.* The major other species found in this community are *Gardenia latifolia, Terminalia arjuna* and *Aegle marmelos.*

vi) *Ziziphus mauritiana - Butea monosperma* community: This community was mostly found in the disturbed areas like fringes of forest close to the villages and in areas were earlier villages existed. The characteristic species of this community were *Ziziphus mauritiana and Butea monosperma.*

3.3.2 Diversity, Richeness and Evenness

Diversity was estimated for all plots which showed stabilization after three hundred fifty plots (Fig 3.3). Thus an estimate of the minimum number of plots that would correctly represent all the vegetation communities in PTR is three hundred fifty plots.

Fig 3.3 Species area curve showing stabilization after 350 plots



It was found that maximum tree diversity was in *Chloroxylon swietenia-Ziziphus oenoplia-Lannea coromandelica-Tectona grandis* community followed by *Lagerstroemia parviflora-Terminalia tomentosa-Diospyros melanoxylon-Anogeissus latifolia* community and *Tectona grandis-Diospyros melanoxylon-Grewia tiliaefolia-Gardenia latifolia* community. *Ziziphus mauritiana-Butea monosperma* community showed least diversity and species richness. The *Tectona grandis-Diospyros melanoxylon-Grewia tiliaefolia-Gardenia latifolia* community showed maximum species richness. Though all the communities were more or less even according to the tree species present but *Lagerstroemia parviflora-Terminalia tomentosa-Diospyros melanoxylon-Anogeissus latifolia* was the most even community where as *Ziziphus mauritiana-Butea monosperma* was the least even (Table 3.2).

Table 3.2 Diversity, richness and evenness in different communities

Vegetation Category	Diversity	Richness	Evenness
Chloroxylon swietenia-Ziziphus oenoplia-Lannea coromandelica-Tectona grandis	0.76	8.2	0.84
Dendrocalamus strictus-Tectona grandis-Gardenia latifolia-Syzygium cumini,	0.66	7.1	0.79
Lagerstroemia parviflora-Terminalia tomentosa-Diospyros melanoxylon-Anogeissus latifolia	0.78	8.8	0.86
Tectona grandis-Lagerstroemia parviflora-Saccopetalum tomentosum	0.62	6.0	0.78
Tectona grandis-Diospyros melanoxylon-Grewia tiliaefolia-Gardenia latifolia	0.76	10.3	0.79
Ziziphus mauritiana-Butea monosperma	0.37	2.40	0.81

3.3.3 Land use/cover mapping

According to Champion and Seth (1968), the area is classified under group 5 and sub-group 5A as Southern Tropical Dry Deciduous Forest. Considering the previous studies in PTR (Sankar et al. 2001 and Areendran 2007), the area was divided into 50 classes initially. Later, there 50 classes were classified under the broad classes of forest, water body/river, open forest, dry river bed and agriculture/settlement. Due to very limited but prominent patches of *Cleistanthus collinus* and teak- dominated (mainly old plantation units) patches present in the study area and the study design, they had not come as prominent communities in vegetation community analysis up to fourth level but they were considered for digital land use/cover classification. So, the non-forest classes were masked and then the forest classes were classified into seven vegetation classes. Finally, fifty classes were merged into eleven classes including seven vegetation classes and four non-forest classes (Fig 3.4). The overall accuracy was found to be 82.2% (Cohen's Kappa- 0.78) (Table 3.3).

Table 3.3 Accuracy assessment for vegetation and land cover classes in Pench tiger Reserve, Madhya Pradesh

Predicted Class	**Actual Class**											
	***Ziziphus Butea* open**	**Miscell-neous**	**Teak Lagerst-roemia**	**Teak-dominated**	**Teak-Mixed**	**Water**	**Sub-mergence**	**Riverine**	***Cleistanthus collinus***	**Agri-habitation**	**Dry River Bed**	**User's Accuracy ***
***Ziziphus Butea*-open**	**8**	2	0	0	0	0	0	0	0	0	0	**80**
Miscellaneous	1	**52**	0	0	9	0	0	3	3	0	0	**76.5**
Teak-Lagerstroemia	0	0	**25**	0	1	0	0	0	0	0	0	**96.2**
Teak-dominated	0	0	0	**8**	0	0	0	0	0	0	0	**100**
Teak-Mixed	0	9	7	2	**31**	0	0	1	0	0	0	**62**
Water	0	0	0	0	0	**10**	0	0	0	0	0	**100**
Submergence	0	0	0	0	0	0	**10**	0	0	0	0	**100**
Riverine	0	0	0	0	0	0	0	**11**	0	0	0	**100**
Cleistanthus collinus	0	0	0	0	0	0	0	0	**7**	0	0	**100**
Agri-habitation	0	0	0	0	0	0	0	0	0	**10**	0	**100**
Dry River Bed	0	0	0	0	0	0	0	0	0	0	**10**	**100**
Producer's accuracy *	**88.9**	**82.5**	**78.1**	**80**	**75.6**	**100**	**100**	**73.3**	**70**	**100**	**100**	
Overall accuracy	**82.2**							**Overall Kappa**	**0.78**			

* The diagonal shows the number of correctly classified sample units for each class. Producer's accuracy is the percentage of the sampling units predicted to belong to the correct class, and user's accuracy is the percentage of the sampling units predicted to belong to a particular class that actually belong to that class.

1. **Miscellaneous forest**: The first two community types i.e. *Chloroxylon swietenia-Ziziphus oenoplia-Lannea coromandelica-Tectona grandis* and *Lagerstroemia parviflora-Terminalia tomentosa-Diospyros melanoxylon-Anogeissus latifolia* were very much similar in their spectral signatures. So they were merged to form a single LULC class. This forest type constitutes association of *Lannea coromandelica*, *Anogeissus latifolia*, *Terminalia tomentosa*, *Diospyros melanoxylon*, *Boswellia serrata*, *Buchanania lanzan*, *Miliusa velutina* and *Bauhinia racemosa*. *Tectona grandis* is also more or less inconspicuous in the type.

2. **Riverine forest**: The community type *Dendrocalamus strictus-Tectona grandis-Gardenia latifolia-Syzygium cumini* formed the Riverine forest in association with *Gardenia latifilia*, *Syzygium cumini*, *Dendrocalamus strictus*, *Terminalia arjuna*, *Ixora parviflora*, *Terminalia tomentosa* and *Tectona grandis*.

3. ***Ziziphus Butea* Open forest**: The community type *Ziziphus mauritiana-Butea monosperma* formed *Zizyphus Butea* open forest. This forest is present on the fringes of villages close to agriculture land and relocated village sites with patches of grassland. The tree species found here are *Ziziphus mauritiana*, *Butea monosperma*, *Madhuca indica* and *Diospyros melanoxylon*. The grass species found here are mostly *Saccharum spontaneum*, *Cyperus scariosus* and *Chloris dolichostachya*.

4. **Teak Mixed forest**: The community type *Tectona grandis-Diospyros melanoxylon-Grewia tiliaefolia-Gardenia latifolia* formed Teak Mixed forest LULC class. Teak dominates 50% of this vegetation type followed by other species such as *Grewia tilifolia*, *Diospyros melanoxylon*, *Terminalia tomentosa*, *Bauhinia racemosa*, *Ougenia dalbergeoides* and *Lagerstroemia purviflora*.

5. **Teak dominated forest**: This forest type could not evolve as a prominent community in the landscape. Teak dominates more than 70% of this forest type followed by other species like *Butea monosperma*, *Miliusa velutina* and *Terminalia tomentosa* found in this forest type. Previous Teak plantation areas

were converted into this forest type in absence of any forest management activities due to its protected area status.

6. **Teak-*Lagerstroemia* forest**: The community type *Tectona grandis-Lagerstroemia parviflora-Saccopetalum tomentosum* formed Teak *Lagerstroemia* forest. Teak and *Lagerstroemia* sp. occur in almost equal proportions along with other species like *Butea monosperma*, *Miliusa velutina*, *Terminalia tomentosa, Bauhinia racemosa*, *Grewia celtidifolia*, *Ziziphus xylopyrus* and *Dendrocalamus strictus*.

7. ***Cleistanthus collinus* forest**: This vegetation type is a monospecific dominant patch with more than 98% occurance of the species.

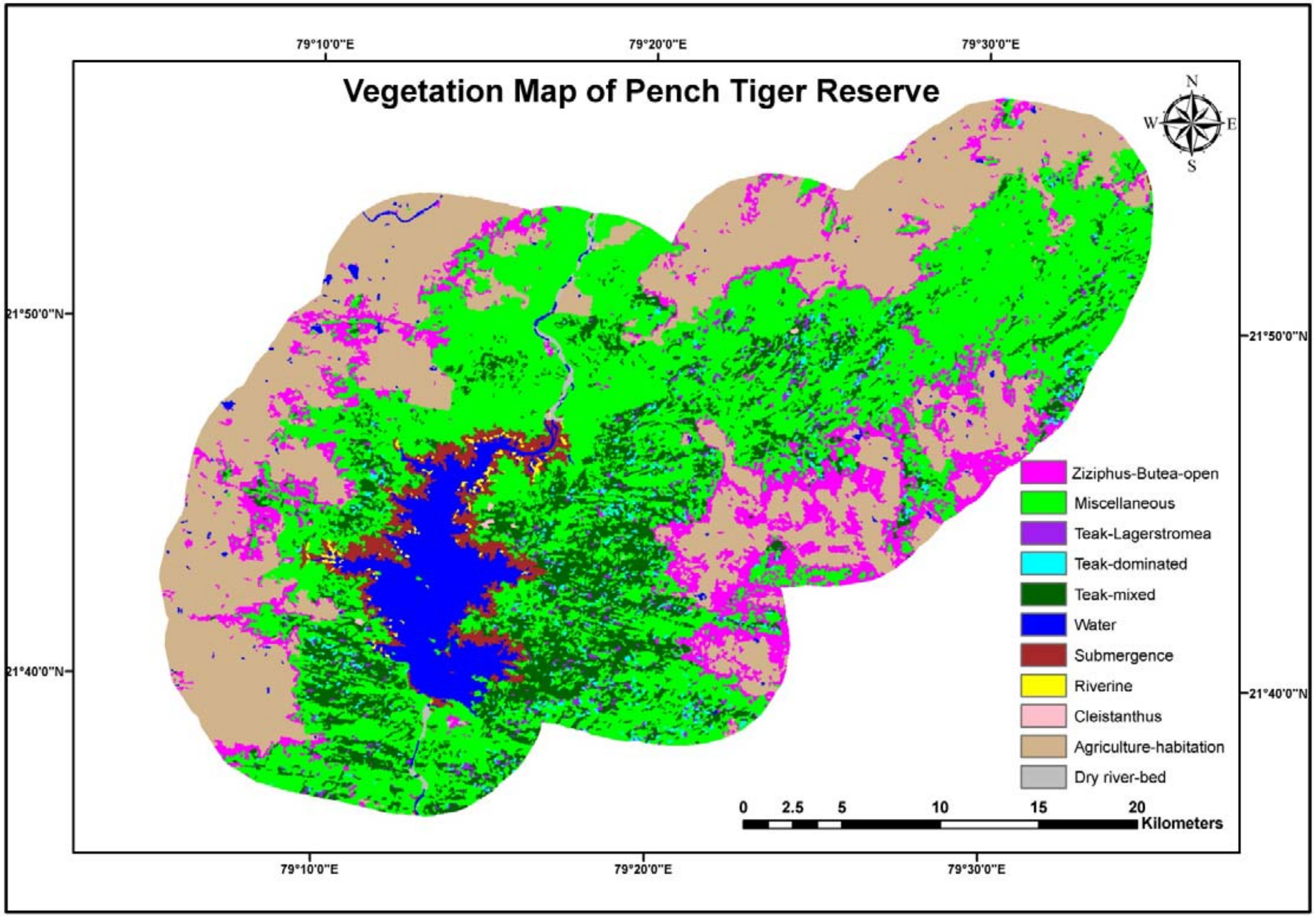
8. **Water body**: This constitutes the Totladoh reservoir, the Pench river and other small tanks/ponds.

9. **Submergence**: This resulted due to the formation of the Totladoh dam and drying up of backwater areas.

10. **Agriculture-Habitation**: As there were no villages inside the PTR, this constitutes the agricultural lands and habitation areas of 99 villages within 5 km buffer of PTR.

11. **Dry river Bed**: This area was the seasonal dried out areas of the Pench river.

Fig 3.4 Land use/cover classes of Pench Tiger Reserve



3.3.4 Area occupied by each land use/cover classes

Miscellaneous forest occupied the maximum proportion of the study area i.e. 38.9% while the *Cleistanthus collinus* forest occupied the least, represented by 0.05%. Table 3.4 shows the areas of different classes mapped.

Table 3.4 Contribution of different land use/cover classes in PTR and its 5 Km buffer

Land Use/cover Classes	Area (Km^2)	Area (%)
Ziziphus Butea-open forest	111.08	9.71
Miscellaneous forest	445.15	38.92
Teak-*Lagerstroemia* forest	14.30	1.25
Teak-dominated forest	13.48	1.18
Teak-Mixed forest	133.59	11.68
Water	59.92	5.24
Submergence	26.45	2.31
Riverine forest	2.83	0.25
Cliestanthus colinus forest	0.55	0.05
Agri-habitation	333.13	29.12
Dry River Bed	3.38	0.05

3.3.5 Canopy Density

As a result of canopy densities, the forest was sub-grouped into four classes viz., (a) above 60%, (b) 30-60%, (c) below 30%, (d) no canopy. (Fig 3.5).

Table 3.5 Accuracy assessment for canopy density mapping

	% Accuracy	Kappa
No canopy	100.0	1
Below 30%	77.6	0.61
30-60%	77.0	0.72
Above 60%	70.3	0.58
Over all	80.5	0.77

a) **Canopy above 60%** - Dense canopy >60% is a peculiar feature of Miscellaneous forest and Teak-mixed forest.

b) **Canopy between 30-60%** - This canopy class is largely found in areas where Teak is a dominant species.

c) **Canopy below 30%** - This is largely found in *Ziziphus Butea* Open forest, it is partially found in Miscellaneous, Teak-mixed, Teak-dominated and *Cleistanthus* forests.

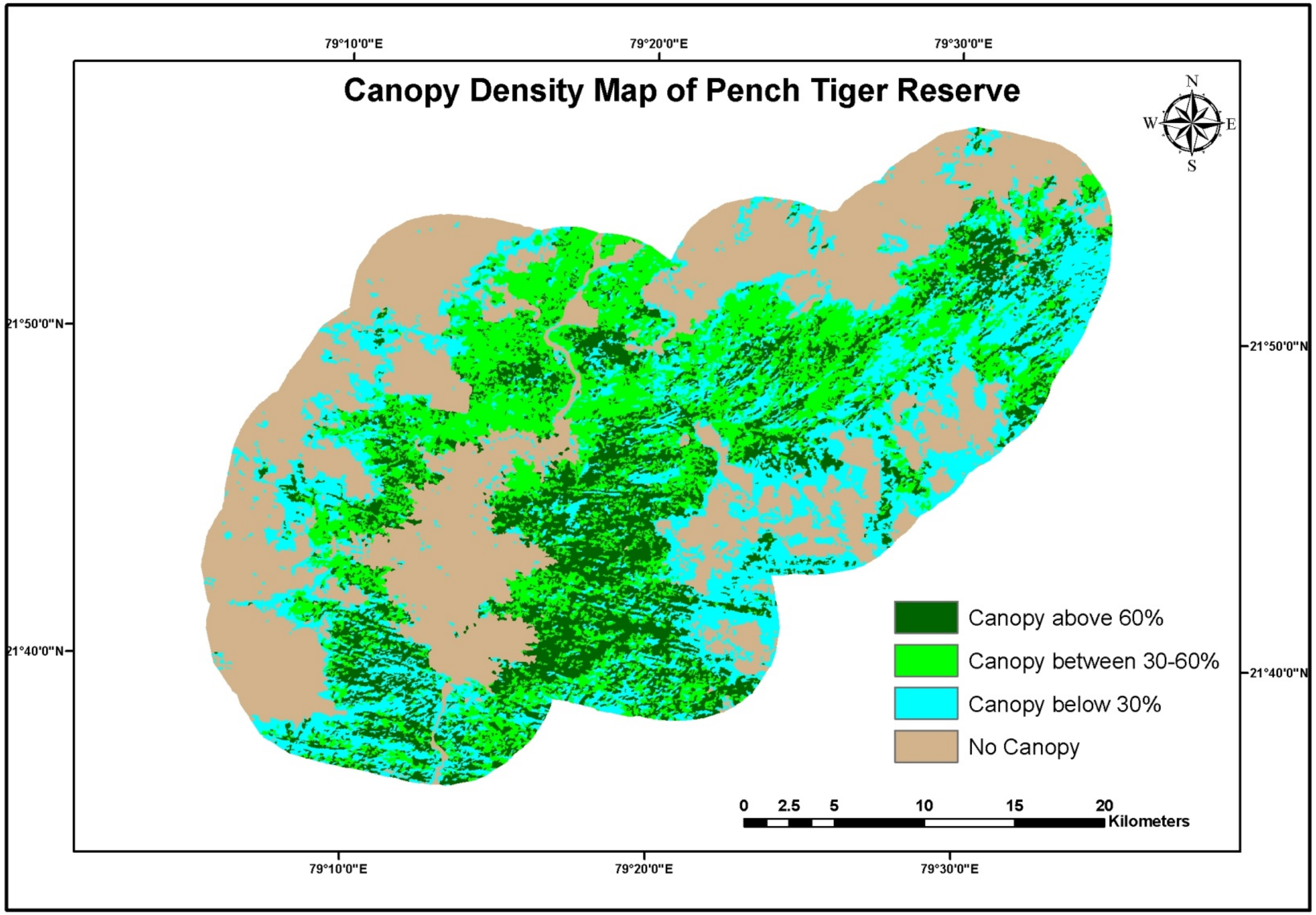
d) **No canopy** – This category is found in open grasslands, water bodies, submergence areas and agriculture-habitation area.

Contributions of different land use/cover classes towards different canopy density classes were estimated as shown in Table 3.6.

Table 3.6 Percent area of different land use/cover classes in different canopy density classes

Land Use/cover Classes	**Above 60% (% area)**	**30-60% (% area)**	**Below 30% (% area)**	**No canopy (% area)**
Ziziphus Butea-open forest	0.00	0.00	100.00	0.00
Miscellaneous forest	18.93	46.36	34.71	0.00
Teak-*Lagerstroemia* forest	17.78	65.77	16.45	0.00
Teak-dominated forest	36.80	57.22	5.98	0.00
Teak-Mixed forest	83.08	13.62	3.30	0.00
Water	0.00	0.00	0.00	100.00
Submergence	0.00	0.00	0.00	100.00
Riverine forest	6.69	89.62	3.69	0.00
Cliestanthus colinus forest	77.56	20.96	1.49	0.00
Agri-habitation	0.00	0.00	0.00	100.00
Dry River Bed	0.00	0.00	0.00	100.00

Fig 3.5 Distribution of canopy density classes in Pench Tiger Reserve



3.3.6 Landscape characterization

Landscapes of the study area have been defined at three levels of hierarchy, starting from broader to narrower levels i.e. landscape level, class level and patch level. An attempt has been made to study landscapes in terms of its vegetation types.

3.3.5.1 At Landscape level: PTR's landscape was found to be heterogeneous in nature with fine patch richness. As shown in Table 3.7, a total of 3526 patches of different types with varying patch sizes could be recognised in the landscape with patch density of 1.9 patches per Km^2. The landscape was not evenly interspersed by different forest types as indicated by the interspersion value of 48.02. The landscape was diverse and uniform in its nature as shown by values of Simpson Diversity Index 0.56 and Simpson Evenness Index 0.66.

Table 3.7 Landscape level heterogeneity in Pench Tiger Reserve

# of patches	3526
Patch density	1.9 patches/km^2
Lagest Patch Index	15.90%
Interspersion Juxtaposition Index	48.02
Simpson Diversity Index	0.56
Simpson eveness Index	0.66

3.3.6.2 At Class level: Proceeding towards the finer levels of the landscape structure i.e. class level, it was found that the landscape was composed of Seven vegetation types viz., Miscellaneous forest, Riverine forest, *Ziziphus Butea* Open forest, Teak-dominated forest, Teak-*Lagerstroemia* forest, Teak-mixed forest and *Cleistanthus* forest. The result of metrics computed at the class level is given in Table 3.8.

Table 3.8 Vegetation class level heterogeneity in Pench Tiger Reserve

TYPE	% of landscape	# of patches	patch density (#/Ha)	Mean patch Size (Ha)	Interspersion juxtaposition Index
Ziziphus Butea-open	9.71	641	0.3481	17.33	21.6
Teak-dominated	1.18	541	0.2938	2.49	57.8
Miscellaneous	38.92	628	0.341	70.88	54.6
Teak-*Lagerstroemia*	1.25	514	0.2791	2.78	58.3
Teak-Mix	11.68	1108	0.6017	12.06	38.8
Riverine	0.25	89	0.0483	3.17	15.8
Cliestanthus	0.05	5	0.0027	10.9	31.4

3.3.6.3 At Patch level: The area of each patch comprising a landscape mosaic is the most useful piece of information contained in a landscape. The analyses (Table 3.9) revealed that among all the vegetation classes, miscellaneous forest had the largest patch of 292.2 Km^2.

Table 3.9 Patch level heterogeneity

TYPE	Largest patch area (Ha)
Ziziphus Butea-open	1101.33
Teak-dominated	14.49
Miscellaneous	29218.86
Teak-*Lagerstroemia*	14.22
Teak-Mix	3988.26
Riverine	22.68
Cliestanthus	18.45

3.4 DISCUSSION

Landscape elements type coupled with satellite imagery can be effectively used to monitor biodiversity (Nagendra and Gadgil 1999). It was observed that at high spatial resolution, many factors affect the recorded reflectance of the plant communities (species, crown closure, crown geometry, stand density, soil moisture and sun angle). This made it possible to map the communities using cluster analysis to a finer level, in spite of heterogeneous landscape. Special consideration was given to the compatibility of ground data collected and the spectral qualities measured by satellite. As a result, different land cover classes and canopy density classes were adequately mapped. Among the land cover classes, miscellaneous forest was the most dominant class in PTR because of no forest management intervention was undertaken for almost thirty years. As PTR comes under biogeographic province Central highlands (Rodgers and Panwar 1988), which is the hottest region of Madhya Pradesh, water is one of the limiting factors. Therefore, very less riverine patches were found. Teak was present in almost all the vegetation community types but very less area was occupied by Teak-dominated patches. The teak dominated patches were found only in plantation areas of recent past. The old plantations of teak had now been converted into Miscellaneous and Teak Mixed Forest, and this could be attributed to restriction in the forest management activities in PTR in the mid 1980s. The *Ziziphus Butea*-open forests were mostly found in the fringes of the park boundary and around villages which exert an anthropogenic pressure thus lead to the degradation of the surrounding forests. All seven vegetation types delineated by satellite data were present in the Pench National Park in more or less uniform fashion than in Pench Wildlife Sanctuary. Presence of natural water sources and high protection status are major reasons contributing to the presence of all vegetation classes in Pench National Park.

The characterization of landscape helped in the identification of problems and its severity, which are useful in planning ecosystem management (Forman and Godron 1986). The analysis support the observation that a small set of indices can capture significant aspects of landscape pattern. These measures are more sensitive than simple comparisons of class proportions. The structural analysis of PTR landscape revealed its heterogeneous nature with large variations in patch size, moderate diversity, high evenness and low intermediate interspersion of forest types. Miscellaneous Forest covered the maximum area of PTR (38.9%), indicating its dominance in terms of vegetation classes. Teak-Mixed Forest was found to be most patchy as it had highest number of patches (1108) with highest patch density (0.6/100ha) followed by *Ziziphus Butea*-open Forest and Miscellaneous Forest (Table 3.8). However, results had shown an interesting pattern that inspite of being dominant in the area; Miscellaneous Forest had low patch density (0.3/100ha) almost half of the Mixed Forest (0.6/100ha). This was because even though Miscellaneous Forest had few patches (628) but it had highest mean patch size (70.9 ha) in comparison to Teak-Mixed Forest (1108) which had lowest mean patch size (12.05 ha) in PTR landscape. This indicated that dominance of Miscellaneous forest was attributed to large size patches, in spite being less in number. The Teak-Lagerstroemia Forest followed by Teak-Mixed Forest had the highest adjacencies among all the vegetation types, indicating that these two forest type shared their edges with rest of the forest types. Nevertheless, Riverine Forest and *Ziziphus Butea*-open Forest had least interspersion among all forest types. This was due to the clumped distribution these forests in the landscape.

This study had focused on the approach of integrating satellite imagery based forest classification and forest inventory data for studying forest landscape patterns. Freely available Landsat TM satellite data had proved to have an immense potential to capture the structural details of the landscape precisely due to its good resolution and multispectral nature. This attribute had been further used for analyzing the patch dynamics in the landscape. Results presented here support focusing on few metrics that represented overall landscape structure for landscape characterization and monitoring. At present, park managers should consider indices as tools for comparing different landscapes patterns and habitat quality. The trends depicted by the application of landscape metrics might be assimilated into prognostic models and scenarios to support strategic decision making for regional conservation and policy development.

Chapter-4 Socio - Economic Profile And Resource Dependency Of Local People

4. 1 INTRODUCTION

A large and growing body of conservation literature exists for understanding interactions between people and landscapes (DeFries et al. 2005, 2009, Nagendra 2007, Joppa et al. 2008, Wittmyer et al. 2008). Countries in South Asia and India in particular, face immense challenges posed by poverty, high densities of people, rapidly changing landscapes, complicated political and institutional regimes, recent economic growth and urbanization. In India, 5 million people live inside nature reserves, and 147 million depend on resources that these reserves provide (Kutty and Kothari 2001). These regions have historically supported and continue to support high biodiversity, with significant conservation value. The high human populations and their dependence on landscapes for basic livelihood needs create the imperative to balance broader conservation objectives and human needs. Rural population in the Indian subcontinent depends heavily on forest resources and resource collection continues in most protected areas despite prohibition (deFries et al. 2010).

India is largely an agrarian country (46% of total land area cultivated), with 57% of labor force dependent on agriculture (UN 2006). India is home to 1.2 billion people and is projected to increase to 1.4 billion people by 2020 (UN 2009). During the last 150 years, human population density has quadrupled from 80 to 324 people/km^2 although density varies across biomes, ranging from the deserts of Rajasthan to the fertile Gangetic Plain (Rangarajan 2007). The majority (70%) of Indians live in rural areas in poverty with 80% of rural people living on less than two dollars a day (UN 2009). Despite high economic growth of approximately eight percent over the last 15 years, the country ranks 88th out of 135 countries under the Human Poverty Index (UN 2009) and 134th out of 182 countries in the human development index (HDI), and 128th out of 182 for GDP per capita (UN 2006). Recent rapid economic and technological changes have improved the lives of millions of people but there is now tremendous development and political pressure to improve lives of all people. Development efforts such as large scale expansion of infrastructure, basic services such as electricity and water, urbanization, mining, dams, tourism are resulting in unplanned land use change and exploitation of natural resources. These rapid changes make this moment particularly pertinent to examine the conservation challenges in India's highly diverse and dynamic landscapes. India is ranked as a megadiversity country (Briggs 2003, Mittermeier and Mittermeier 2005). Rich biological diversity found in this country includes >400 mammals (particularly the largest viable populations of tigers and Asian elephants), and two global hotspots the Western Ghats and Eastern Himalayas (Karanth et al. 2009).

Pench Tiger Reserve, located in the Satpura-Maikal landscape of Central Indian Highlands, represents a typical example of the complexities and inequities involved in planning large-scale involved in making conservation policies. Mainly belonging to the Gond tribal community, these villagers primarily depends on agriculture and non-timber forest product (NTFP) collections for their livelihood. Many previous studies have showed concerns over grazing and over exploitation due to NTFP and fuel wood collections which poses a significant threat to natural habitats and biodiversity (Shukla 1990, Jayapal 1997, Bhaskar 1997, Sankar et al. 2001, David 2002, Areendran 2007, Acharya 2007). Areendran (2007) showed that intensively exploited habitats are subject to changes in green biomass. Six villages namely Piorthori, Sapat, kandlai, Palaspani, Umrighat and Chhindewani were relocated outside of the park due to the formation of Totladoh reservoir in 1990. Two other villages, Alikatta and Chedia were also shifted outside in 1992 and 1994 respectively due to the notification of Pench National Park in 1983. As per current status there is no village inside the National Park and Sanctuary but there are 99 villages within 5 Km buffer of PTR. Due to no protection and conservation measures outside PTR boundary, these villages exert immense pressure on the PA which will be discussed in details in the next chapter.

A Field survey among local communities around PTR was undertaken from January 2009 to June 2009 in order to assess the extent of dependence upon forest products and economic status of the house holds.

4. 2 METHODOLOGY

Village level information on population density, sex structure, literacy, fertile land holding, employment structure, live stock holding were collected from all the 99 villages present around 5 Km buffer of PTR. These villages were distributed in five ranges (Khawasa, Kurai, Rukhad, Gumtara and Bichua). A detailed data collection was done from February to June 2009. All the villages of each range were finally classified into three different distance categories as Category-I (within 1 Km), Category II (1 Km-2 km) and Category III- (2 km-5 Km) and the smallest and largest village in all categories in each ranges were chosen for household sampling. The household questionnaire survey assessed a) Quantity of fuel wood non-wood forest product extracted from forest, b) community/caste, c) Economic status as per their income (rich, medium and poor). Data collected using a structured questionnaire (Sankar 2008) and a survey was conducted thus achieving a household sampling effort of 90% to almost 100% varying in different villages. This close-ended questionnaire survey was administered to 1926 (98.7%) households of category-I sampling villages, 1324 (96.2%) households of category II sampling villages and 1471 (95.6%) households of Category-III sampling villages (Table 4.1, 4.2 & 4.3). This close-ended questionnaire survey was administered with varying sampling proportions in different villages. In addition to the questionnaire survey, the quantity of biomass extracted was approximated visually by comparing the head loads of known weight. The quantity collected by all the sampled households in 30 villages was estimated and extrapolated to other house holds in the sampled villages, since all the households collected fuel wood.

Table 4.1 Number of households surveyed and percent sampling achieved in villages of Category-I

Village	Range	# of Households	# of household surveyed	% of Household surveyed
Kokiwara	Bichua	55	55	100
Dodhgaon	Bichua	261	253	97
Pathra khurd	Gumtara	52	52	100
Gumtara	Gumtara	533	520	98
Karmajhiri	Khawasa	46	46	100
Turia	Khawasa	338	332	98
Khamrith	Kurai	24	24	100
Pindkapar	Kurai	484	468	97
Murer	Rukhad	12	12	100
Patarai	Rukhad	172	164	95
Total			1926	**98.7**

Table 4.2 Number of households surveyed and percent sampling achieved in villages of Category-II

Village	Range	# of Households	# of household surveyed	% of Household surveyed
Mohgaon khurd	Bichua	83	79	95
Surrewani	Bichua	139	136	98
Thota raiyat	Gumtara	45	45	100
Patri	Gumtara	271	265	98
Durgapur	Khawasa	49	49	100
Sarahiri	Khawasa	198	186	94
Vijaypani II	Kurai	123	119	97
Mohgaon (Yadav)	Kurai	189	170	90
Tewni	Rukhad	82	77	94
Airma	Rukhad	204	198	97
Total			1324	**96.2**

Table 4.3 Number of households surveyed and percent sampling achieved in villages of Category-III

Village	Range	# of Households	# of household surveyed	% of Household surveyed
Dongargaon	Bichua	67	61	91
Deori	Bichua	248	237	96
Davajhir	Gumtara	57	55	96
Rampuri	Gumtara	345	334	97
Arjuni	Khawasa	60	58	97
Pachdhar	Khawasa	145	140	97
Harduli	Kurai	91	85	93
Pipariya	Kurai	250	238	95
Niwari	Rukhad	38	38	100
Mohgaon sadak	Rukhad	236	225	95
Total			1471	**95.7**

4. 3 RESULTS

4. 3.1 People and livestock

Out of ten villages in Category-I of the Tiger Reserve, Murer was found to be the smallest with only 12 households whereas Gumtara was the largest with 533 households (Table 4.1). Among the villages in Category-II, Patri was found to be the largest with a total of 271 households and Thota Raiyat was the smallest with 45 households (Table 4.2), whereas for villages in Category-III, Rampuri was the largest with 345 households and Niwar was the smallest with 38 households (Table 4.3).

4.3.1.1 Sex ratio and child to female ratio:

The average sex ratio amongst all the sampled households was found to be 98 females per 100 males, which is slightly higher than the national average i.e. 93 females per 100 males. The observed sex ratio among Category-I villages was 98 females to 100 males with the lowest exhibited by Tokadimaal (57 females per 100 males) and the highest (118 females per 100 males) found in Naharjhir (Table 4.4). Sex ratio for the villages in Category-II was found to be the highest in Salhe (110 females / 100 males) and lowest in Tewni (91 females / 100 males). For villages in Category-III, Kardhaiya had the lowest (65 females / 100 males) and Ghatkohka had the highest (127 females / 100 males) sex ratio. Nearly 27.6 % of the population sampled falls under children category, thus indicating a high population growth rate (Table 4.4, 4.5, 4.6). Also, a high female to children ratio of 183 children per 100 females represented a high growth in population. In Category-I the highest female to children ratio was observed in Murer (300 children per 100 females) and the lowest in Jeerawada (119 children per 100 females) amongst the sampled households (Fig. 4.1). For the villages in Category-II, female to children ratio was found highest in Chhota Singardweep (237 children / 100 females) and lowest in Mohgaon (Yadav) (128 children / 100 females) (Fig. 4.2) whereas the same for villages in Category-III found to be highest in Khursipar (398 children / 100 females) and lowest in Amajhiri (114 children / 100 females) (Fig. 4.3).

Table 4.4 Demographic details of different villages in Category-I

Villages	Ranges	Family	Total Population	Male	Female	Children	Sex ratio (# of females/ 100 males)
Thuyepani	Bichua	212	967	246	227	494	**92.3**
Dodhgaon	Bichua	261	1223	350	348	525	**99.4**
Pulpuldoh	Bichua	202	944	213	203	528	**95.3**
Kokiwara	Bichua	55	251	65	65	121	**100.0**
Pathrakala	Bichua	83	370	92	81	197	**88.0**
Chirrewani	Bichua	134	663	135	142	386	**105.2**
Pathra khurd	Gumtara	52	177	45	42	90	**93.3**
Jamtara	Gumtara	322	1256	320	330	606	**103.1**
Naharjhiri	Gumtara	90	339	82	97	160	**118.3**
Gumtara	Gumtara	533	1961	533	529	899	**99.2**
Bordi	Gumtara	60	268	65	66	137	**101.5**
Karmajhiri	Khawasa	46	230	66	65	99	**98.5**
Barelipar	Khawasa	75	364	98	103	163	**105.1**
Tikadimal	Khawasa	73	446	169	97	180	**57.4**
Tikari raiyat	Khawasa	50	254	69	61	124	**88.4**
Vijaypani	Khawasa	160	708	199	190	319	**95.5**
Awarghani	Khawasa	76	333	83	85	165	**102.4**
Turia	Khawasa	338	1700	587	423	690	**72.1**
Ambadi	Kurai	86	444	118	106	220	**89.8**
Khamrith	Kurai	24	127	36	31	60	**86.1**
Khamba	Kurai	61	380	98	99	183	**101.0**
Satosa	Kurai	107	495	140	147	208	**105.0**
Jeerewada	Kurai	176	786	228	254	304	**111.4**
Potia	Kurai	261	1081	288	307	486	**106.6**
Pindkapar	Kurai	484	1867	552	532	783	**96.4**
Raiyarao	Kurai	101	366	119	105	142	**88.2**
Kodajhiri	Kurai	175	793	211	218	364	**103.3**
Patarai	Rukhad	172	823	219	229	375	**104.6**
	Range						**Sex ratio**

Table 4.4 continued

Villages		Family	Population	Male	Female	Children	(# of females/ 100 males)
Alesur	Rukhad	90	429	119	122	188	**102.5**
Katangi	Rukhad	76	352	90	87	175	**96.7**
Murer	Rukhad	12	59	11	12	36	**109.1**
Dhutera	Rukhad	139	644	165	175	304	**106.1**
Aagri	Rukhad	60	310	81	90	139	**111.1**
Gandatola	Rukhad	71	282	68	77	137	**113.2**

Table 4.5 Demographic details of different villages in Category-I I

Villages	Range	Family	Total Population	Male	Female	Children	Sex ratio (# of females/ 100 males)
Surrewani	Bichua	139	579	166	158	255	**95.2**
Mohgaon khurd	Bichua	83	349	94	90	165	**95.7**
Daini	Bichua	168	431	203	228	308	**112.3**
Thota raiyat	Gumtara	45	163	43	40	80	**93.0**
Thota maal	Gumtara	258	964	267	280	417	**104.9**
Singardeep	Gumtara	90	487	116	110	261	**94.8**
Patri	Gumtara	271	1083	273	274	536	**100.4**
Salhe	Khawasa	74	383	73	80	230	**109.6**
Sarahiri	Khawasa	198	1032	302	308	422	**102.0**
Kohka	Khawasa	131	665	169	168	328	**99.4**
Teliya	Khawasa	179	793	221	242	330	**109.5**
Durgapur	Khawasa	49	229	57	62	110	**108.8**
Vijaypani II	Kurai	123	595	147	153	295	**104.1**
Mohgaon (Yadav)	Kurai	189	725	209	226	290	**108.1**
Setewani	Kurai	137	611	171	185	255	**108.2**
Tewni	Rukhad	82	420	131	120	169	**91.6**
Airma	Rukhad	204	915	259	240	416	**92.7**

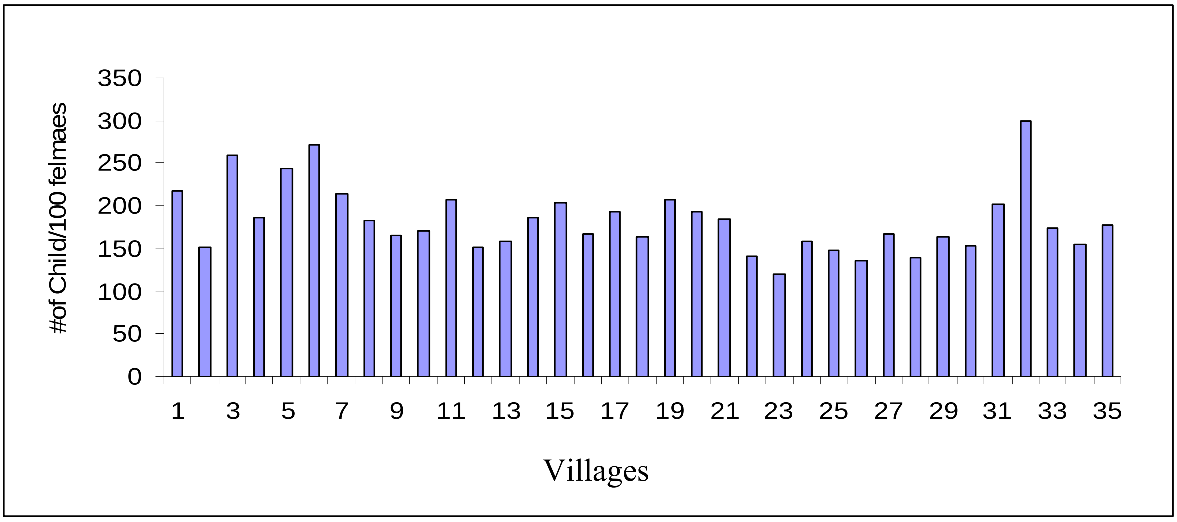
Table 4.6 Demographic details of different villages in Category-I I I

Villages	Range	Family	Total population	Male	Female	Children	Sex ratio (# of females/ 100 males)
Dongargaon	Bichua	67	296	85	74	137	**87.1**
Kardhaiya	Bichua	231	1096	324	211	561	**65.1**
Marjatpur	Bichua	127	663	180	170	313	**94.4**
Sanwri	Bichua	241	1012	247	249	516	**100.8**
Deori	Bichua	248	1029	244	236	549	**96.7**
Saliwada	Bichua	87	416	98	105	213	**107.1**
Bisanpur	Bichua	91	352	87	77	188	**88.5**
Kundai	Bichua	181	791	186	185	420	**99.5**
Rampuri	Gumtara	345	1998	607	486	905	**80.1**
Davajhir	Gumtara	57	290	81	70	139	**86.4**
Kumbhpani	Gumtara	91	419	106	105	208	**99.1**
Bandhanmaal	Gumtara	169	710	160	180	370	**112.5**
Chargaon	Gumtara	105	423	112	112	199	**100.0**
Silota raiyat	Gumtara	75	367	102	88	177	**86.3**
Silota khurd	Gumtara	83	317	79	82	156	**103.8**
Silota kala	Gumtara	125	574	149	139	286	**93.3**
Paraspani	Khawasa	142	702	174	196	332	**112.6**
Pachdhar	Khawasa	145	581	164	179	238	**109.1**
Mundiarith	Khawasa	70	345	85	87	173	**102.4**
Kuppitola	Khawasa	75	348	96	107	145	**111.5**
Arjuni	Khawasa	60	266	77	83	106	**107.8**
Amajhiri	Kurai	173	743	208	249	286	**119.7**
Nayegaon	Kurai	110	503	142	139	222	**97.9**
Harduli	Kurai	91	329	96	97	136	**101.0**
Pipariya	Kurai	250	932	278	280	374	**100.7**
Ghatkohka	Rukhad	177	789	151	192	446	**127.2**
Panjara	Rukhad	41	183	48	56	79	**116.7**
Sindariya	Rukhad	120	496	135	144	217	**106.7**
Mohgaon teetri	Rukhad	111	525	149	126	250	**84.6**
Niwari	Rukhad	38	154	32	37	85	**115.6**
Karhaiya	Rukhad	192	847	228	240	379	**105.3**

Table 4.6 continued

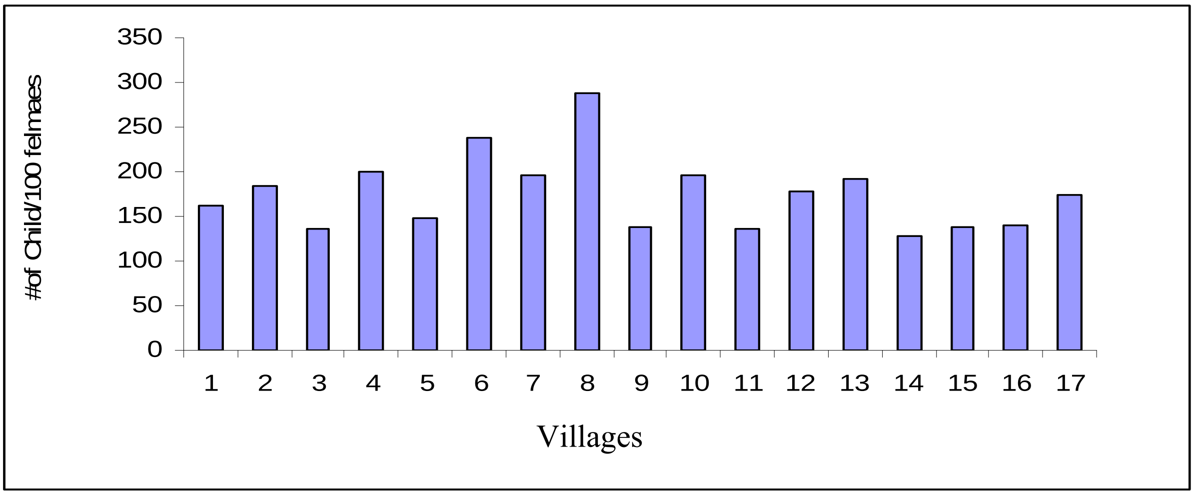
Villages	Range	Family	Total population	Male	Female	Children	Sex ratio (# of females/ 100 males)
Mohgaon sadak	Rukhad	236	985	281	281	423	**100.0**
Khamarpani	Bichua	443	1946	565	499	882	**88.3**
Ghatkamtha	Bichua	178	805	198	218	389	**110.1**
Dunda seoni	Bichua	101	409	110	114	185	**103.6**
Khursipar	Bichua	116	455	106	70	279	**66.0**
Boriya	Bichua	64	340	33	83	224	**251.5**
Tekapar	Bichua	56	270	68	68	134	**100.0**
Antra	Bichua	55	258	72	72	114	**100.0**
Kanhargaon	Bichua	162	741	187	184	370	**98.4**
Banskheda	Gumtara	301	1319	351	364	604	**103.7**
Kanhasagar	Gumtara	92	389	103	106	180	**102.9**
Khairanj	Gumtara	48	196	48	49	99	**102.1**
Kothar	Khawasa	19	83	24	23	36	**95.8**

Fig. 4.1 Child to female ratios in different villages in Category-I



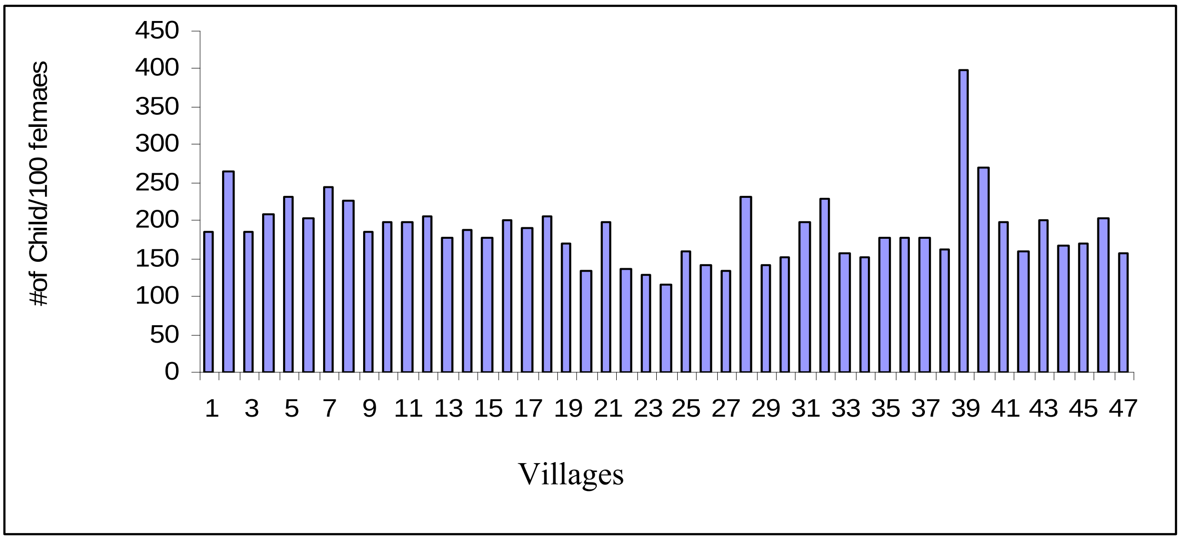
1. Thuyepani, 2. Dodhgaon, 3. Pulpuldoh, 4 Kokiwara, 5. Pathrakala, 6.Chirrewani, 7.Pathra khurd, 8.Jamtara, 9. Naharjhiri, 10.Gumtara, 11.Bordi, 12.Karmajhiri, 13.Barelipar, 14.Tikadimal, 15.Tikari raiyat, 16.Vijaypani, 17.Awarghani, 18.Turia, 19.Ambadi, 20.Khamrith, 21.Khamba, 22.Satosa, 23.Jeerewada, 24.Potia, 25.Pindkapar, 26.Raiyarao, 27.Kodajhiri, 28.Bhodki, 29.Patarai, 30.Alesur, 31.Katangi, 32.Murer, 33.Dhutera, 34.Aagri, 35.Gandatola

Fig. 4. 2 Child to female ratios in different villages in Category-II



1. Surrewani, 2.Mohgaon khurd, 3.Daini, 4.Thota raiyat, 5.Thota maal, 6.Singardeep, 7.Patri, 8.Salhe, 9.Sarahiri, 10.Kohka, 11.Teliya, 12.Durgapur, 13.Vijaypani II, 14.Mohgaon (Yadav), 15.Setewani, 16.Tewni, 17.Airma

Fig. 4. 3 Child to female ratios in different villages in Category-III

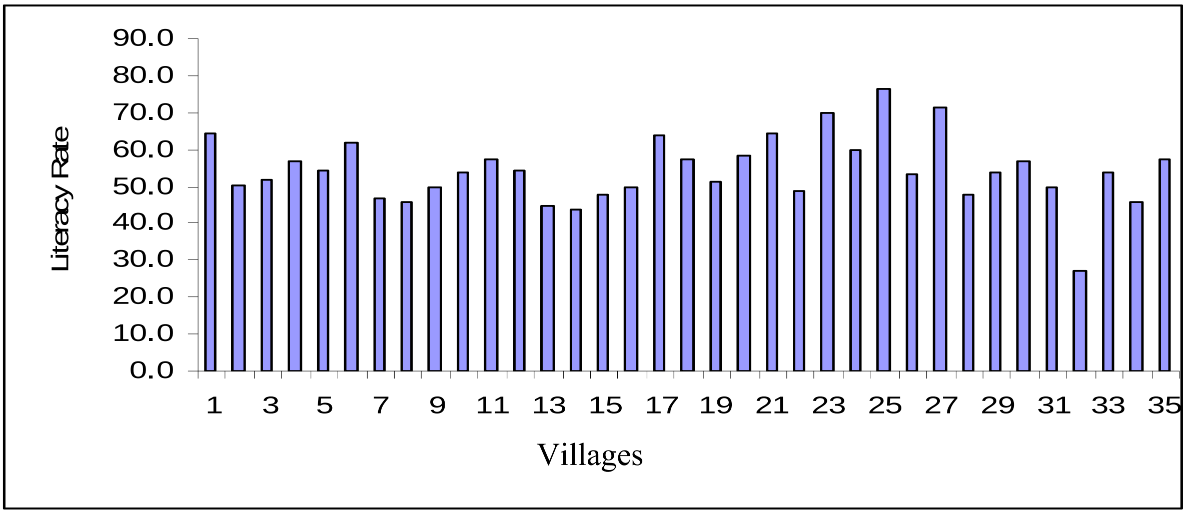


1.Dongargaon, 2.Kardhaiya, 3.Marjatpur, 4.Sanwri, 5.Deori, 6.Saliwada, 7.Bisanpur, 8.Kundai, 9.Rampuri, 10.Davajhir, 11.Kumbhpani, 12.Bandhan maal, 13.Bandhan raiyat, 14.Khamariya maal, 15.Chargaon, 16.Silota raiyat, 17.Silota khurd, 18.Silota kala, 19.Paraspani, 20.Pachdhar, 21.Mundiarith, 22.Kuppitola, 23.Arjuni, 24.Amajhiri, 25.Nayegaon, 26.Harduli, 27.Pipariya, 28.Ghatkohka, 29.Panjara, 30.Sindariya, 31.Mohgaon teetri, 32.Niwari, 33.Karhaiya, 34.Mohgaon sadak, 35.Khamarpani, 36.Ghatkamtha, 37.Dholpur, 38.Dunda seoni, 39.Khursipar, 40.Boriya, 41.Tekapar, 42.Antra, 43.Kanhargaon, 44.Banskheda, 45.Kanhasagar, 46.Khairanj, 47.Kothar.

4.3.1.2 Literacy rate:

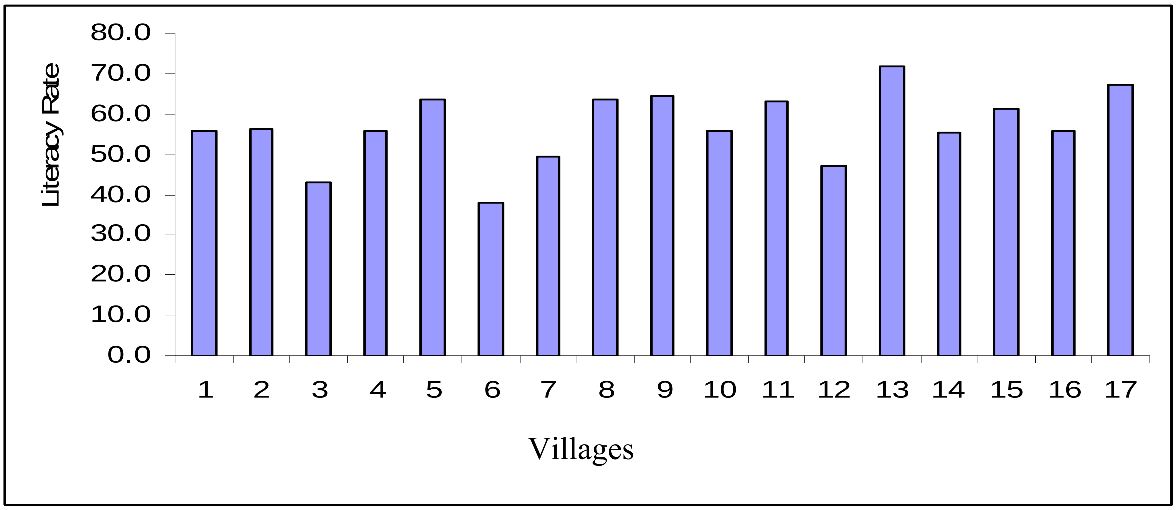
Literacy, as defined in Census operations (2001), is the ability to read and write with understanding in any language. A person who can merely read but cannot write is not classified as literate. Any formal education or minimum educational standard is not necessary to be considered literate. The overall reported literacy rate of the 99 villages was 55.1 %. The lowest literacy rate in Category-I was reported from Murer (27 %) and the highest in Kodajhiri (71 %) (Fig. 4.4). The literacy rate pertaining to Category-II villages was found to be the highest in Vijaypani II (71 %) and lowest in Singardweep (38 %) (Fig. 4.5). However, among the villages in Category III, Khursipar reported the highest literacy rate of 82 % and Tekapar, the lowest with 7 % of literacy rate (Fig. 4.6).

Fig. 4.4 Literacy rate among the villagers in different villages in Category-I



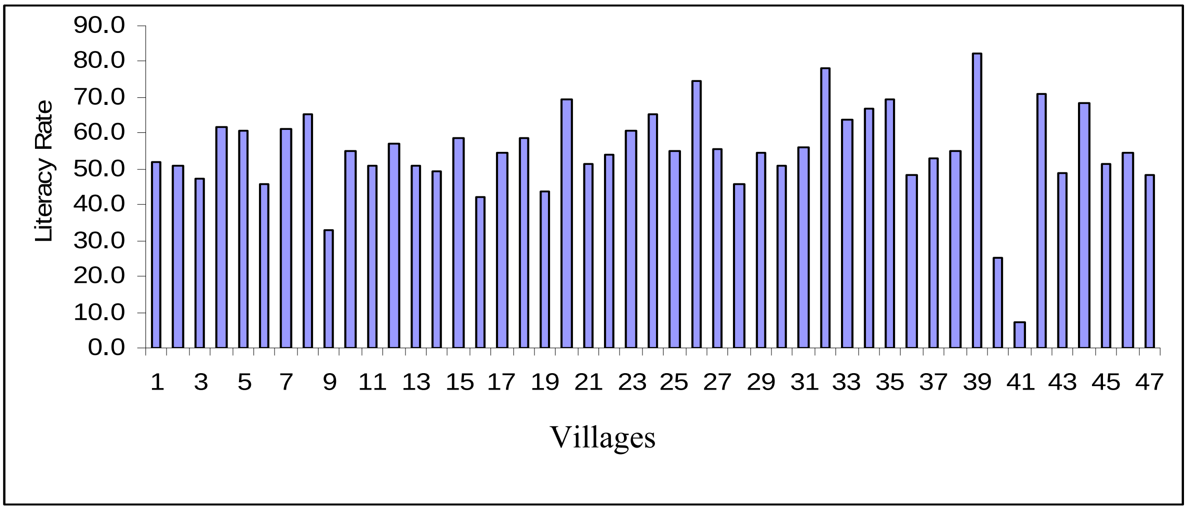
1. Thuyepani, 2. Dodhgaon, 3. Pulpuldoh, 4 Kokiwara, 5. Pathrakala, 6.Chirrewani, 7.Pathra khurd, 8.Jamtara, 9. Naharjhiri, 10.Gumtara, 11.Bordi, 12.Karmajhiri, 13.Barelipar, 14.Tikadimal, 15.Tikari raiyat, 16.Vijaypani, 17.Awarghani, 18.Turia, 19.Ambadi, 20.Khamrith, 21.Khamba, 22.Satosa, 23.Jeerewada, 24.Potia, 25.Pindkapar, 26.Raiyarao, 27.Kodajhiri, 28.Bhodki, 29.Patarai, 30.Alesur, 31.Katangi, 32.Murer, 33.Dhutera, 34.Aagri, 35.Gandatola

Fig. 4. 5 Literacy rate among the villagers in different villages in Category-II



1.Surrewani, 2.Mohgaon khurd, 3.Daini, 4.Thota raiyat, 5.Thota maal, 6.Singardeep, 7.Patri, 8.Salhe, 9.Sarahiri, 10.Kohka, 11.Teliya, 12.Durgapur, 13.Vijaypani II, 14.Mohgaon (Yadav), 15.Setewani, 16.Tewni, 17.Airma

Fig. 4. 6 Literacy rate among the villagers in different villages in Category-III



1.Dongargaon, 2.Kardhaiya, 3.Marjatpur, 4.Sanwri, 5.Deori, 6.Saliwada, 7.Bisanpur, 8.Kundai, 9.Rampuri, 10.Davajhir, 11.Kumbhpani, 12.Bandhan maal, 13.Bandhan raiyat, 14.Khamariya maal, 15.Chargaon, 16.Silota raiyat, 17.Silota khurd, 18.Silota kala, 19.Paraspani, 20.Pachdhar, 21.Mundiarith, 22.Kuppitola, 23.Arjuni, 24.Amajhiri, 25.Nayegaon, 26.Harduli, 27.Pipariya, 28.Ghatkohka, 29.Panjara, 30.Sindariya, 31.Mohgaon teetri, 32.Niwari, 33.Karhaiya, 34.Mohgaon sadak, 35.Khamarpani, 36.Ghatkamtha, 37.Dholpur, 38.Dunda seoni, 39.Khursipar, 40.Boriya, 41.Tekapar, 42.Antra, 43.Kanhargaon, 44.Banskheda, 45.Kanhasagar, 46.Khairanj, 47.Kothar.

Among all the villages, the average child literate to adult literate was 1.58:1 i.e. 158 child literate per 100 adult literate. In category-I villages, the highest and lowest child literate to adult literate were found in Pathra Khurd (2.95:1) and lowest in Turia (0.68:1) (Table 4.7). In Category II and Category III the same were highest in Singardweep (3.3:1) and Tekapar (9:1) respectively and lowest in Mohgaon (Yadav) (0.62:1) and Panchdhar (0.58:1) respectively (Table 4.8 & 4.9).

Table 4.7 Child literate to adult literate of different villages in Category-I

Range	Village	# of literate adult	# of literate children	Children to Adult Literacy rate
Bichua	Thuyepani	224	398	177.7
Bichua	Dodhgaon	253	359	141.9
Bichua	Pulpuldoh	148	339	229.1
Bichua	Kokiwara	57	86	150.9
Bichua	Pathrakala	69	131	189.9
Bichua	Chirrewani	105	304	289.5
Gumtara	Pathra khurd	21	62	295.2
Gumtara	Jamtara	214	358	167.3
Gumtara	Naharjhiri	69	99	143.5
Gumtara	Gumtara	477	579	121.4
Gumtara	Bordi	48	105	218.8
Khawasa	Karmajhiri	58	67	115.5
Khawasa	Barelipar	56	106	189.3
Khawasa	Tikadimal	77	118	153.2
Khawasa	Tikari raiyat	38	83	218.4
Khawasa	Vijaypani	183	170	92.9
Khawasa	Awarghani	108	105	97.2
Khawasa	Turia	580	397	68.4
Kurai	Ambadi	109	119	109.2
Kurai	Khamrith	36	38	105.6
Kurai	Khamba	136	108	79.4
Kurai	Satosa	124	118	95.2
Kurai	Jeerewada	354	194	54.8
Kurai	Potia	324	321	99.1
Kurai	Pindkapar	950	473	49.8
Kurai	Raiyarao	85	110	129.4
Rukhad	Bhodki	40	56	140.0
Rukhad	Patarai	230	211	91.7
Rukhad	Alesur	118	125	105.9
Rukhad	Katangi	66	110	166.7

Table 4.7 continued

Range	Village	# of literate adult	# of literate children	Children to Adult Literacy rate
Rukhad	Murer	1	15	1500.0
Rukhad	Dhutera	169	178	105.3
Rukhad	Aagri	65	77	118.5
Rukhad	Gandatola	75	86	114.7

Table 4.8 Child literate to adult literate of different villages in Category-II

Range	Village	# of literate adult	# of literate children	Children to Adult Literacy rate
Bichua	**Surrewani**	140	183	130.7
Bichua	**Mohgaon khurd**	82	114	139
Bichua	**Daini**	193	124	64.2
Gumtara	**Thota raiyat**	33	58	175.8
Gumtara	**Thota maal**	303	310	102.3
Gumtara	**Singardeep**	43	142	330.2
Gumtara	**Patri**	193	344	178.2
Khawasa	**Salhe**	65	178	273.8
Khawasa	**Sarahiri**	385	278	72.2
Khawasa	**Kohka**	144	226	156.9
Khawasa	**Teliya**	273	229	83.9
Khawasa	**Durgapur**	48	60	125
Kurai	**Vijaypani II**	189	237	125.4
Kurai	**Mohgaon (Yadav)**	246	154	62.6
Kurai	**Setewani**	199	174	87.4
Rukhad	**Tewni**	137	98	71.5
Rukhad	**Airma**	321	295	91.9

Table 4.9 Child literate to adult literate of different villages in Category-III

Range	Village	# of literate adult	# of literate children	Children to Adult Literacy rate
Bichua	**Dongargaon**	74	80	108.1
Bichua	**Kardhaiya**	202	357	176.7
Bichua	**Marjatpur**	134	181	135.1
Bichua	**Sanwri**	242	384	158.7
Bichua	**Deori**	189	434	229.6
Bichua	**Saliwada**	59	132	223.7
Bichua	**Bisanpur**	77	138	179.2
Bichua	**Kundai**	151	365	241.7
Gumtara	**Rampuri**	428	229	53.5
Gumtara	**Kumbhpani**	95	118	124.2
Gumtara	**Bandhan raiyat**	70	62	88.6
Gumtara	**Khamariya maal**	223	233	104.5
Gumtara	**Chargaon**	122	127	104.1
Gumtara	**Silota raiyat**	48	106	220.8
Gumtara	**Silota khurd**	65	107	164.6
Gumtara	**Silota kala**	128	209	163.3
Khawasa	**Paraspani**	158	148	93.7
Khawasa	**Pachdhar**	255	149	58.4
Khawasa	**Mundiarith**	79	98	124.1
Khawasa	**Kuppitola**	104	84	80.8
Khawasa	**Arjuni**	98	63	64.3
Kurai	**Amajhiri**	273	211	77.3
Kurai	**Nayegaon**	163	113	69.3

Table 4.9 continued

Range	Village	# of literate adult	# of literate children	Children to Adult Literacy rate
Kurai	**Harduli**	138	108	78.3
Kurai	**Pipariya**	267	250	93.6
Rukhad	**Ghatkohka**	141	222	157.4
Rukhad	**Panjara**	44	56	127.3
Rukhad	**Sindariya**	111	141	127
Rukhad	**Mohgaon teetri**	137	157	114.6
Rukhad	**Niwari**	50	70	140
Rukhad	**Karhaiya**	280	258	92.1
Rukhad	**Mohgaon sadak**	393	264	67.2
Bichua	**Khamarpani**	719	637	88.6
Bichua	**Ghatkamtha**	171	219	128.1
Bichua	**Dholpur**	94	225	239.4
Bichua	**Dunda seoni**	98	128	130.6
Bichua	**Boriya**	17	69	405.9
Bichua	**Tekapar**	2	18	900
Bichua	**Antra**	113	70	61.9
Bichua	**Kanhargaon**	131	232	177.1
Gumtara	**Banskheda**	489	415	84.9
Gumtara	**Kanhasagar**	85	116	136.5
Gumtara	**Khairanj**	34	73	214.7
Khawasa	**Kothar**	17	23	135.3

4.3.1.3 Livestock:

. The total number of livestock within 5 Km of PTR was estimated as 36143 with 9035 cows, 3130 buffaloes, 14299 oxen and 9679 goats. The overall livestock population comprised of 1178 buffaloes (9%), 3146 cows (24%), 3490 goats (27%) and 5243 oxen (40%) in all villages of Category-I **(Table 4.10)** with the highest livestock population recorded in Gumtara (1055) and lowest in Khamrith (51).

Gumtara had the maximum number of cows (248) and oxen (459) whereas Turia had the maximum number of buffaloes (169) and goats (346). Khamrith had the least number of livestock with four cows and 10 goats while Awarghani had the least number of Oxen (4). The Category II villages had 570 buffaloes (8%), 1811 cows (27%), 1783 goats (26%) and 2571 oxen (38%) with Thota maal (693) had the highest and Thota raiyat (130) with lowest number of livestock population (Table 4.11). The estimated livestock population in the Category III villages constituted of 1382 buffaloes (8%), 4078 cows (25%), 4406 goats (27%) and 6485 (40%) oxen. In Category III villages Rampuri (1249) had the highest and Kothar (56) had the lowest number of livestock (Table 4.12)

Table 4.10 Total livestock population in different villages in Category-I

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Thuyepani	Bichua	573	110	52	266	145
Dodhgaon	Bichua	814	180	126	312	196
Pulpuldoh	Bichua	467	90	40	225	112
Kokiwara	Bichua	148	32	10	66	40
Pathrakala	Bichua	327	63	15	112	137
Chirrewani	Bichua	338	72	22	149	95
Pathra khurd	Gumtara	190	87	13	48	42
Jamtara	Gumtara	802	212	127	285	178
Naharjhiri	Gumtara	447	145	15	160	127
Gumtara	Gumtara	1155	248	140	459	308
Bordi	Gumtara	221	40	18	86	77
Karmajhiri	Khawasa	145	50	8	54	33
Barelipar	Khawasa	280	80	12	129	59
Tikadimal	Khawasa	206	46	15	91	54
Vijaypani	Khawasa	427	125	33	151	118
Awarghani	Khawasa	140	72	10	4	54
Turia	Khawasa	1124	204	169	405	346
Ambadi	Kurai	184	20	6	91	67
Khamrith	Kurai	51	4	0	37	10

Table 4.10 continued

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Khamba	Kurai	126	29	2	79	16
Satosa	Kurai	285	70	20	121	74
Jeerewada	Kurai	490	125	51	151	163
Potia	Kurai	737	172	92	297	176
Pindkapar	Kurai	517	170	50	172	125
Raiyarao	Kurai	219	52	32	86	49
Kodajhiri	Kurai	342	121	13	128	80
Bhodki	Rukhad	109	16	3	56	34
Patarai	Rukhad	553	106	14	266	167
Alesur	Rukhad	274	89	12	136	37
Katangi	Rukhad	268	62	12	129	65
Murer	Rukhad	61	20	-	13	28
Dhutera	Rukhad	451	96	34	235	86
Aagri	Rukhad	197	52	1	84	60
Gandatola	Rukhad	222	60	2	81	79

Table 4.11 Total livestock population in different villages in Category-II

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Surrewani	Bichua	304	82	12	167	43
Mohgaon khurd	Bichua	268	78	28	79	83
Daini	Bichua	309	74	25	123	87
Thota raiyat	Gumtara	130	37	12	56	25
Thota maal	Gumtara	693	171	92	298	132
Singardeep	Gumtara	294	72	18	109	95
Patri	Gumtara	593	119	28	268	178
Salhe	Khawasa	234	80	16	84	54
Sarahiri	Khawasa	598	154	45	277	122
Kohka	Khawasa	576	178	19	206	173
Teliya	Khawasa	428	86	78	132	132
Setewani	Kurai	389	122	35	134	98

Table 4.11continued

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Vijaypani II	Kurai	434	88	64	170	112
Mohgaon (Yadav)	Kurai	548	175	10	162	201
Tewni	Rukhad	267	70	20	109	68
Airma	Rukhad	527	186	29	191	121

Table 4.12 Total livestock population in different villages in Category-III

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Dongargaon	Bichua	134	18	18	55	43
Kardhaiya	Bichua	593	81	17	283	212
Marjatpur	Bichua	377	61	49	148	119
Sanwri	Bichua	559	132	56	245	126
Deori	Bichua	499	128	43	232	96
Saliwada	Bichua	186	39	7	111	29
Bisanpur	Bichua	288	86	28	96	78
Kundai	Bichua	491	96	85	140	170
Rampuri	Gumtara	1249	416	96	465	272
Davajhir	Gumtara	184	44	22	70	48
Kumbhpani	Gumtara	357	89	18	102	148
Bandhan raiyat	Gumtara	243	53	18	59	113
Khamariya maal	Gumtara	434	89	28	172	145
Chargaon	Gumtara	266	69	6	109	82
Silota raiyat	Gumtara	251	59	19	93	80
Silota khurd	Gumtara	218	47	13	88	70
Silota kala	Gumtara	384	92	28	146	118
Paraspani	Khawasa	467	137	14	170	146
Pachdhar	Khawasa	226	85	11	64	66
Mundiarith	Khawasa	210	49	7	84	70
Kuppitola	Khawasa	240	76	41	107	16

Table 4.12 continued

Village	Range	Total Livestock	Cows	Buffaloes	Oxen	Goats
Arjuni	Khawasa	261	70	39	67	85
Nayegaon	Kurai	243	48	12	96	87
Harduli	Kurai	146	49	27	56	14
Pipariya	Kurai	452	200	16	172	64
Ghatkohka	Rukhad	519	112	30	252	125
Panjara	Rukhad	136	36	7	64	29
Sindariya	Rukhad	266	57	15	139	55
Mohgaon teetri	Rukhad	268	50	10	117	91
Niwari	Rukhad	84	19	5	30	30
Karhaiya	Rukhad	522	104	34	215	169
Mohgaon sadak	Rukhad	384	145	35	151	53
Khamarpani	Bichua	621	189	75	213	144
Ghatkamtha	Bichua	618	140	72	228	178
Dholpur	Bichua	407	78	45	144	140
Dunda seoni	Bichua	250	56	22	96	76
Khursipar	Bichua	262	32	4	198	28
Boriya	Bichua	207	41	4	95	67
Tekapar	Bichua	310	49	4	108	149
Antra	Bichua	172	40	12	72	48
Kanhargaon	Bichua	284	45	13	156	70
Banskheda	Gumtara	807	225	142	292	148
Kanhasagar	Gumtara	203	48	16	66	73
Khairanj	Gumtara	131	30	-	56	45
Kothar	Khawasa	56	17	-	12	27

4.3.2 Socio-economic profile from household survey

The study indicated that the indigenous tree species of Pench Tiger Reserve play an integral and important role in the lives of the villagers residing around the Tiger Reserve. Fuelwood was the major forest product collected by all the villagers and was the primary source of domestic energy for almost all the households. In this study, data from 30 villages were presented which were selected for household sampling.

4.3.2.1 Forest product collection:

Various forest products were collected by people for domestic use/ consumption. The major tree species exploited as fuel wood in PTR are *Phyllanthus emblica, Boswellia serrata, Anogeissus latifolia, Butea monosperma, Terminalia tomentosa, Diospyros melanoxylon* and *Madhuca indica.* Few respondents reported fodder collection from the forest areas and hence the said data was not processed for further analysis. The main NTFP collection is restricted to the collection of Tendu (*Diospyros melanoxylon*) leaves, flower and seeds of Mahua (*Madhuca indica*), fruits of Awla (*Phyllanthus emblica*) and fruits of Chiranji (*Buchnania lanzan*)**.**

My estimates suggested that a total of 2265 headloads of fuelwood per day is extracted by all the 10 villages in Category I. The average head load, each weighing about 30 kilograms, the estimated total weight of the harvested fuel wood comes to 67950 kg per day combined for the 10 villages. Maximum extraction, which is obvious to be directly proportional to the number of households, was reported from Pindkapar and the minimum from Murer (Fig. 4.7). Similarly, for the villages in Category II, the fuel wood exploitation was estimated to be 59850 kg per day and 49020 kg per day for the villages located in Category III (Fig. 4.8, 4.9).

This fuel wood collected, though it is not generally sold by the villagers possesses a high commercial value. The market value for a single head load of fuel wood is approximately Rs.15. This cost when combined with the quantity of fuel wood exploited annually gives an economic value of Rs. 96,80,89,500 for only 30 villages out of 99 villages around the Tiger Reserve. Table 4.13 gives a detail account of the fuel wood exploitation and its economic values in all the three Categories.

Table 4.13 Details of commercial value of fuel wood in Pench Tiger Reserve

Attributes	Category I	Category II	Category III
Quantity of fuel wood exploited annually (kg)	24801750	21845250	17892300
Economic value of fuel wood exploited daily (Rs.)	1019250	897750	735300
Economic value of fuel wood exploited annually (Rs,)	372026250	327678750	268384500

Fig. 4. 7 Quantity of fuel wood in kilograms exploited per day by the villages located in Category I

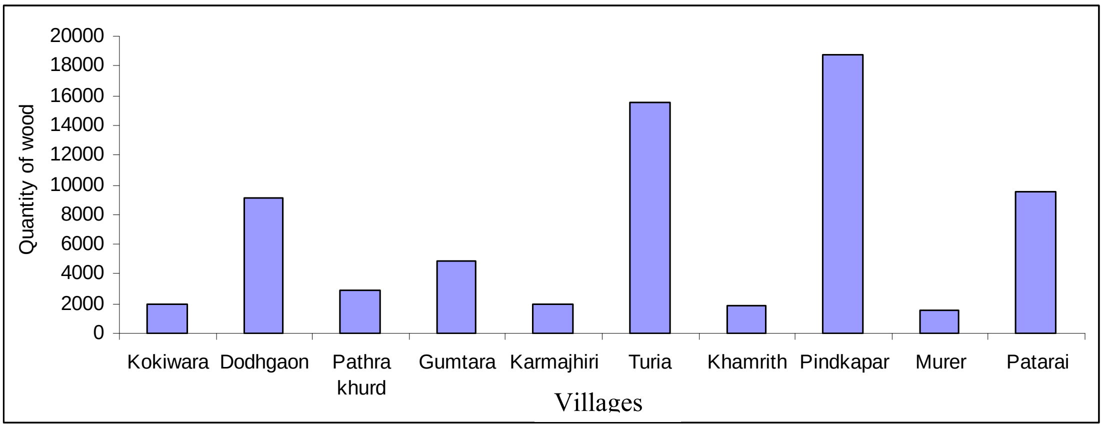


Fig. 4. 8 Quantity of fuel wood in kilograms exploited per day by the villages located in Category II

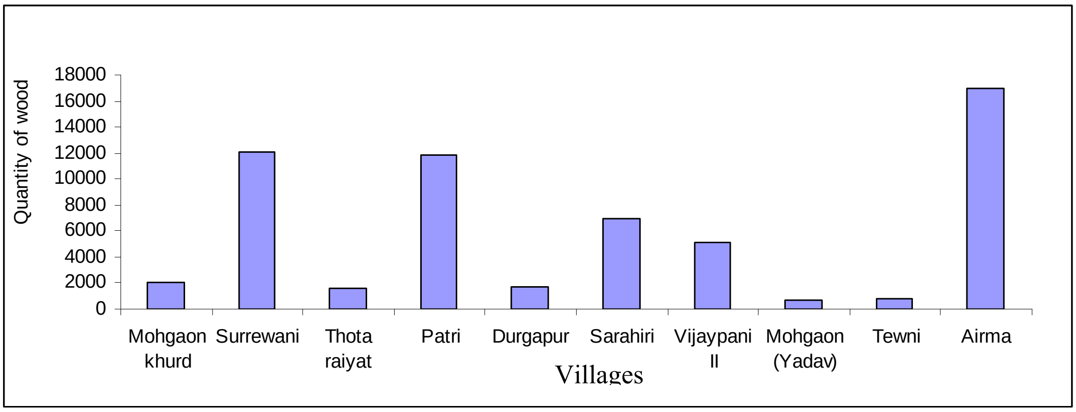
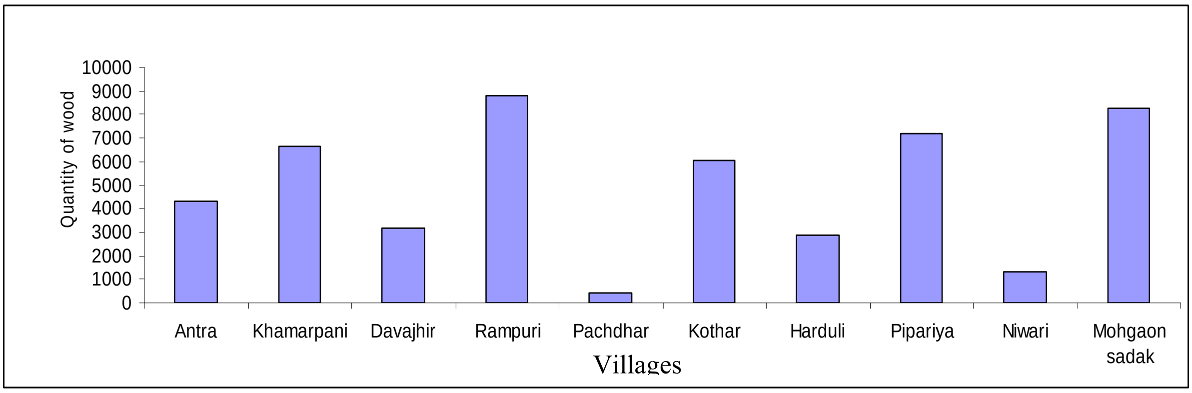


Fig. 4. 9 Quantity of fuel wood in kilograms exploited per day by the villages located in Category III



The quantity of NTFP collected by the sampling villages in different Categories is given in the Table 4.14. Amount of NTFP collected was highest among Category I villages and lowest in Category III villages. In Category I villages, the NTFP collection was highest in Turia and lowest in Pindkapar (Fig. 4.10 & Fig. 4.11). Tewni and Thota Raiyat reported highest and lowest tendu patta collections respectively in Category II villages (Fig. 4.12) but for other NTFPs, Tewni was the lowest and Mohgaon (Yadav) was the highest (Fig. 4.13). Among Category III villages, Khamarpani and Piparia were the highest and lowest NTFP collectors respectively (Fig. 4.14 & Fig. 4.15). The estimated market price of Tendu patta is Rs. 55 per 100 bundles of 50 leaves, Rs. 12 per Kg of Mahua flower, Rs. 20 per Kg of Mahua seeds, Rs. 60 per Kg of Chironji seeds and Rs. 30 per Kg for Awla fruit.

Table 4.14 Details of NTFP collected in 30 villages around Pench Tiger Reserve

Categories	Tandu patta (100 bundles)	Mahua flowers (100Kg)	Mahua seeds (100Kg)	Chironji (100 Kg)	Awla (100Kg)
Category I	872000	762	235	20	5.2
Category II	856000	623	214	36.5	7
Category III	240000	511	118	16.8	12.25

Fig. 4. 10 Quantity of Tendu patta (Value per 100 bundles) exploited per year by the villages located in Category I

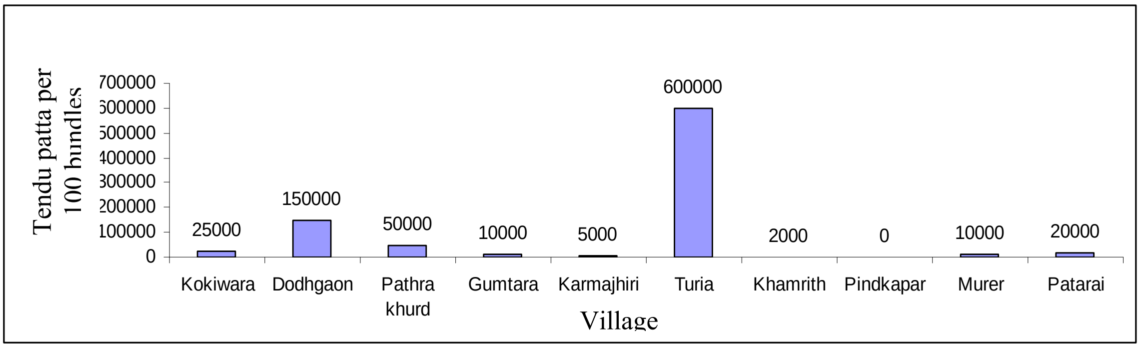


Fig. 4. 11 Quantity of Mahua flowers and seeds, Chironji and Awla (Value per 100 Kg) exploited per year by the villages located in Category I

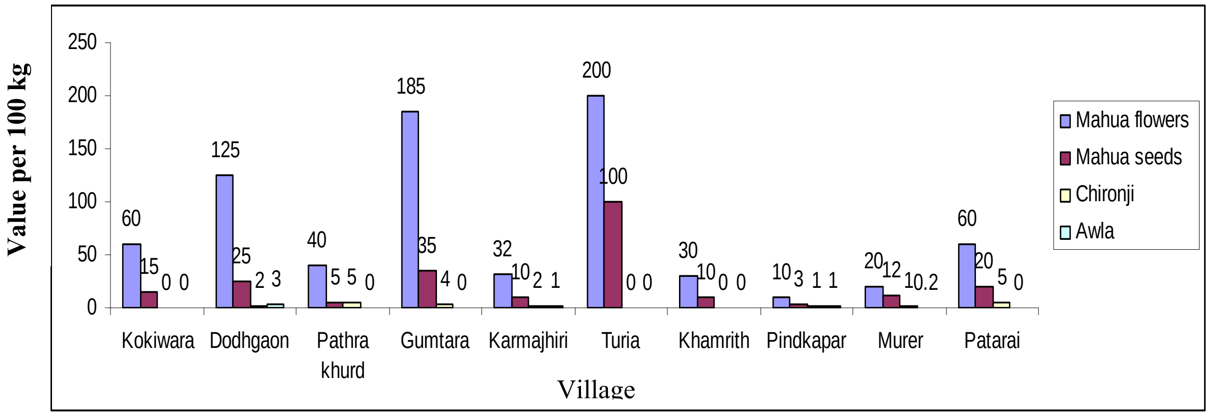


Fig. 4. 12 Quantity of Tendu patta (Value per 100 bundles) exploited per year by the villages located in Category II

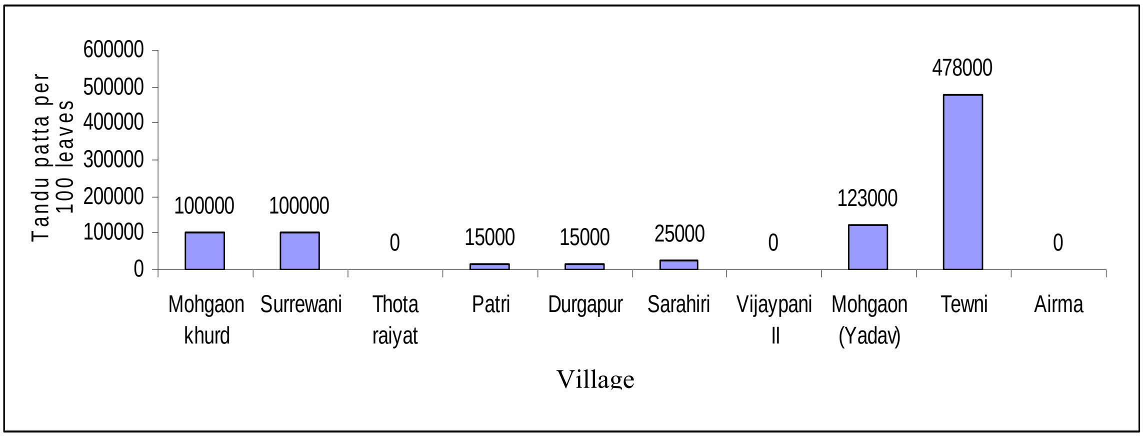


Fig. 4. 13 Quantity of Mahua flowers and seeds, Chironji and Awla (Value per 100 Kg) exploited per year by the villages located in Category II

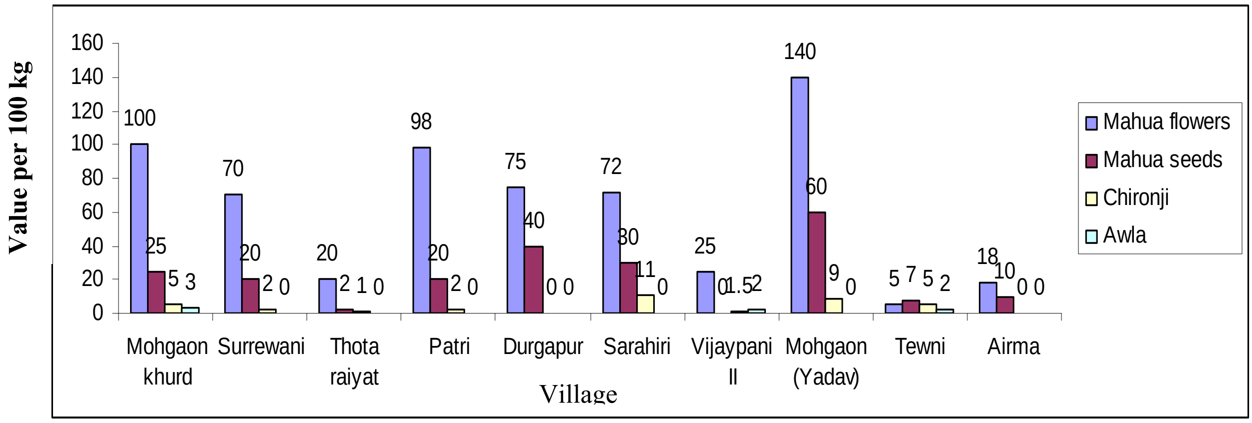


Fig. 4. 14 Quantity of Tendu patta (Value per 100 bundles) exploited per year by the villages located in Category III

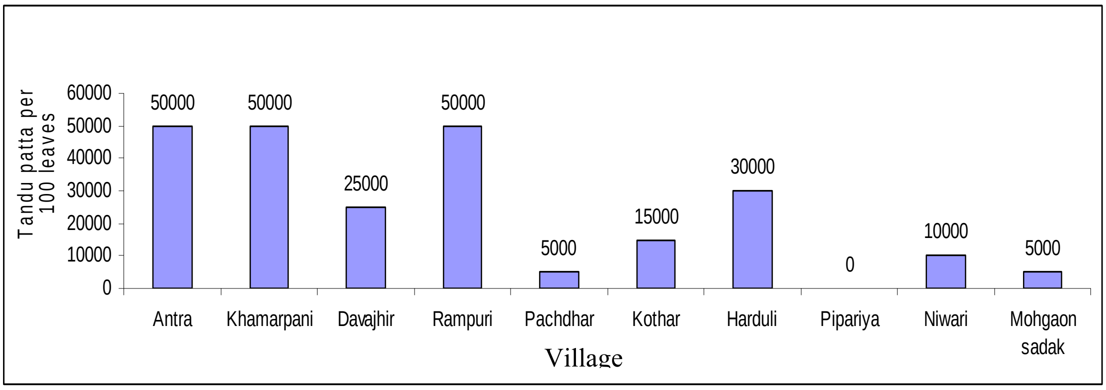
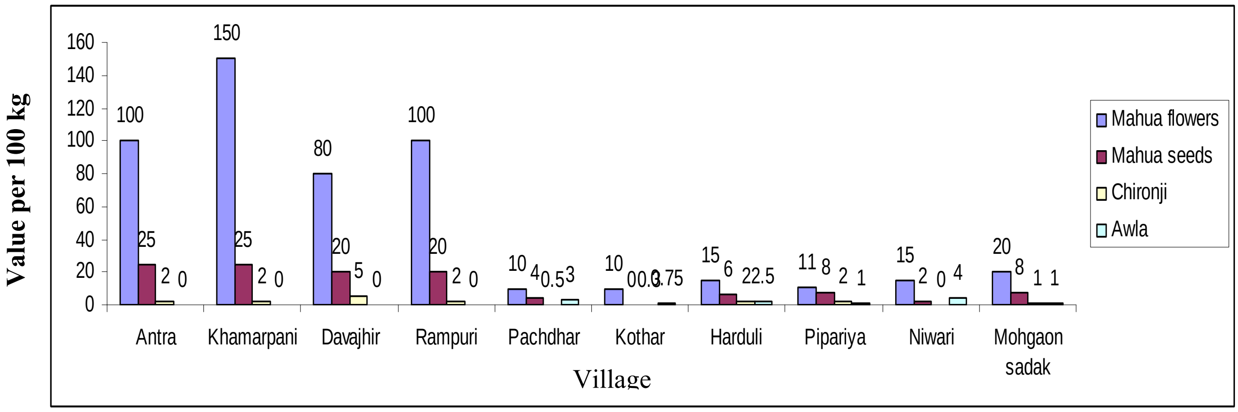


Fig. 4. 15 Quantity of Mahua flowers and seeds, Chironji and Awla (Value per 100 Kg) exploited per year by the villages located in Category III



4.3.2.2 Community or Caste structure:

Irrespective of the sampling effort which was not 100% in all the villages, I managed to get the total caste structure of all the households in the sampled villages in all the Categories of the Tiger Reserve. Villagers mostly belonged to Gond tribe (Scheduled Tribe). The detailed community caste population structure is given in Table 4.15, 4.16 and 4.17 for Category I, II and III respectively.

Table 4.15 Details of community/caste structure in the villages of Category I

Village	ST Population	SC Population	OBC Population	General Population
Kokiwara	160	0	91	0
Dodhgaon	982	69	172	0
Pathra khurd	177	0	0	0
Gumtara	905	166	869	21
Karmajhiri	230	0	0	0
Turia	292	85	1290	33
Khamrith	127	0	0	0
Pindkapar	337	320	572	638
Murer	59	0	0	0
Patarai	633	28	149	13

Table 4.16 Details of community/caste structure in the villages of Category II

Village	ST Population	SC Population	OBC Population	General Population
Mohgaon khurd	142	21	186	0
Surrewani	460	38	74	7
Thota raiyat	32	131	0	0
Patri	815	103	156	9
Durgapur	227	0	2	0
Sarahiri	725	177	104	26
Vijaypani II	422	0	173	0
Mohgaon (Yadav)	584	43	98	0
Tewni	329	0	91	0
Airma	90	69	753	3

Table 4.17 Details of community/caste structure in the villages of Category III

Village	ST Population	SC Population	OBC Population	General Population
Antra	136	31	87	4
Khamarpani	438	140	915	453
Davajhir	283	0	7	0
Rampuri	632	518	598	250
Pachdhar	172	20	346	43
Kothar	83	0	0	0
Harduli	63	52	214	0
Pipariya	799	41	92	0
Niwari	62	46	46	0
Mohgaon sadak	362	23	558	42

4.3.2.3 Land holding and major movable property:

Among Category I villages, maximum numbers of farmers and landless households were found in Gumtara and minimum in Murer (Fig. 4.16). Kokiwara (45.5%) and Patarai (7.6%) villages had the highest and lowest proportion of landless households respectively (Table 4.17). Similarly Patri and Durgapur registered most and least number of both farmers and landless households in Category II. Airma (7.8%) and Mohgaon (Khurd) (38.6%) had the highest and lowest proportions of landless households (Table 4.17). In Category III, Khamarpani and Kothar had the maximum and minimum number of farmers, whereas highest and lowest numbers of landless households were found in Piparia and Antra respectively (Fig. 4.18). Kothar (63.2) and Panchdhar (13.8%) had minimum and maximum proportion of landless families in Category III (Table 4.17).

Fig. 4. 16 Number of farmer and landless families in Category I villages

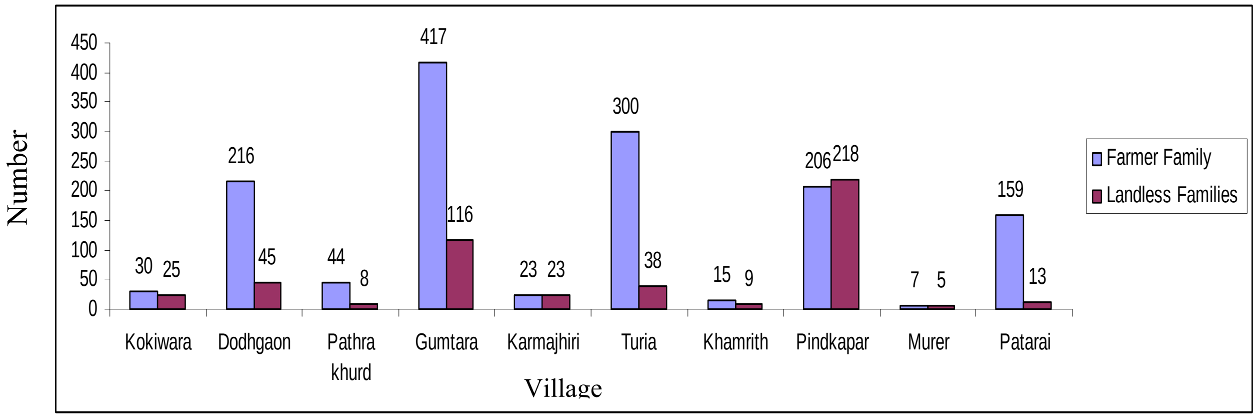


Fig. 4. 17 Number of farmer and landless families in Category II villages

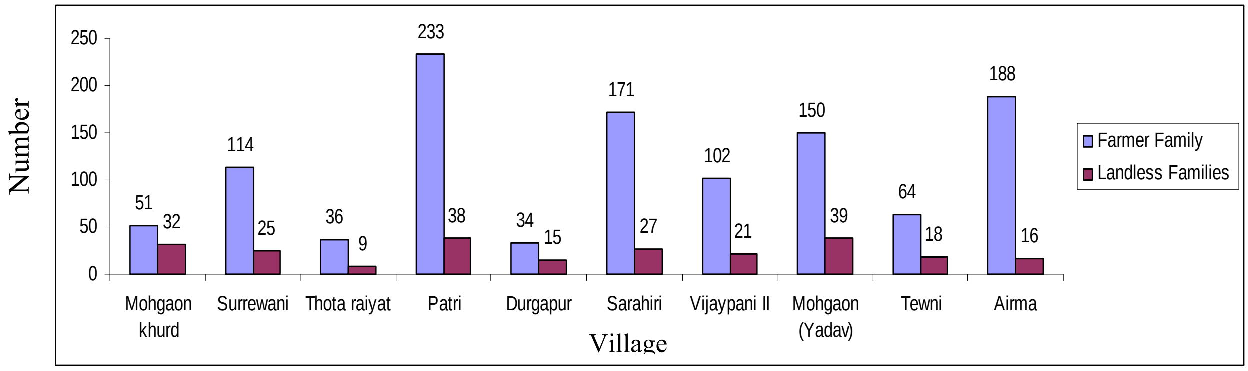


Fig. 4. 18 Number of farmer and landless families in Category III villages

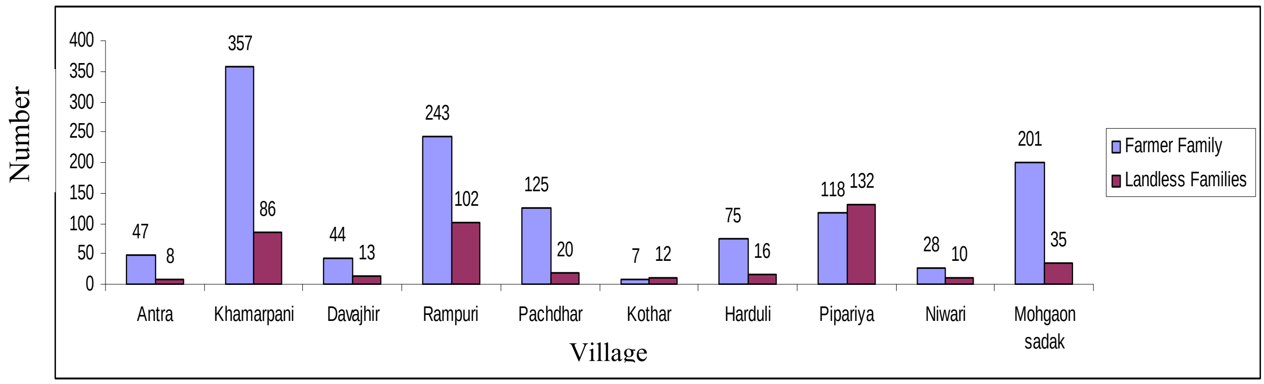


Table 4.18 Proportion of landless families towards total households

Category	Village	Proportion of Landless families to total Households
Category-I	Kokiwara	45.5
	Dodhgaon	17.2
	Pathra khurd	15.4
	Gumtara	21.8
	Karmajhiri	50.0
	Turia	11.2
	Khamrith	37.5
	Pindkapar	51.4
	Murer	41.7
	Patarai	7.6
Category-II	Mohgaon khurd	38.6
	Surrewani	18.0
	Thota raiyat	20.0
	Patri	14.0
	Durgapur	30.6
	Sarahiri	13.6
	Vijaypani II	17.1
	Mohgaon (Yadav)	20.6
	Tewni	22.0
	Airma	7.8
Category-III	Antra	14.5
	Khamarpani	19.4
	Davajhir	22.8
	Rampuri	29.6
	Pachdhar	13.8
	Kothar	63.2
	Harduli	17.6
	Pipariya	52.8
	Niwari	26.3
	Mohgaon sadak	14.8

People here mainly grew paddy, wheat, corn, sugarcane, soyabean, pulses and gram largely for their own consumption. Of the total land holdings of the villages in the Category I, Dudhgaon had the highest agricultural land whereas Karmajhiri registered the least (Fig. 4.19). Among the villages in Category II, Sarahiri and Thota raiyat were the maximum and minimum agricultural land holding villages respectively (Fig. 4.20). Kothar and Mohgaon sadak were the biggest and smallest agricultural land holders among the category III sampling villages (Fig. 4.21).

Fig. 4. 19 Total agricultural land available in Category I villages

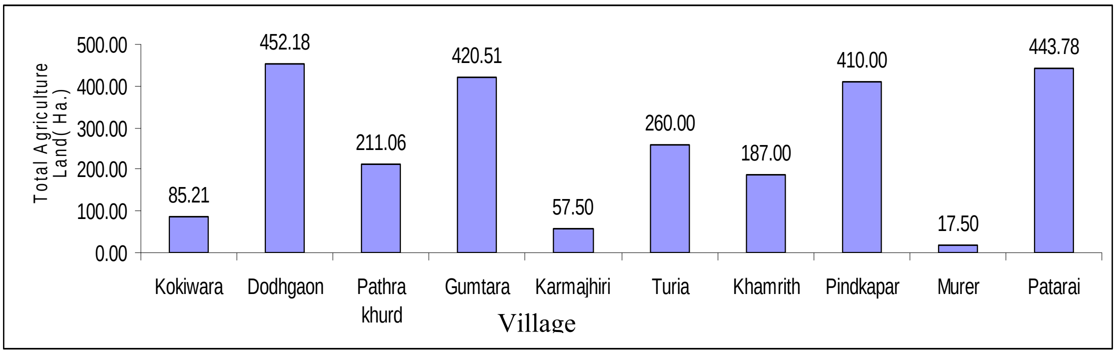


Fig. 4. 20 Amount of agricultural land available in Category II villages

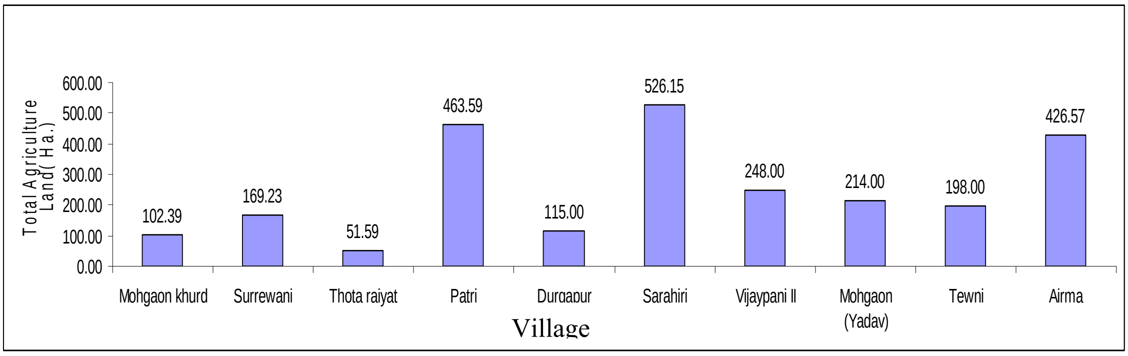
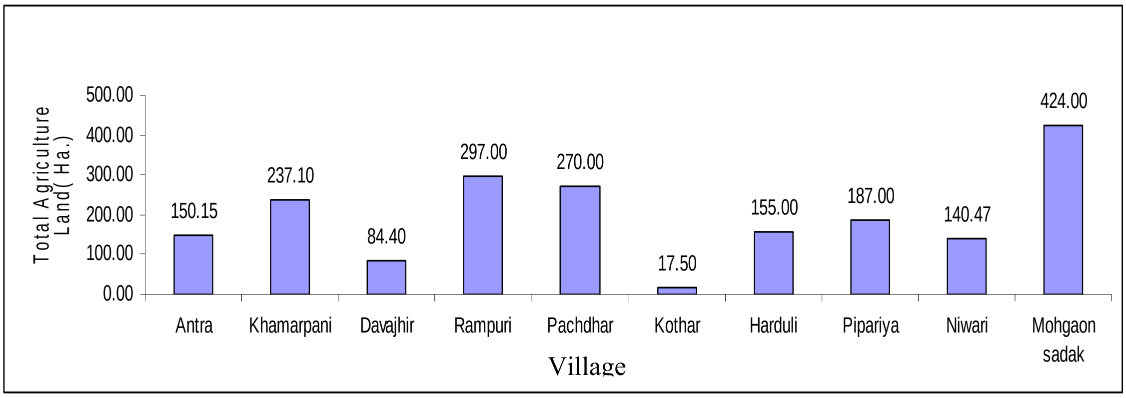


Fig. 4. 21 Total agricultural land available in Category III villages



Pindakar had the maximum number of two wheelers whereas Turia has the maximum number of four-wheelers/tractors among all the 30 villages sampled. Majority of Turia's four wheelers are gypsies which are used as tourist vehicle for park tour. A detailed account of two wheelers and four wheelers are given in Table 4.19.

Table 4.19 Number of Two and Four wheelers present in the villages

Category	Village	Bike	Tractor/ Four wheeler
Category-I	Kokiwara	3	0
	Dodhgaon	10	3
	Pathra khurd	2	1
	Gumtara	68	18
	Karmajhiri	3	1
	Turia	60	49
	Khamrith	3	1
	Pindkapar	100	15
	Murer	0	0
	Patarai	13	0
Category-II	Mohgaon khurd	10	3
	Surrewani	5	2
	Thota raiyat	2	1
	Patri	13	2
	Durgapur	3	0
	Sarahiri	11	1
	Vijaypani II	10	2
	Mohgaon (Yadav)	7	3
	Tewni	5	0
	Airma	10	2
Category-III	Antra	-	2
	Khamarpani	18	2
	Davajhir	3	0
	Rampuri	10	2
	Pachdhar	15	14

Table 4.9 continued

	Village	Bike	Tractor/ Four wheeler
	Kothar	0	0
	Harduli	8	0
	Pipariya	10	0
	Niwari	0	0
	Mohgaon sadak	15	10

4.3.2.4 Income level:

Though agricultural practices, daily wage labour, selling of NTFP, milk and milk product selling and livestock selling contribute to the annual household income in most of the rural households in India, but due to nil response by most of the respondents regarding selling of livestock and milk related products, income pertaining to these could not be estimated during the presnt study in PTR. Most of the respondents did not answer regarding how much agricultural products they have sold in a year and hence the estimated income due to agriculture by local people in this study was the actual market cost of the harvested crops. Among the villages in Category-I, Turia and Khamrith were the highest and lowest respectively in the annual income (Table 4. 19) but the average monthly family income was found highest in Pathra Khurd and lowest in Gumtara (Fig. 4.22). Similarly though Thota raiyat and Sarrahiri had the maximum and minimum gross annual income (Table 4.20), Tewni and Thota raiyat had lowest and highest average monthly family income respectively (Fig. 4.23). In Category III villages, Kothar and Rampuri had lowest and highest annual income (Table 4.21) and Niwari and Khamarpani had maximum and minimum average monthly family income respectively (Fig. 4.24). The annual income in different villages due to agricultural harvest, daily wage labour and by selling NTFPs are given in details in the Tables 4.20, 4.21 and 4.22.

Table 4.20 Reported Annual Income from different sources in different villages surveyed in Category-I

Village	Annual income from different sources (Rs.)			Gross Income
	Agriculture	As Causal Labours	Collection of NTFPs	
Kokiwara	936700	196800	242500	1376000
Dodhgaon	6820800	336300	1047500	8204600
Pathra khurd	1585150	59800	352500	1997450
Gumtara	5117250	86600	363000	5566850
Karmajhiri	613700	171900	103000	888600
Turia	2775400	284000	3800000	6859400
Khamrith	185001	37200	71000	293200
Pindkapar	4376600	1629300	28000	6033900
Murer	186800	37300	116400	340500
Patarai	4737200	97100	252500	5086800

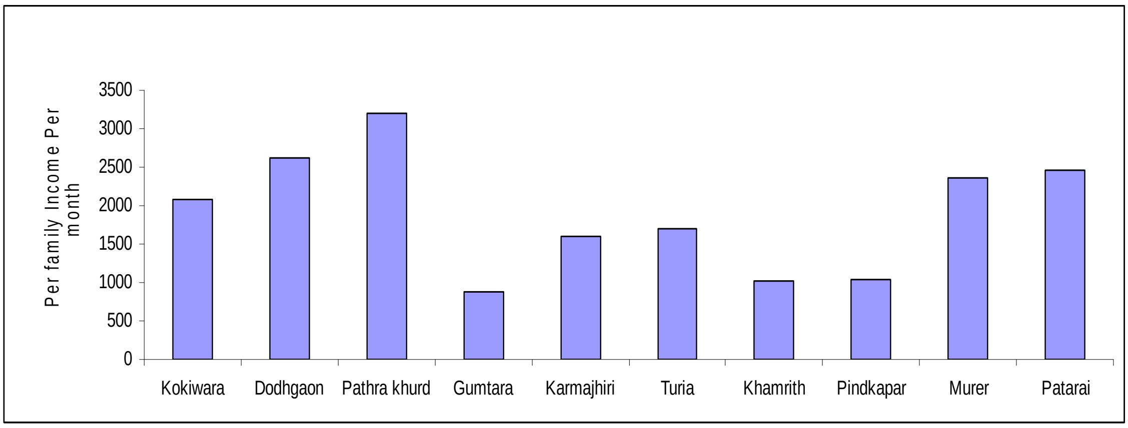
Table 4.21 Reported Annual Income from different sources in different villages surveyed in Category-II

Village	Annual income from different sources (Rs.)			Gross Income
	Agriculture	As Causal Labours	Collection of NTFPs	
Mohgaon khurd	1393000	167000	761000	2321000
Surrewani	2240900	130500	689000	3060400
Thota raiyat	683850	47000	30500	761350
Patri	4329650	198300	249500	4777450
Durgapur	1227600	78300	277500	1583400
Sarahiri	5616500	14900	349000	5980400
Vijaypani II	2647300	109600	40750	2797650
Mohgaon (Yadav)	2284400	203600	1037000	3525000
Tewni	2113600	93900	2686500	4894000
Airma	4553500	83500	48000	4685000

Table 4.22 Reported Annual Income from different sources in different villages surveyed in Category-III

Village	Annual income from different sources (Rs.)			Gross Income
	Agriculture	As Causal Labours	Collection of NTFPs	
Antra	224850	55500	459000	739350
Khamarpani	1922000	597000	509000	3028000
Davajhir	995600	90200	300000	1385800
Rampuri	2832700	708100	444000	3984800
Pachdhar	2882100	138800	65250	3086150
Kothar	186800	83300	97225	367325
Harduli	1654500	111000	218250	1983750
Pipariya	1996100	916300	48500	2960900
Niwari	1499400	69400	94000	1662800
Mohgaon sadak	4526100	242900	80500	4849500

Fig. 4.22 Estimted per family per month income in Category I villages



Village

Fig. 4.23 Estimated per family per month income in Category II villages

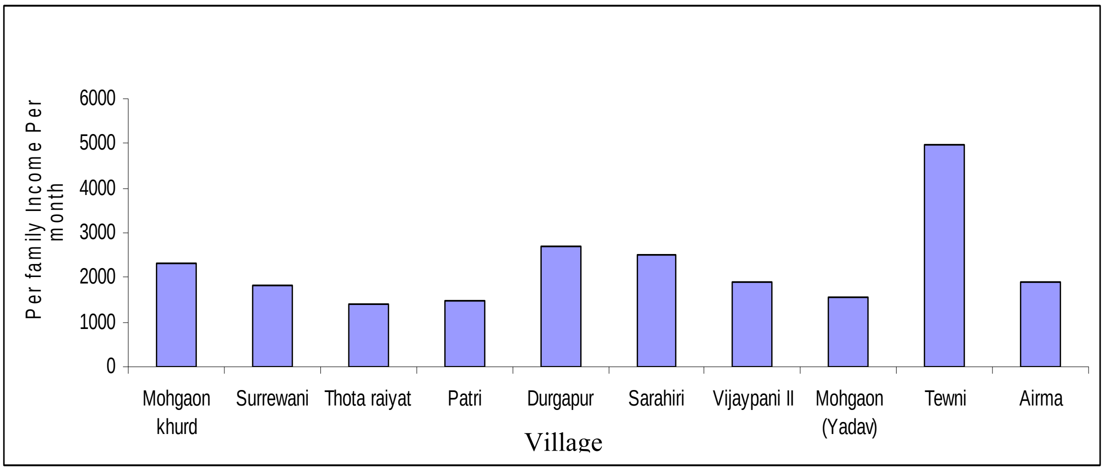
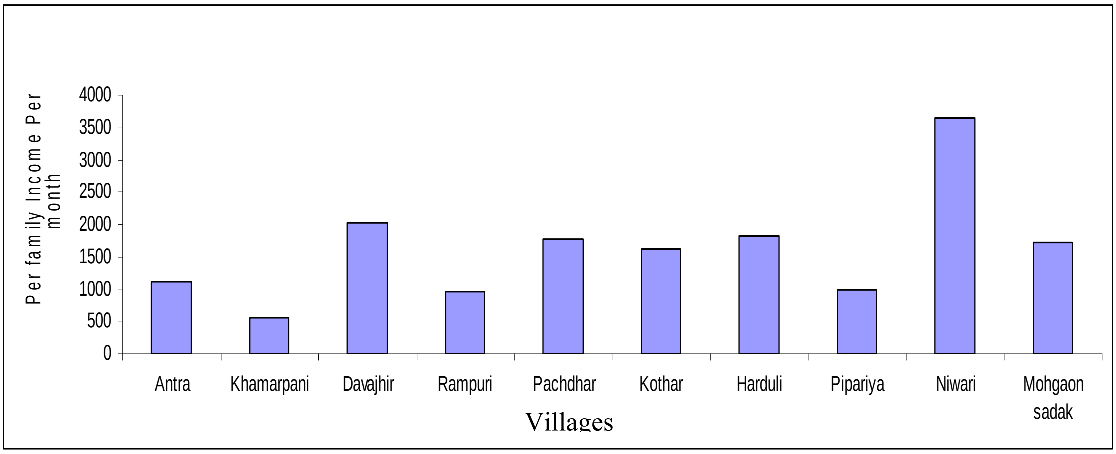


Fig. 4.24 Per family per month income in Category III villages



On the basis of income, land holdings, livestock holdings, possession of two and four-wheelers, households in the sampled villages are classified into three economic classes (Fig. 4.25, 4.26 and 4.27).

Fig. 4.25 Number of people in different levels of economic status in Category I villages

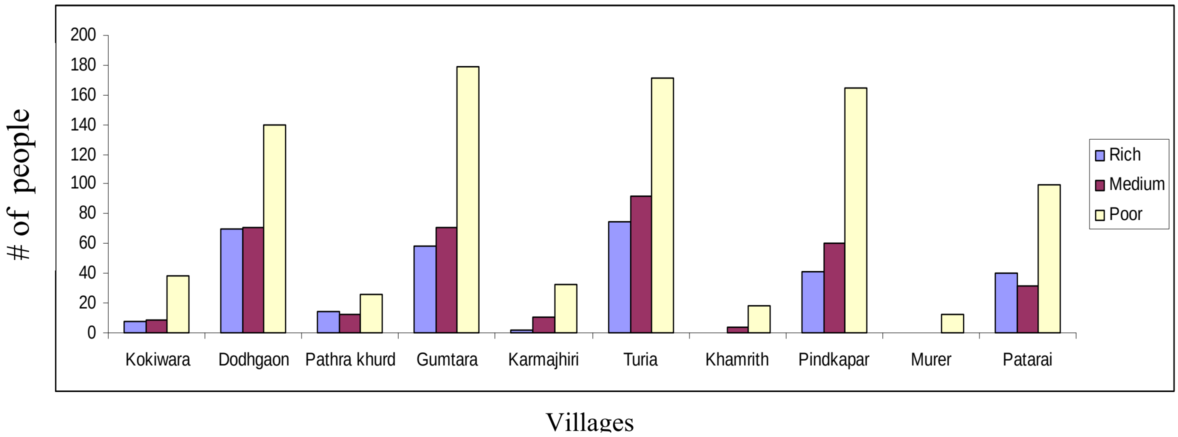


Fig. 4.26 Number of people in different levels of Economic status in Category II villages

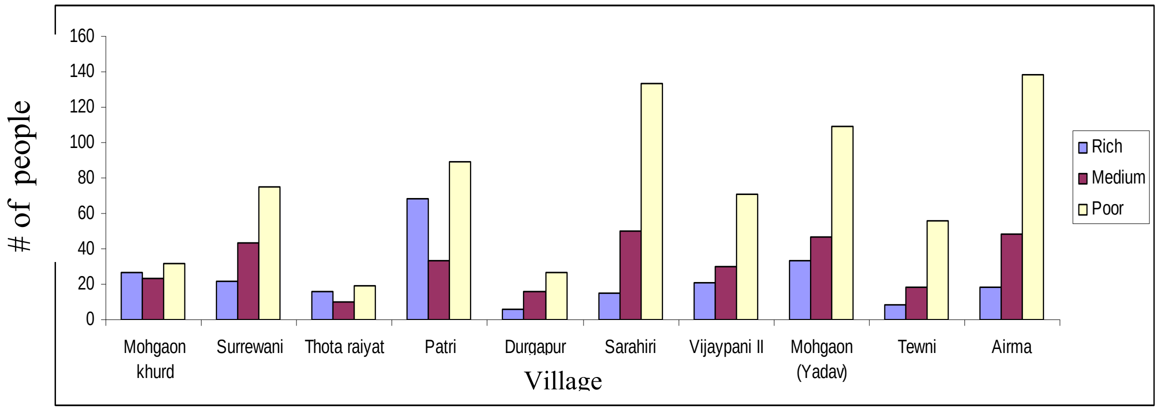
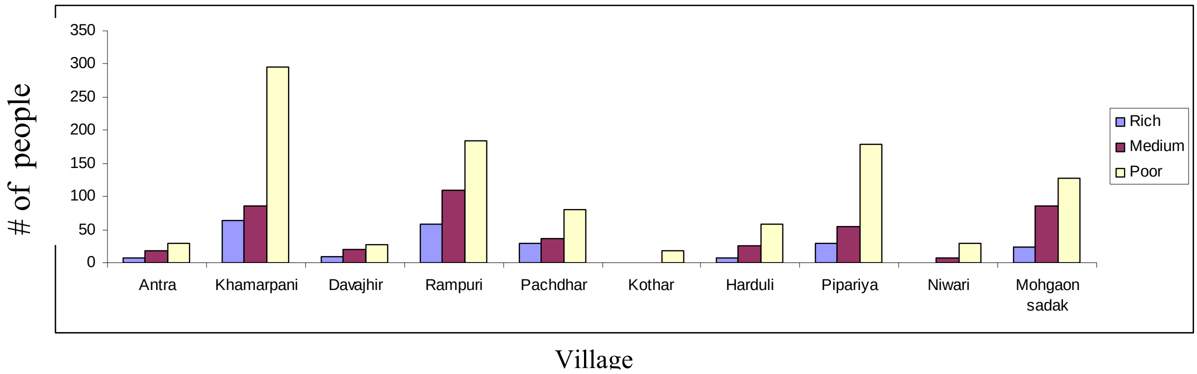


Fig. 4. 27 Number of people in different levels of Economic status in Category III villages



4.4 DISCUSSION

As is clearly evident from the study conducted that a large human population, residing around the Pench Tiger Reserve, is almost entirely dependent on the forest resources of the Reserve for the sustenance of its livelihood which has also been reported by David (2001). Consequently, there appears an immediate need to look into the entire scenario as early as possible though different approaches like LPG and biogas units as a substitute of fuel wood and alternative liveliwood measures. In recent years, the Governments of India and various state governmental and non-governmental bodies are making efforts to identify and address conservation and local community needs in a more integrated manner. The key to successful conservation in a human dominated landscape lies in communities' access to a wider menu of development options in addition to sharing any benefits of biodiversity conservation while not carrying a disproportionate share of the costs. All over the world, economic benefit-sharing with local people, sustainable use options for forest rsources, community-based protection and democratic co-management taking communities as equal partner are being experimented to improve the effectiveness of wildlife conservation. Such a shift has become imperative in the face of increasing evidence that the "fences-and-fines" approach is failing miserably in most Indian Tiger Reserves (MoEF 2005).

4.4.1 General patterns

My study showed that human pressure on the forest and requirements of forest biomass are widespread and intensive in PTR. The observed sex ratio and child to female ratio revealed that the tribes in this landscape do not have any demographic threat in recent future. Stability within the community with respect to population structure is important for conservation planning needs. The observed literacy rate was more or less similar in all the villages around PTR but the best result that came up with the study was the ratio of child to adult literates i.e. 158 child literate pre 100 adult literate in average. If efforts are increased to involve children into more conservation oriented training, it will definitely lead to better awareness regarding less dependency on forest resources and also conserving endangered species and forests. As people are largely agriculturalists in this landscape, in all the three village categories oxen contributed the most among livestock. Cows were generally kept for breeding and selling of the young calves. Milk production and selling was not a major source of income in this landscape and milk was largely used for domestic purpose. Buffaloes were kept by people for milk production but the amount of milk was varied a lot even in this small landscape. Goats were kept as a substitute for cash. Goats contributed as the second largest livestock category and their browsing in the forest area may deplete the available browse cover for wild ungulates.

4.4.2 Local community dependence on forests

Pressure on forests from forest dwelling communities can be classified into two broad categories: rural needs for (i) energy and (ii) income generation. Fuel–wood is a major source of energy for rural households in India and other developing countries (Cecelski et al. 1979, Heltbert et al. 2000). Wood harvesting is widespread because wood is abundant, inexpensive and easily available in forests. The villagers living around the Pench Tiger Reserve (PTR) largely dependent on fuel wood collected from the forest for cooking. The extensively large amount of fuel wood being extracted from the landscape seemed to result in the quick depletion and degradation of the forest resources in the near future. Long-term use of the forests for grazing and firewood removal by local residents had been reported as the primary cause for degradation and biodiversity loss (Kumar and Shahabuddin 2005). A World Bank report has estimated that about 247 million rural people in India depend on forests for part of their subsistence or cash livelihoods, and two thirds use fuel–wood as an energy source (World Bank 2006). The report also stated that about 41% of Indian forests had been degraded over the past several decades which had reduced forest productivity to about one-third of its potential (World Bank 2006). Therefore intensive harvesting of biomass was leading towards forest degradation. The number of head loads of fuel–wood extracted from forest had a decreasing trend from villages in Category I to category III which could be interpreted as closer the villages from forest more the extraction of fuel wood. Apart from fuel–wood harvest, intensive livestock grazing and removal of biomass in the form of NTFP from forests had negative impacts on vegetation and soils (Ganesan 1993, Garrigues 1999, Silori and Mishra 2001). Extensive forest degradation in certain regions suggested that the intensive use of forests for sustenance and consumption was no longer viable (Davidar et al. 2007).

The fuel wood exploited, when estimated for their commercial values possessed extremely high economic value in the market at local as well as national level. Collection for subsistence livelihoods could be a major driver of deforestation although the relationship between deforestation and wealth was not straightforward (Angelsen and Kaimowitz 1999 and Cropper and Griffiths 1994). Deforestation had multiple scalable causes that differ geographically (Godoy et al. 1997, Giest and Lambin 2002), suggesting that policy might have to be site and case-centric to be effective.

Alternatives to fuel–wood were difficult to put into practice. Complicated renewable energy devices were not easily accepted in the rural areas (Arjunan et al. 2006). The reasons for the relative failure of acceptance were multiple and include economic, social, practical considerations among others. Energy plantations were one possible solution to the chronic energy needs of rural populations.

Non-Timber Forest Product extraction contributed significantly to local household income in tropical regions and had been viewed as preferable to conversion to other land uses when it was sustainable. NTFP collection also followed similar trend as fuel wood extraction i.e. closer the village more the collection was. However, non-sustainable resource extraction could have deleterious consequences for biodiversity and might affect the livelihoods of the users (Davidar et al. 2007).

4.4.3. Community and catse:

Caste, gender and community played a dominant role in the socio-economics of rural households; dominant communities often excluded marginalized sections of society from access to forest resources (Cecelski et al. 1979, Arjuman et al. 2005). Dominated by Gond tribes, it would be nice to discuss whether community or caste structure really played a role in the degradation of forest quality and was addressed in the next chapter.

4.4.4. Economic status:

The local residents mainly depended on the agricultural harvest, daily wage labour and sell of NTFP to earn their livelihoods. The local people, apart from a smaller percentage generally did not prefer to work outside. The fact could firstly be attributed to the illiteracy prevailing among them due to which they did not get work outside other than as daily wage labourers for which they were paid Rs. 2500 to 3000 per month and also they reported to have nobody to look after their family in their absence, most of them having young children, land and cattle. This fact resulted into more number of poor families in category I villages which are closer to forest but far from the communication networks. Category I villages like Gumtara and Pindapar harboured a major population of landless people as they were major market place and very well connected to the district head quarters. People from other area had migrated temporarily or permanently in search of new opportunities to these villages. Some of the small villages like Kokiwara, Karmajhiri and Kothar had an alarming amount of landless families i.e. more than 50%. Because of small size and very little available land (Karmajhiri and Kokiwara are forest villages), land distribution to increasing population was not possible, resulting a huge population only depending on daily wage labour and NTFP collection which was very much fluctuating in different years. Due to the ban in selling tribal lands close to PTR, Category I villages still hold a good amount of agricultural land. Just to give an example Turia which is the main entry point for the park tour and hub for the entire tourist resorts, an acre of land costs Rs. 30,00,000. Turia had the most number of four wheelers specially four wheel drive vehicles, as these were the only vehiches which were allowed to take tourists inside park.

The local residents mainly depended on the sale of agricultural harvest; daily wage labour and sell of NTFPs. NTFPs were collected during the months of April, May and June during summer. Most of the daily wage works were like road construction, fire line burning etc., also coincides with winter and pre-summer season. People start working in their agricultural lands just prior to monsoon. So, except a few big agriculturists most of the farmers also work as daily wage labour and collect NTFP to increase their family income. Landless people suffer most as in one hand they could not take benefit from agriculture on the other hand their daily wage labour was also not secured.

Category II villages had the highest average monthly family income Rs. 2259 as being at middle of the domain, they harbors benefits from the forest as well as from outside market. Because of the same reason least number of poor families were found in Category II sampled villages.

The presence of alternative livelihoods not only influenced people's acceptance of the Protected Area, which is crucial to ensure the future viability of the Protected Area, but also reduced the dependence of people on the Protected Area.

Therefore, provisions of alternative sources of employment are necessary for the long-term survival of the Park. Proper medical facilities should be made available to the local communities as they are going through miserable situations due to unavailability of proper road network at most of the places. It was reported that the villagers have to walk down for more than 8 to 10 Km to visit a doctor. Extreme caution should me maintained doing programmes related to sustainable harvesting of forest and forest products as most of these activities failed due to constant population growth and penetration of market forces. Under these conditions, promoting sustainable livelihoods based on harvesting forest products is not a viable conservation strategy.

Chapter-5. Landscape change and anthropogenic attributes

5.1 Introduction

In recent years, a critical approach to environmental sustainability has resulted in greater importance being given to scientific research into the causes and effects of land use and land cover changes. Some of this work has been supported by the Land-Use and Land Cover Change (LULCC) project of the International Geosphere–Biosphere Programme (IGBP) and International Human Dimensions Programme (IHDP) on Global Environmental Change, which for more than a decade has made significant contributions to an analysis of the changes occurring in the territory (Lambin and Geist 2006).

Although the causes behind these changes are diverse, above all in the case of forest cover, they can nevertheless be organized into two large groups: a) proximate causes and b) underlying causes (Lambin 1997). The former constitute activities and actions which directly affect land use, such as wood extraction or road construction, whilst the latter comprise the root causes of these, such as demographic, economic, technological, institutional and cultural factors (Geist and Lambin 2001, Verburg et al. 2004).

In most of the forested landscape of Southern Asia, identifying key drivers of forest change becomes even more difficult due to the long history of human occupation and use of these forests. In the recent past, a number of studies in India have focused on the impacts of human settlements on protected areas (PAs). These studies fall into two categories, those based primarily on ground measurements of vegetation across a human-use gradient (Barve et al. 2005, Kumar and Shahabuddin 2005, Karanth et al. 2006, Shahabuddin and Kumar 2006, 2007) and others that rely on some remotely sensed data from one, two or three date satellite data to assess changes over space and/or time (Barve et al. 2005, Nagendra et al. 2006, Ostrom and Nagendra 2006, Robbins et al. 2007).

According to Angelsen and Kaimozwitz (1999), the first step when analyzing the causes is to identify the agents involved in the processes of change, that is to say, the sources of deforestation. Among the primary sources identified are colonization programs, the spread of agricultural and cattle rearing activities, excessive commercial wood extraction and illegal logging (Morán and Galleti 2002). In recent years, various empirical studies have been carried out in order to identify those factors most frequently related to the loss of forest cover (Angelsen and Kaimozwitz 1999, Nelson et al. 2001). In practice, many of these factors interact, leading to a complex web of relationships between the causal factors of change and their processes, as well as human behavior and organization (Verburg et al., 2004).

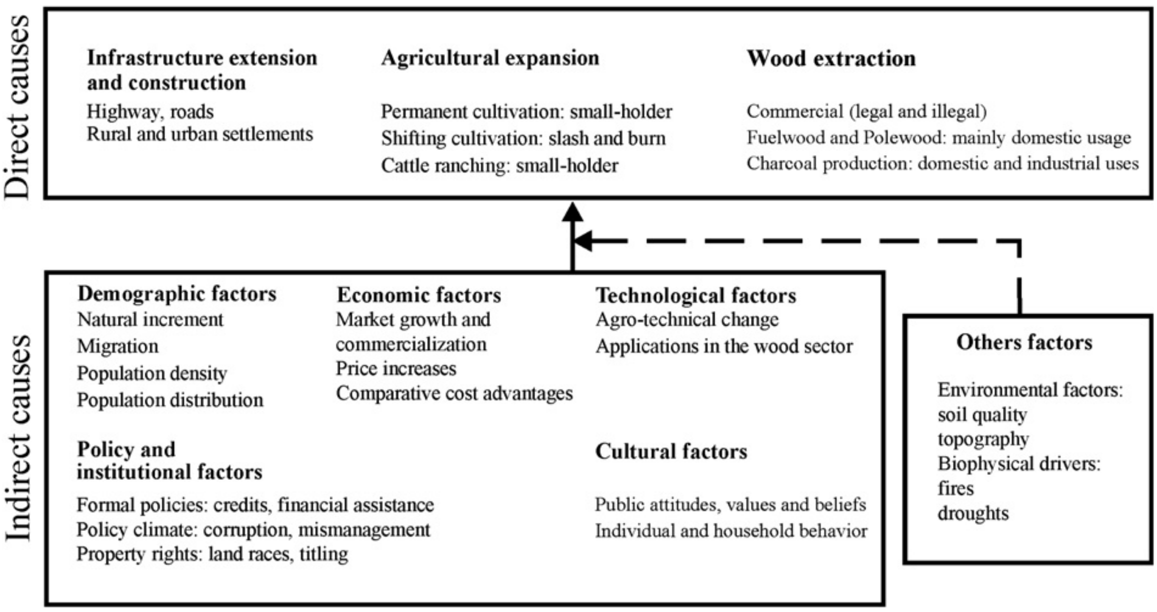
Direct causes can be divided into three main groups: a) infrastructure extension, b) agricultural expansion and c) wood extraction (Fig. 5.1). The first group comprises infrastructures such as roads, tracks, human settlements and hydroelectric dams which are responsible for the flooding of large extensions of forest. In the second group, a shift in land use towards agricultural and cattle rearing activities is the most frequent cause. Fire is another factor with a close connection with forest cover changes in India specially in the North-Eastern region are converted to other uses through slash-and-burn techniques. The third group also plays an important role in the loss of forest cover, and depends to a large extent on local and national regulations, on government vigilance and the flow of capital.

Indirect causes comprise the factors which lead to or underlie direct causes, and can be divided into five large groups: a) demographic factors, b) economic factors, c) technological factors, d) policy and institutional factors and e) cultural factors (Fig. 5.1). In terms of scale, indirect causes may function directly at a local level and indirectly at national or even global level (Geist and Lambin 2001), although some authors have indicated that establishing a clear correlation between forest cover loss and indirect causes is more difficult than establishing the same for direct causes (Kaimowitz and Angelsen 1998).

The demographic factors influencing loss of forest cover are basically those related to population growth, density and spatial distribution, in addition to certain migratory processes. Meanwhile, the principle economic factors are commercialization and market growth, accessibility of regional and national markets, and the rising price of wood and certain agricultural products, with the latter leading to deforestation in order to cultivate the product. Indices related to poverty and marginalization, low standards of living and unemployment also have a significant influence in some regions.

There are two opposing sides to policy and institutional factors. On the one hand, there are official policies such as subsidies, credit and insurance for agro-forestry production, legislation concerning forestry and environmental issues, and other, more influential, policies such as the colonization and development programs officially promoted by government (Fig. 5.1) departments. On the other hand, tacit policies, such as corruption and even the particular interests of political parties also contribute to the process of deforestation. As for cultural factors, some of these are related to marginalized groups which, in the case of India, usually mean indigenous tribal people. Lastly, there is another group of factors associated with forest cover loss processes which are located somewhere between direct and indirect causes. The most common of these factors are those related to the characteristics of the land itself, such as its quality and suitability for agricultural production of some kind, or its topography and altitude; but they can also be associated with natural hazards such as drought, flooding, naturally-occurring forest fires and plagues, or social hazards such as infiltration or terrorist activities, the displacement of refugees and economic crises, among others.

Fig. 5.1 Causes of deforestation (Source: Geist and Lambin 2001)



In recent years, a large body of researchers had analysed and modeled the changes of occupation and land use using quantitative methods. It has been demonstrated, for example, that agent-based models (ABM) are a useful tool for studying the environment (Bousquet and Le Page 2004, Hare and Deadman 2004).

ABM have been applied to simulate the impact of human decisions on land use and land cover change (Brown et al. 2004, Evans et al. 2001, Hoffman et al. 2002, Ligtenberg et al. 2001, Loibl and Toetzer 2003, Parker et al. 2003), and the deforestation of tropical forests (Huigen 2002, Lim et al. 2002, Manson 2002, Manson and Evans 2007). Also multilevel models working on different temporal and spatial scales have been developed (Pan and Bilsborrow 2005, Overmars and Verburg 2006, Walsh et al. 2001).

Deininger and Minten (1996) have shown how factors such as bank loans, the price of timber and poverty rates are closely and positively related to deforestation processes nationally, whereas technical assistance, protected natural areas and the indigenous population are negatively related. For their part, Blackman et al. (2008) have investigated the factors which lead to deforestation in the woodland of the southern sierra in Oaxaca, Mexico. According to their results, proximity and some variables related to land tenancy best account for deforestation patterns in the area. Alix-García (2007) has studied how cooperation from communities and the way communities organize common property, affect deforestation. According to his results, the price of timber and the quantity of common land are strongly and positively related to deforestation, the opposite being true for the variables of cooperation and gradient. Although the use of geographically weighted regression (GWR) is common in studies of occupational change and land use, where it is used in order to explore and describe spatial data, primarily when spatial non-stationary relationships prevail (Brunsdon et al. 1998).

One of the few studies to have used GWR when investigating deforestation is that of Witmer (2005), who examined the correlation between population density and global deforestation. His results suggest that in the coming decades, deforestation will be more intense in tropical Africa than in the Amazon. In order to model and understand the reasons and driving forces behind the loss of forest cover in and around Pench Tiger Reserve (PTR), a method of quantitative analysis was applied which facilitated global and local understanding of the processes leading to this loss in four different areas of forest cover between the years 1999 and 2009, and which took account of the complex interaction of biophysical, socioeconomic, cultural and political factors.

This study highlighted some key impact of landscape change due to different anthropogenic activities like dam construction, cattle grazing, wood extraction and by different demographic, economic and policy attributes. Lack of long-term historical data in all the aspects mentioned above had limited this study scale both temporally and spatially. For this study GWR was used because unlike the “classic” methods it considers the location of the phenomenon studied. It is important to highlight that this study does not seek any causal depth in its models, but is rather concerned to provide an approach to and a description of relationships that occur spatially. It is therefore necessary to recognize that this technique has its shortcomings, especially those related to the significant levels of local coefficients, multi-collinearity and spatial autocorrelation (Griffith 2008, Wheeler and Tiefelsdorf 2005).

5.2 METHODOLOGY

5.2.1 Satellite Imagery and GIS

A multi-temporal and multi-spectral dataset were used for this study (Table 5.1). While the sensors offer different spatial and spectral resolutions, such multi-spectral datasets are often unavoidable in studies spanning over several decades and have been successfully applied in other regions (Zoran and Anderson 2006, Ahmed et al. 2009). The images used for this study are from the post-monsoon season (October to January) to minimize the cloud cover and phenological variations. The park boundary along with a 5 km buffer was used for this study. Multiple zones were then created starting from the park boundary as per the Category I, II & III mentioned in the earlier chapter up to the required buffer limit of 5 Km. I used this buffer-zone approach to understand the role of distance from the park boundary in the land cover changes. This study involves comparisons of land cover changes of a park and its surrounding matrix.

Table 5.1 Details of satellite imagery used in the study

Satellite	Sensor	Year of accusation	Resolution	Data source
Landsat	MSS	1977	60 m	http://earthexplorer.usgs.gov
Landsat	TM	1989	30 m	http://earthexplorer.usgs.gov
Landsat	ETM+	1999	30 m	http://earthexplorer.usgs.gov
Landsat	TM	2009	30 m	http://earthexplorer.usgs.gov

5.2.2. Image pre-processing

Image pre-processing was carried out in ERDAS Imagine 9.0 software package. Geometric rectification was carried out on all the Landsat images using the 1:50000 Survey of India (SOI) toposheets and nearest neighbor resampling algorithm, with root mean square (RMS) error of less than 0.5 pixels (<15 m) via image-to-image registration. Radiometric calibration and atmospheric correction were carried out to correct for sensor drift, differences due to variations in the solar angle and atmospheric effects (Green et al. 2005).

5.2.3 Image classification

A hybrid approach was used to classify the images. First, an unsupervised classification method with ISODATA clustering was used to generate preliminary classes. Then similar classes were merged based on spectral signatures and training samples collected during May 2007 to June 2008. Finally, I defined five land cover classes – Teak associated forest, Miscellaneous forest, Open forest, Non-forest (agri-habitation and cleared forest) and water (reservoir, small ponds, and rivers) based on distinct spectral signatures and used those signatures for supervised classification with the minimum distance to means classification algorithm. Accuracy testing was performed using 460 training samples. Previous compartment history data was used as a historical record on land use/cover along with the training samples. The overall classification accuracy was over 91% with a kappa value of 0.87. Each image was classified following the same method, rather than applying signatures from one date back in time.

5.2.4 Change detection

For this analysis Idrisi Andes (© Clark Labs) was used. Regression analysis was done on every set of NDVIs to estimate the time frame when maximum change in green leaf biomass occurred in the study area. Post-classificatiion change detection is a widely used pixel based change detection method (Jensen et al. 1995), where two (or more) classified images are compared using a change detection matrix. For this study, two date image trajectory images (1977-1989, 1989-1999, 1999-2009) were generated for PTR and three buffer categories from PTR. In order to maintain the spatial compatibility, the classified MSS image was artificially down-scaled to 30 m before performing the change trajectory analysis. The trajectory images from the four dates with five land cover classes for each date resulted many possible change trajectories. Since interpretation of these trajectories may be confusing, I further collapsed these trajectories into eleven categories namely 1) Stable miscellaneous forest, 2) Stable teak-associated forest, 3) Stable open forest, 4) Stable water, 5) Stable Non-forest, 6) Teak to Miscellaneous, 7) Deforestation, 8) Reforestation, 9) Degradation and 11) Up-gradation. The category “Deforestation”in this study means any of the three vegetative cover classes when converted to “Non-forest”. “Reforestation” was exactly opposite condition of that. “Degradation” means when

"Miscellaneous" or "Teak-associated forest" were converted into "Open forest" and similarly "Upgradation" was reverse of that.

5.2.5 Calculation of landscape metrics

A series of non-redundant landscape metrics was applied to the present and historical classified land use/cover maps. Landscape metrics have long been used in similar studies and they allow the objective description of the temporal patterns of landscape change (Turner et al. 2001). Forest landscape composition was quantified by means of the area covered by each class (CA, Class Area). Landscape structure was assessed by means of patch-based metrics such as the total and per class number of patches, shape-based metrics, size-based metrics and edge-based metrics (Haines-Young and Chopping 1996). The number of patches (NumP) is a useful measure to evaluate the weight of landscape configuration in large ecological processes (McGarigal and Marks 1995). In order to analyse patch shape we used the area weighted mean shape index (AWMSI) that measures the average patch shape, weighted on patch shape size. Specifically, larger patches are weighted more heavily than smaller patches in calculating the average patch shape for the considered class or landscape (McGarigal and Marks 1995). Area weighted mean patch size and patch size standard deviation (PSSD) were used as size-based metrics (McGarigal and Marks 1995). Edge metrics were used in order to analyse habitat loss and forest fragmentation (Bender et al. 1998). Statistics representing the amount of edge or degree of edge effect, like total edge (TE) was estimated.

5.2.6 Anthropogenic driving forces of landscape change

Direct and indirect causes comprise the factors which lead to or underline direct causes, and can be divided into four large groups: a) demographic factors, b) economic factors, c) technological factors and d) policy and institutional factors

Some of the direct and indirect causes had been measured for this study. In the year of 1987 a hydroelectric dam was constructed in PTR, as a result a large forest land was lost under water. The loss was a direct cause of infrastructural development which was estimated.

During the structured questionnaire survey which was discussed in detail in the previous chapter, respondents were also asked about the distance moved for collecting fuel wood and NTFPs and livestock grazing from each village. Though historical data on these were lacking; as people traditionally maintain a path or course while going to collect fuel wood, NTFPs or livestock grazing, this study tried to look into whether there were any notable detrimental impact like deforestation and forest degradation within the buffered distances (average distances gathered from questionnaire survey for fuel wood and NTFP collection and livestock grazing) around those villages. After buffering, area was merged with the PTR boundary which resulted into three zones 1) Core zone (Only inside PTR), 2) Middle area (Inside both PTR and extraction distance buffer) and 3) Outside area (Only in extraction distance buffer). This process was carried out for fuel wood and NTFP collection. After 2001, Forest department had raised Cattle Proof Walls (CPW) in certain places where there was a possibility of village livestock going inside PTR for grazing. So at the present scenario there is no livestock grazing inside PTR. There might be some old routes or areas which were affected by grazing but due to lack of historical data, analysis was done only in the areas outside PTR.

In the year 1977 Pench got a Wildlife Sanctuary status and then 1983 it became National Park. It became 19th Tiger Reserve of India in 1992. These changed protection and conservation policies in PTR in terms of new legislations, more man power to look after and obviously more funds to keep the pace. To gather information on changes in the landscape due to changes in the policies on preservation and conservation under the Wildlife Protection Act 1972, reforestation, upgradation, deforestation and degradation of forest were estimated among landscapes inside and outside PTR. Different Categories namely i) Core (PTR), ii) Category I (within 1 Km of PTR), iii) Category II (1 Km to 2 Km from PTR) and Category III (2 Km to 5 Km from PTR) were used to evaluate the status of land use/cover type with the help of landscape metrics which gave in depth critics on landscape health over the years.

To access the impact of increase in price of land and importance of area, five villages Turia, Awarghani, Teliya, Kohka and Kuppitola where all the tourist resorts are situated; were selected. Deforestation and degradation were estimated in this region for the study period.

In GWR 1:50,000 scale digital maps produced by the SOI were used for the purposes of reference. To find the possible factors that were related to loss of forest cover, an exhaustive search was made of geographic and statistical information including data of 2001 Population census which had demographic and economic factors for all the 99 villages of Seoni and Chhindwara Districts around PTR. Using these variables, an analysis using Pearson's correlation coefficient was carried out in order to measure the extent of association between explanatory variables. As a result, thirteen uncorrelated independent variables with highest explanatory power were finally selected (Table 5.2). In accordance with the classification proposed by Geist et al. (2006) and previous studies on the subject, the variables were organized into three large groups: a) socioeconomics, b) biophysical and c) proximity.

After an exploratory analysis, overall deforestation and degradation were selected as dependent variables. These dependent variables were then transformed into percentage values reflecting the proportion of forest cover in 1999. Losses of less than 1 ha were considered irrelevant to this study as it was the minimum detectable unit.

To calibrate the models, Spatial Analysis in Macroecology 4.0 (SAM 4.0) software (Rangel et al. 2010) was used. Two models were calibrated individually, and were taken as the dependent variables. In addition, this software offers results in parameters such as coefficient of determination, AICc and the adjusted R^2 from both the "global regression" using the classic Ordinary Least Squares (OLS) method as well as the local regression (GWR) method. Moreover, it was decided to compare the adjusted R^2 of both methods as ways of selecting the models which best explain variance in the data. As a methodological option, the proposal was to apply GWR in this study, which would offer an estimate for each parameter in each village.

Table 5.2 List of independent variables used in the model

Variables	Description
Socioeconomic	
VAR_NO_HH	Variation in number of household (2001-2009)
VAR_TOT_P	Variation in total population (2001-2009)
VAR_P_SC	Variation in total Scheduled cast population (2001-2009)
VAR_P_ST	Variation in total Scheduled tribe population (2001-2009)
VAR_P_LIT	Variation in number of Literate (2001-2009)
VAR_FRM_HH	Variation in number of farmer household (2001-2009)
VAR_WRK_HH	Variation in number of worker household (2001-2009)
VAR_TOT_IR	Variation in total Irrigated land (2001-2009)
Biophysical	
PROTECT	Percentage of pixels in protected natural areas
SLOPE10	Percentage of pixels in with slope less than 10%
SLOPE20	Percentage of pixels in with slope between 10% and 20%
Proximity	
EUC_ROAD	Mean euclidean distance from major public transporting roads

5.2.7 Future Land use land cover prediction by Cellular Automata- Markov model

A Markov chain is a stochastic process that consists of a finite number of states of a system in discrete time steps and some known transition probabilities pij, where pij is the probability of that particular system moving from time step i to time step j. For example, for a system composed of multiple land covers, the state of a particular cell at time step i denotes the type of land cover of that particular cell at time step i, which might change (or remain the same) in the next time step j. The transition probability denotes the probability of each class changing to every other class (or remaining the same) from time step i to time step j. With Markov chain analysis, future land cover can be modeled on the basis of the preceding state; that is, a matrix of actual transition probabilities between states can be used to predict future changes in the landscape from current patterns (Brown et al. 2000). Cellular automata is a dynamic and spatially explicit modeling approach that encompasses five components – (a) a space composed of discrete cells, (b) a finite set of possible states associated to every cell, (c) a neighborhood of adjacent cells whose state influences the central cell, (d) uniform transition rules through time and space, and (e) a discrete time step to which the system is updated (Wolfram 1984). A combination of Markov and cellular automata approaches has been shown to improve models describing complex natural patterns (Marshall and Randhir 2008, Fan et al. 2008, Peterson et al. 2009). The modeled landscapes were generated using the software IDRISI, the Andes version. The MARKOV module of the software analyzes a pair of land cover images and outputs a transition probability matrix, a transition area matrix, and a collection of conditional probability images. The transition probability matrix is a text file that records the probability of each land cover category changing to every other category. The transition areas matrix is a text file that records the number of pixels that are expected to change from each land cover type to each other land cover type over the specified number of time units. The conditional probability images report the probability of each land cover type to be found at each pixel after the specified number of time units. These images are calculated as projections from the later of the two input land cover images. The CA MARKOV module then utilizes the transition area matrix and a base-image to model future landscapes. In addition, the CA MARKOV module integrates the spatial information based on the conditional probability images, where the CA model changes a particular pixel from one land cover class in time step i to another class in time step j based on the state of the local neighborhood. In other words, the CA model utilizes a collection of the conditional probability images (also known as the suitability images) to start an iterative process of relocating the pixels to the proximity of the same land cover class until it meets the area predicted by the Markov model for each land cover class. For this study, land cover maps (30 m resolution) from 1999 and 2009 as input maps in a CA-Markov model to predict Land cover for 2019 with the assumption that the pre-1999 drivers acting on the landscape are the only drivers guiding post-1999 changes. The transition probabilities for 2009 were calculated by the MARKOV module based on the transitions between 1999 and 2009. The CA MARKOV module then used these transitions to predict spatial patterns for 2019 using the 2009 image as the base-image.

5.3 RESULTS

5.3.1 Multiple year Image classification

As a result of hybrid classification approach, the study area was classified into five land use/cover classes for all the time series: 1) Miscellaneous, 2) Teak-associated forest, 3) Open forest, 4) Water and 5) Non-forest. Percentage representation of each category in each time series was given in Table 5.3.

Table 5.3 Percentage occurance of different land use / cover types in different years

Land use/cover classes	1977 (%)	1989 (%)	1999 (%)	2009 (%)
Miscellaneous	18	23.5	27.4	35.6
Teak-associated	40.7	30.4	27.3	17.7
Open	13	15.9	10.2	10.5
Non-forest	28.2	27.9	29.5	30.9
Water	0.1	2.3	5.6	5.3

5.3.2 Spatial and temporal land use/cover change trajectories

Regression analysis between 1977 and 1989, 1989 and 1999 and 1999 and 2009 using NDVI maps showed a significant change in the green biomass with R^2 varying from 0.6 to 0.74 (Fig 5.2, 5.3 & 5.4).

Fig 5.2 Regression analysis between 1999 and 2009

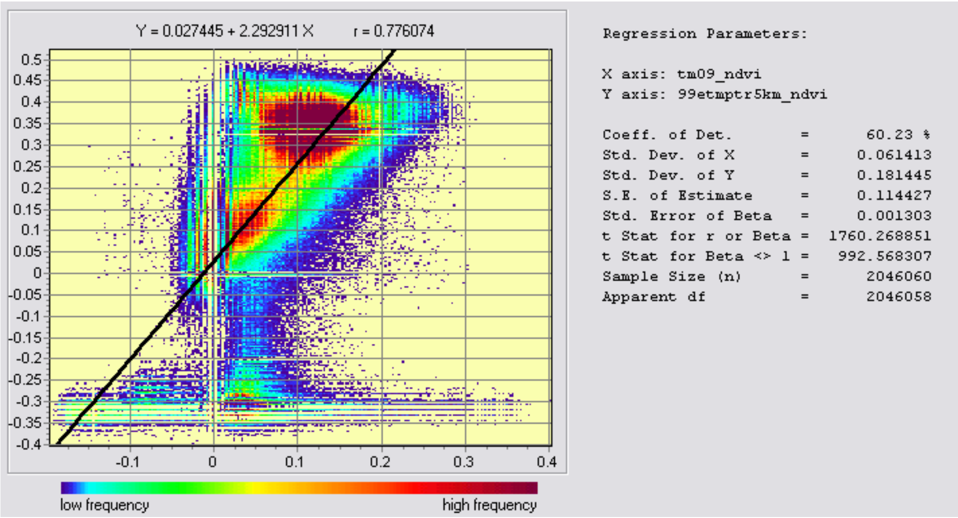


Fig 5.3 Regression analysis between 1989 and 1999

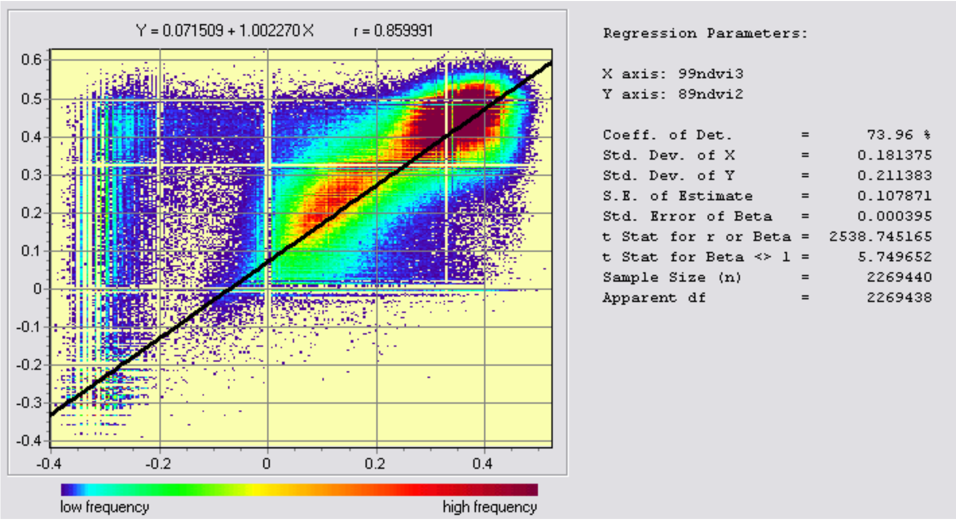
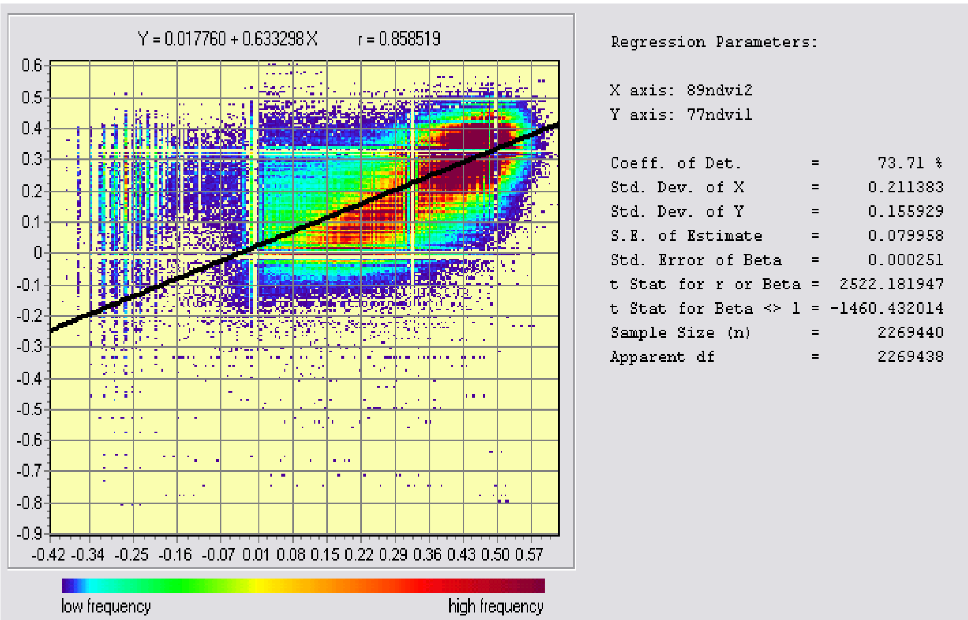


Fig 5.4 Regression analysis between 1977 and 1989



The two-date change trajectories reveald a distinct spatiotemporal pattern of forest-cover changes (Fig. 5.5, 5.6 & 5.7). As outlined in Table 5.4, PTR suffered notable deforestation before 1999, which became negligible in later years. While the proportion of stable miscellaneous forest consistently increased throughout the study period, post-1989 witnessed greater stability. In addition to stable land use/cover types, ‘‘deforestation’’ and ‘‘reforestation’’ classes, two-date change trajectories provided information on unique forest transition dynamics, namely “Teak to

Miscellaneous", "Upgradation", "Degradation" (Table 5.4), which mainly represent rotational forests showing various forest transition pathways.

Table 5.4 Percentage representation of two date change trajectories

Land use/cover	**1977 - 1989 (%)**	**1989 - 1999 (%)**	**1999 – 2009 (%)**
Stable* Miscellaneous forest	10.4	15.1	18.7
Stable Teak-associated forest	19.5	14.5	10.2
Stable Open forest	5.1	5.1	5.2
Stable Water	0.1	2.2	5.7
Stable Non-forest	21.6	23.3	26.5
Reforestation	5.7	2.6	2.5
Teak to Miscellaneous	13.9	9.3	14.5
Upgradation	4.4	6.2	1.8
Deforestation	12.4	15.3	9.3
Degradation	6.9	6.4	5.6

* Stable means in both previous and later date, area belongs to same LULC

Fig 5.5 Land use/cover change between 1977 and 1989 in Pench Tiger Reserve

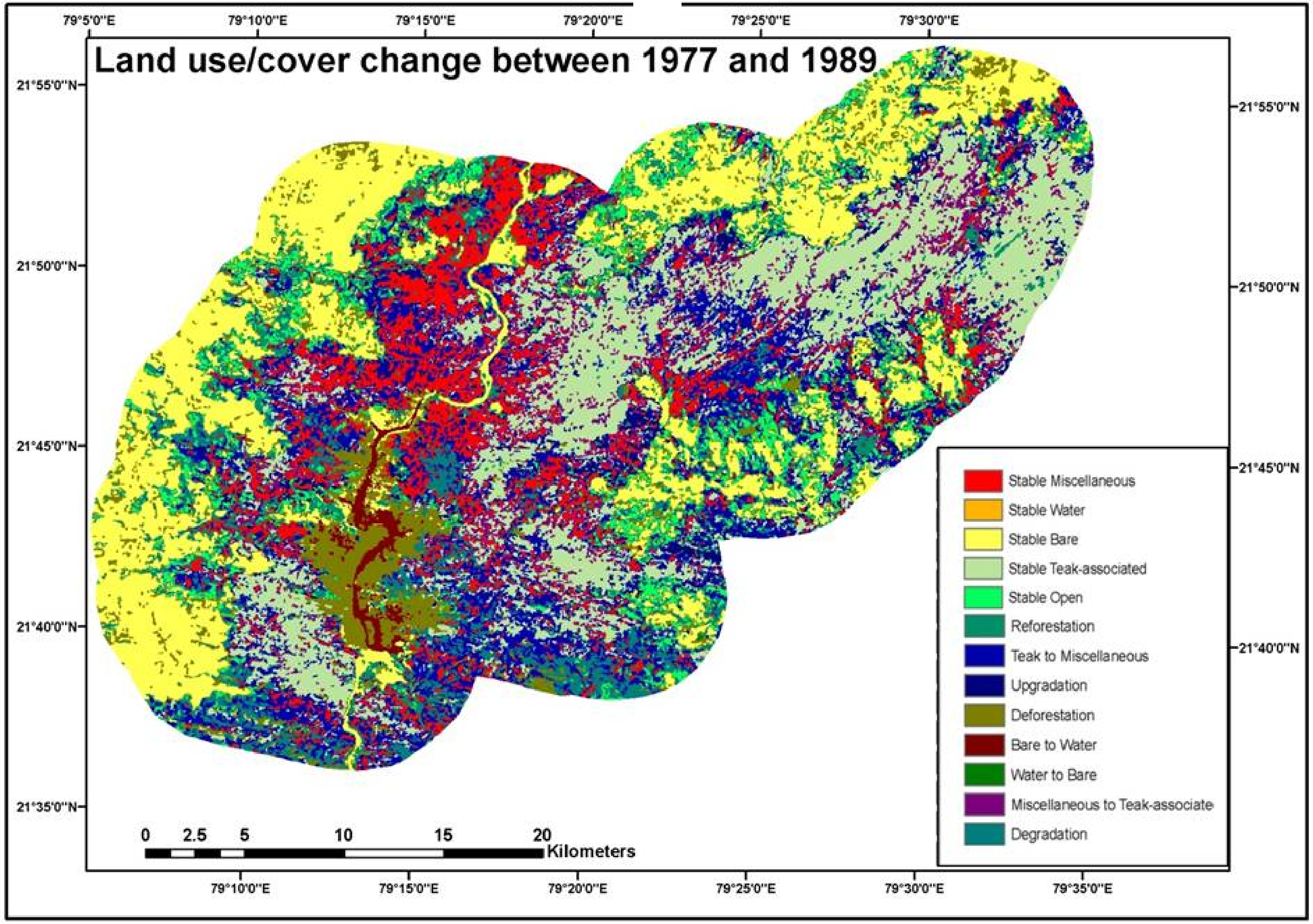


Fig 5.6 Land use/cover change between 1989 and 1999 in Pench Tiger Reserve

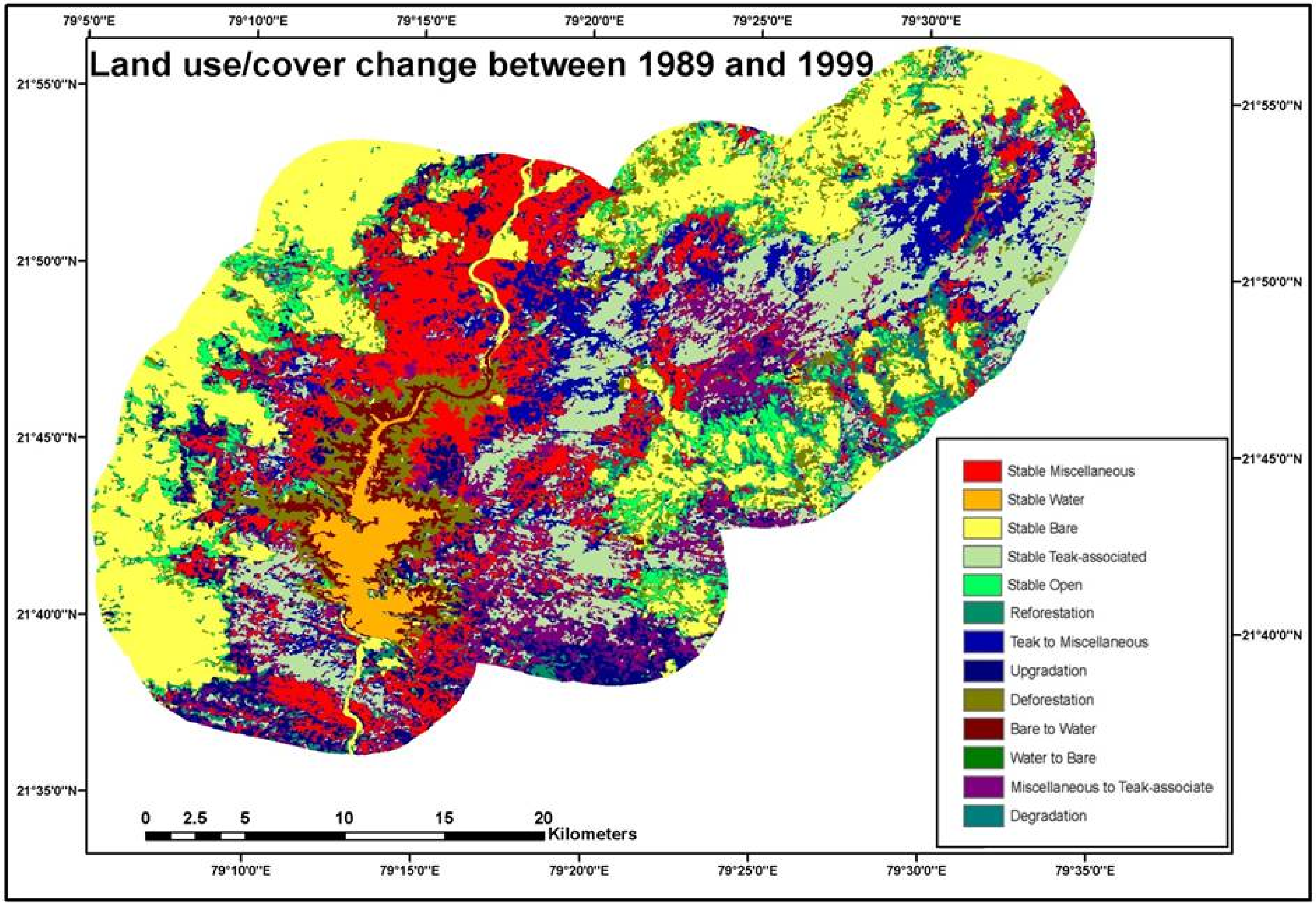
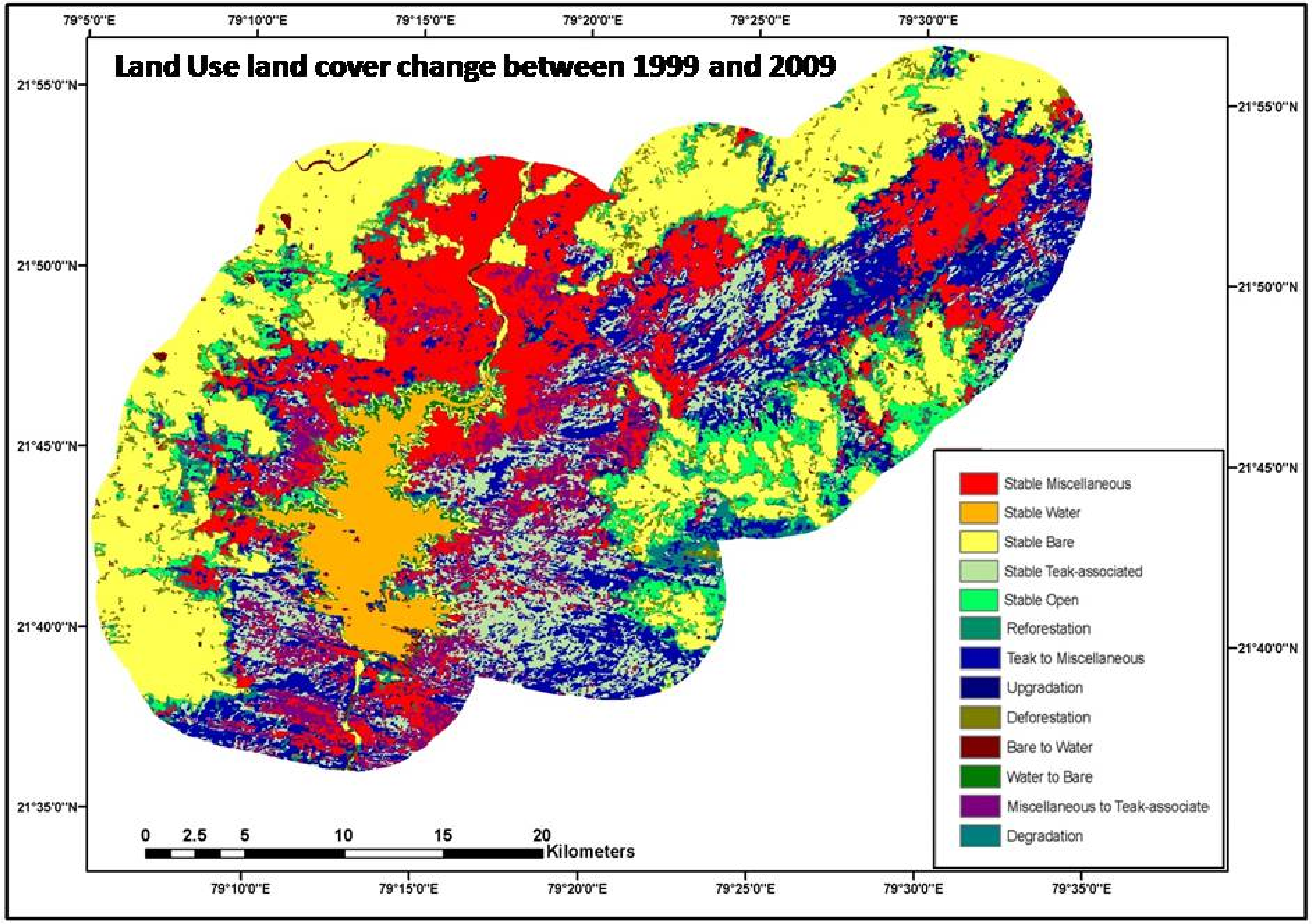


Fig 5.7 Land use/cover change between 1999 and 2009 in Pench Tiger Reserve



5.3.3 Landscape pattern indices

The overall trend corresponded to an absolute decrease in forest cover of about 11.1% of the forest surface present in 1977. This was due to the creation of hydroelectric dam in 1987 (impact of dam was discussed later in details) and deforestation (Fig. 5.5 & 5.6). The forest surface showed a pronounced fragmentation in 1977 with a high number of patches (Fig. 5.7) and this fragmentation dramatically decreased in 2009, with a little exception of Miscellaneous forest which showed some increase in number of patches in last 10 years. (Fig. 5.6). The general trend of decrease in forest area and of the reduction in the number of patches was reflected by the increase in mean patch size, except for Teak-associated forest which showed fluctuations during the study period (Fig. 5.8). The patch size standard deviation index (Fig. 5.9) showed an increase in the size variability for Miscellaneous forest, open forest and baren land and a corresponding decrease for Teak-associated forest. The shape of the forests also changed in a clear way, with an increase of AWMSI (area weighted mean shape index) for the Miscellaneous and Open forest (Fig. 5. 10), while Non-forest areas showed constant decrease and Teak- associated forest in the first part decreased and increased at last. In general, an increase in the geometric complexity of forest patch shapes was observed. The investigation of the total edge length showed a substantially similar trend in total edge (TE) between 1977 and 2000 (Fig. 5.13), with a decrease of TE in all land use/cover types except TE for Miscellaneous forest.

Fig. 5.8 Area (Ha) occupied by different land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

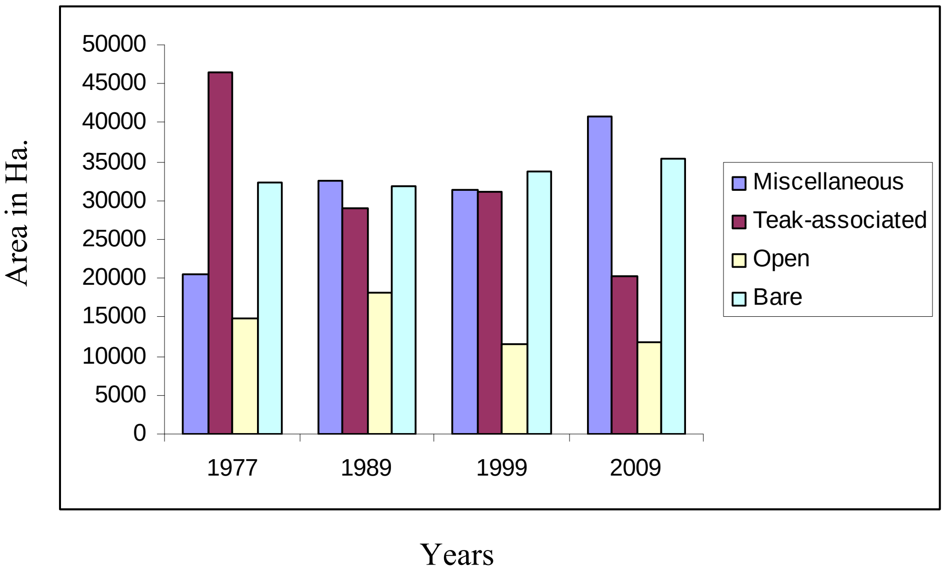


Fig. 5.9 Number of patches found in each land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

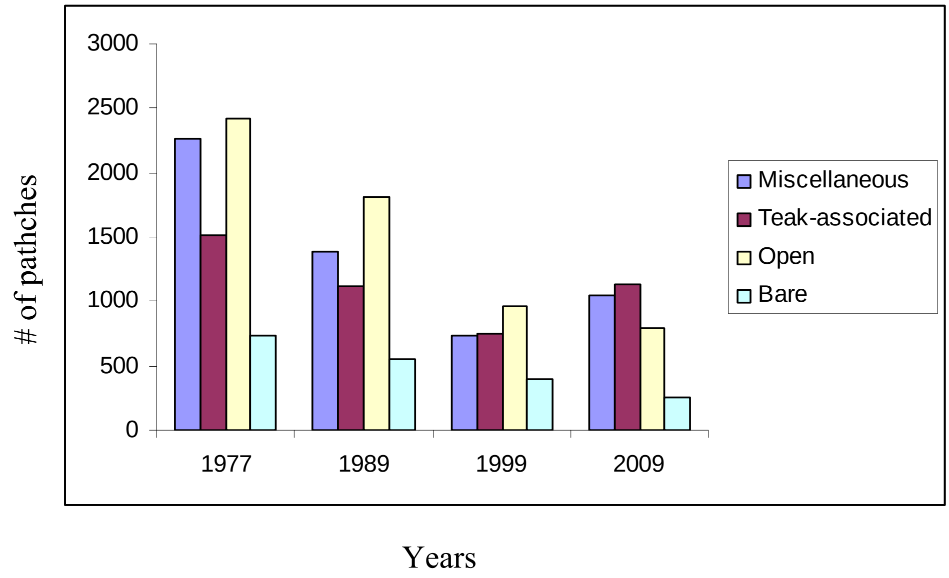


Fig. 5.10 Mean patch size (Ha) of each land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

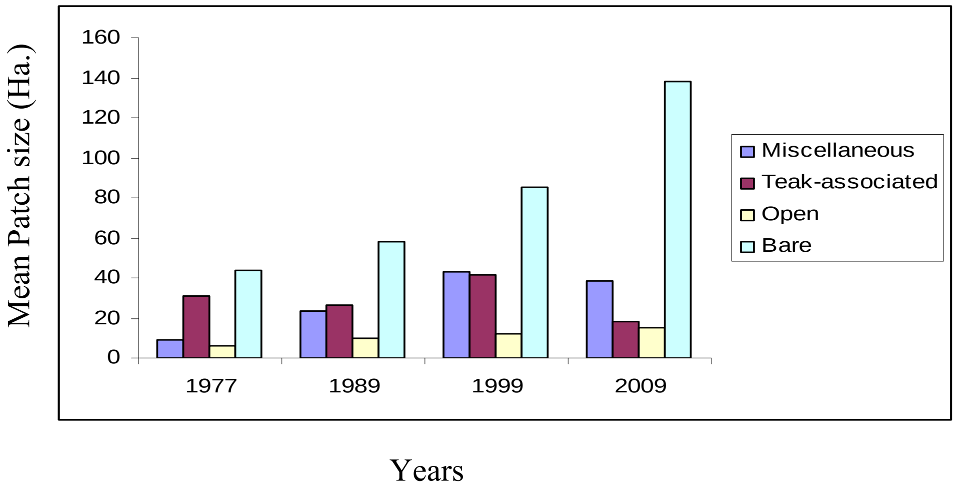


Fig. 5.11 Patch size standard deviation of each land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

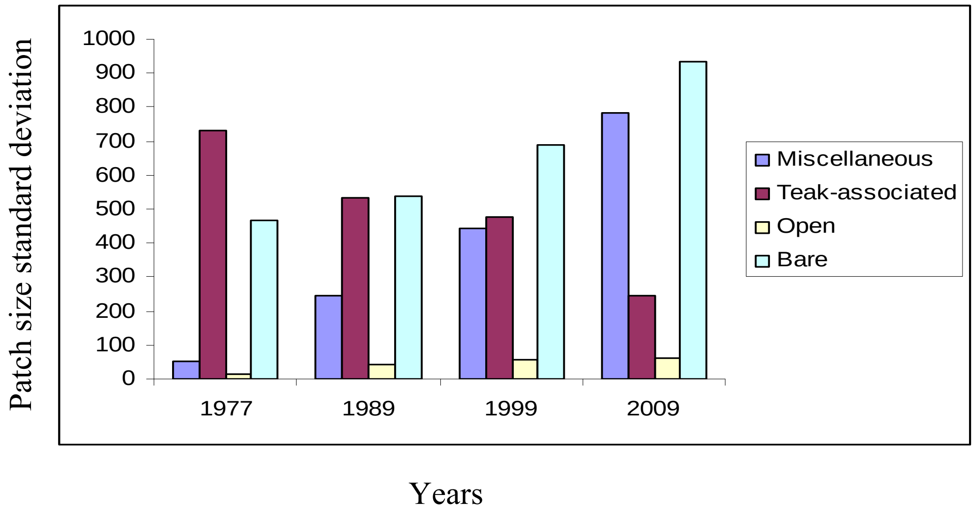


Fig. 5.12 Area weighted mean shape index (AWMSI) of each land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

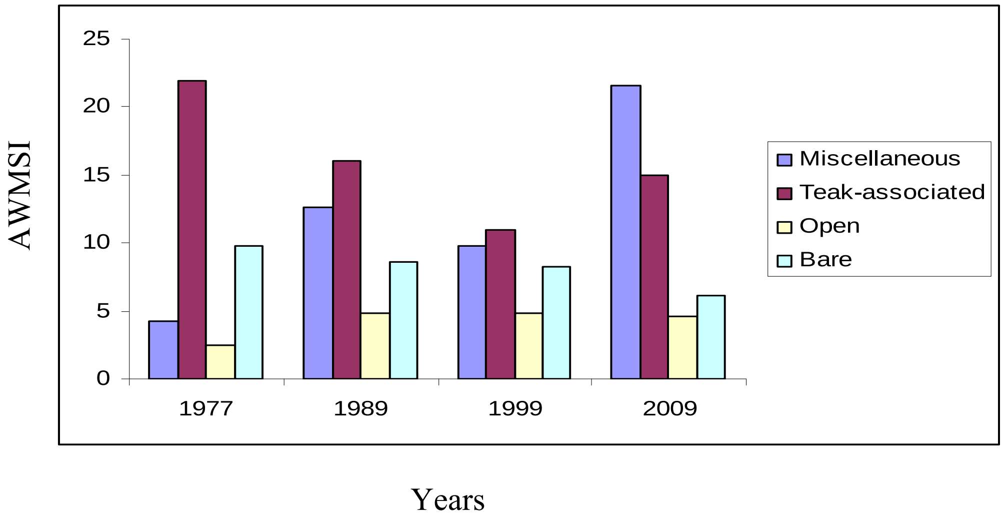
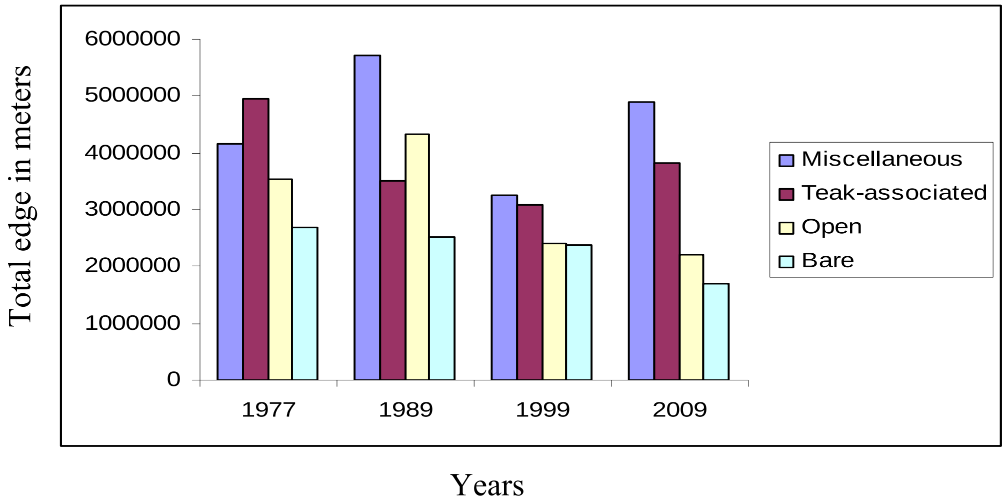


Fig. 5.13 Total edge (m) of each land use/cover class between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh



5.3.4 Anthropogenic driving forces of landscape change

5.3.4.1 *Direct cause: Infrastructural development*:

Creation of Totladoh hydroelectric dam in 1987 had caused a loss of 76.7 km^2 area of the landscape. Loss of area in different land use/cover classes is given in the Table 5.5.

Table 5.5 Loss of different forest area due to the creation of hydroelectric dam

Land use/cover	Area(Km^2)
Miscellaneous Forest	25.4
Teak-associated Forest	17.5
Open Forest	12.7
Non-Forest	21.2

5.3.4.2 *Landscape Changes due to Cattle grazing, Fuel wood collection and NTFP extraction:*

Average distance moved by villagers by each target villages was measured on the basis of questionnaire survey for the 30 sampled villages for cattle grazing, fuel wood and NTFP extraction (Table 5.6).

Table 5.6 Average distances traveled by villagers for different purposes**Category**	**Range**	**Village**	**Distances(Km)**		
			Fuel wood collection	**Livestock grazing**	**NTFP collection**
Category-I	Bichua	**Kokiwara**	1	1	1
	Bichua	**Dodhgaon**	2.6	2.1	2.2
	Gumtara	**Pathra khurd**	2.3	2	2
	Gumtara	**Gumtara**	2.9	2.6	2.9
	Khawasa	**Karmajhiri**	2	2.6	1.9
	Khawasa	**Turia**	4	2	3.9
	Kurai	**Khamrith**	1.8	2.1	1.8
	Kurai	**Pindkapar**	3.9	1.9	2
	Rukhad	**Murer**	2.2	1.5	2
	Rukhad	**Patarai**	2.9	3.3	3.2
Category-II	Bichua	**Mohgaon khurd**	4.2	3.7	3.7
	Bichua	**Surrewani**	4.4	3.5	4
	Gumtara	**Thota raiyat**	3.8	4	3.8
	Gumtara	**Patri**	3.2	2.5	4.1
	Khawasa	**Durgapur**	1.5	3	1.7
	Khawasa	**Sarahiri**	2.8	3.2	2.8
	Kurai	**Vijaypani II**	3.3	3.5	3.3
	Kurai	**Mohgaon (Yadav)**	4	1.75	2.2
	Rukhad	**Tewni**	5.2	5.8	3.1
	Rukhad	**Airma**	7	3.6	4.8
Category-III	Bichua	**Antra**	8.3	4	5.6
	Bichua	**Khamarpani**	5.9	5	5.1
	Gumtara	**Davajhir**	4.4	2.6	4
	Gumtara	**Rampuri**	7.1	3.5	4.3
	Khawasa	**Pachdhar**	4.4	5	2.2
	Khawasa	**Kothar**	7	4.4	4.9
	Kurai	**Harduli**	2.2	2.8	2.8
	Kurai	**Pipariya**	4.4	4.1	3.6
	Rukhad	**Niwari**	5.7	5.2	4.6
	Rukhad	**Mohgaon sadak**	7.8	6.2	5.6
	Bichua	**Antra**	8.3	4	5.6

The major amount of deforestation in the core area (with PA and outside collection/extraction distance) between 1977 and 1989 and between 1989 and 1999 were due to the formation of Totladoh reservoir which has resulted an increase in the area of submergence in respective years (Table 5.7 & 5.8). Between the year 1999 and 2009, the observed deforestation rates were very low in the core area which might be because of the protection measures taken by the forest department. In the Middle area (within PA and within collection/extraction distance), though the deforestation rates went down in the last 10 years, an increase in degradation was observed in this category (Table 5.7 & 5.8). In the Outside area (Outside PA and within collection/extraction distance), both deforestation and degradation were almost same over the years (Table 5.7 & 5.8).

Table 5.7 Deforestation and degradation within fuel wood collection distances

	1977-1989		**1989-1999**		**1999-2009**	
Category	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**
Core	13.05	4.59	10.62	0.08	0.44	1.1
Middle area	1.92	4.17	5.60	2.72	0.53	3.17
Outside	7.64	5.07	8.48	5.39	6.66	4.83

Table 5.8 Deforestation and degradation within NTFP collection distances

	1977-1989		**1989-1999**		**1999-2009**	
Category	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**	**Deforest - ation (Km^2)**	**Degrad - ation (Km^2)**
Core	11.33	4.44	9.99	0.32	0.40	1.17
Middle	1.80	4.23	5.43	2.88	0.57	3.40

area						
Outside	8.06	4.86	8.93	5.73	7.11	5.06

When I analysed deforestation and degradation of forest within the livestock grazing distances, similar kind of trends were found (Table 5.8). Historical records which were lacking, could have offered a better explanation in this regard.

Table 5.9 Deforestation and degradation within grazing distances between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

Loss	1977-1989	1989-1999	1999-2009
Deforestation (Km^2)	8.10	9.00	7.04
Degradation (Km^2)	4.75	5.89	4.59

5.3.4.3 *Impact of increase in protection policy on landscape change:*

The reforestation was higher inside PTR than outside throughout the study period. Past 20 years result (Table 5.10) showed almost no reforestation in the landscape outside PTR. Similar trend prevails for upgradation also. As indicated earlier, the higher deforestation rates during 1977-1989 and 1989- 1999 inside PTR were because of the formation of reservoir and increase in extent. The deforestation and degradation rates were almost similar for outside areas over the years (Table. 5.9).

Table 5.10 Reforestation, Upgradation, Deforestation and Degradation inside (Core) and outside PTR between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

Change category	1977-1989		1989-1999		1999-2009	
	Core	Outside	Core	Outside	Core	Outside
Reforestation* (Km^2)	7.38	2.76	3.55	0.85	2.70	0.19
Upgradation# (Km^2)	5.19	3.92	7.26	4.27	1.85	1.82
Deforstation$ (Km^2)	6.06	8.40	7.47	7.69	0.49	5.41
Degradation£ (Km^2)	4.32	8.25	1.74	4.36	2.40	4.19

* Later date has forest over non-forest on the previous date. # Open forest in the previous date converted to either Mixed or Teak-mixed forest on the later date. $ later date is non-forest in places of forest on the earlier date. £ Mixed or Teak-Mixed forest on the earlier date converted into open forest on later date.

According to Class area (CA), Miscellaneous forests showed constant increase in inside PTR, Category I and Category II and Teak- associated forest showed constant decrease (Fig. 5.12a , 5.13a & 5.14a) but in Category III both the forests registered decrease (Fig. 5.15a). For Teak associated forest inside PTR, since the Total edge (TE) increased (Fig. 5.12b) and Mean Patch Area (MPA) decreased (Fig. 5.12c), the Number of Patches (NP) must have increased in this area. Miscellaneous forest showed increase in TE and MPA in all categories (Fig. 5.12b, 5.12c, 5.13b, 5.13c, 5.14b, 5.14c, 5.15b & 5.15c). In Category I, II and III, Teak associated forest showed decrease in TE (Fig. 5.13b, 5.14b & 5.15b) with a decrease in MPA (Fig. 5.13c, 5.14c & 5.15c) which means that there was decrease in NP. As there was very less open forest inside PTR, they represented similar trend for all the landscape metrics over the years (Fig. 5.12a, 5.12b, 5.12c, 5.12d). CA, TE and MPA of Open forests increased from Category I to category III (Fig. 5.13a, 5.13b, 5.13c, 5.14a, 5.14b, 5.14c, 5.15a, 5.15b & 5.15c) indicating an increase in the NP over the years. Area Weighted Mean Shape Index (AWMSI) for Miscellaneous forest, Teak-associated forest and Open forest constantly decreased from Inside PTR to Category II but suddenly increased in Category III (Fig. 5.12d, 5.13d, 5.14d and 5.14d).

Fig. 5.14 Landscape characterization of Different LULC classes in core area a) Area (Ha), b) Total edge, c) Mean patch area (Ha), d) Area weighted mean shape index between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

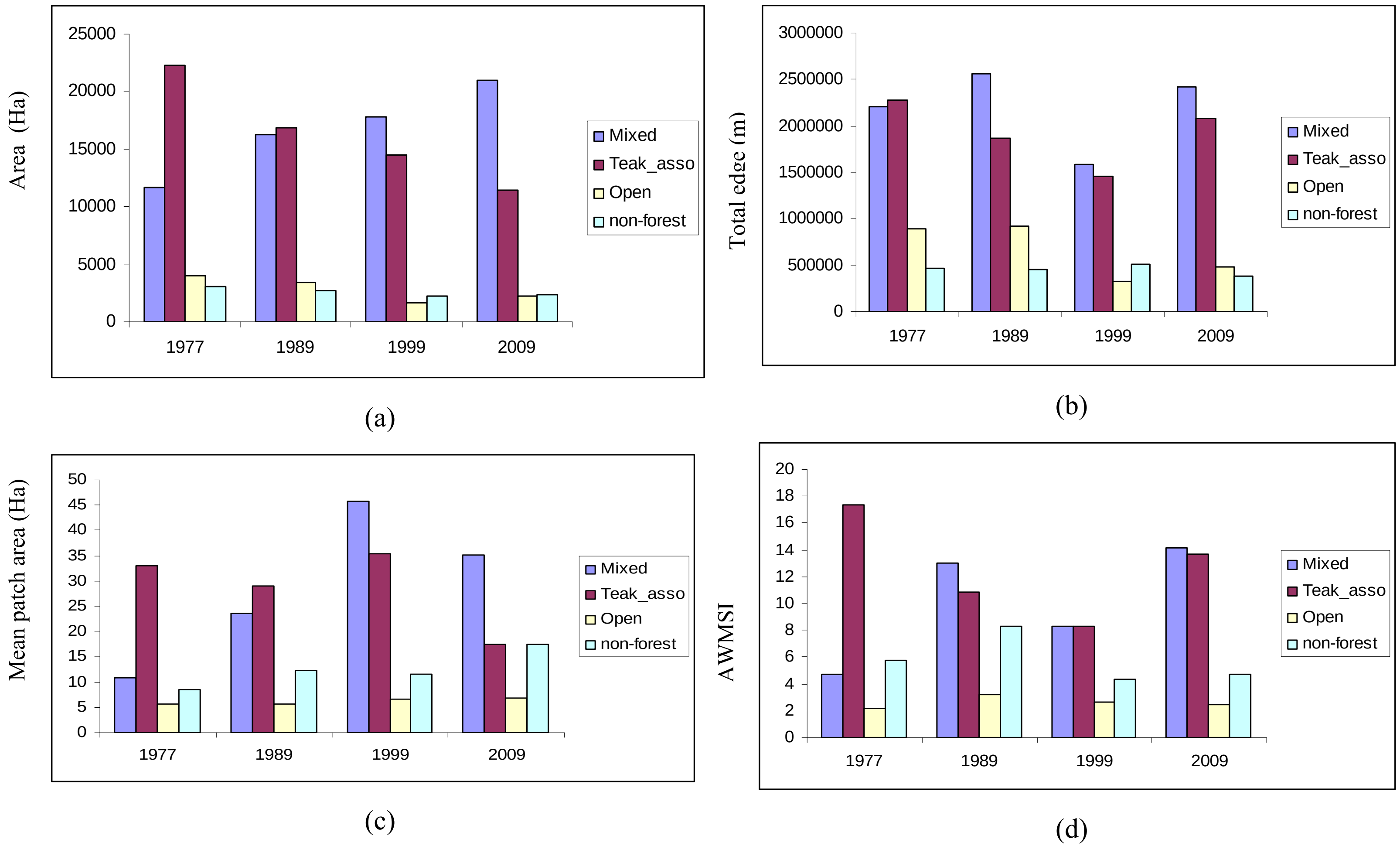


Fig. 5.15 Landscape characterization of Different LULC classes in Category I a) Area (Ha), b) Total edge, c) Mean patch area (Ha), d) Area weighted mean shape index between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

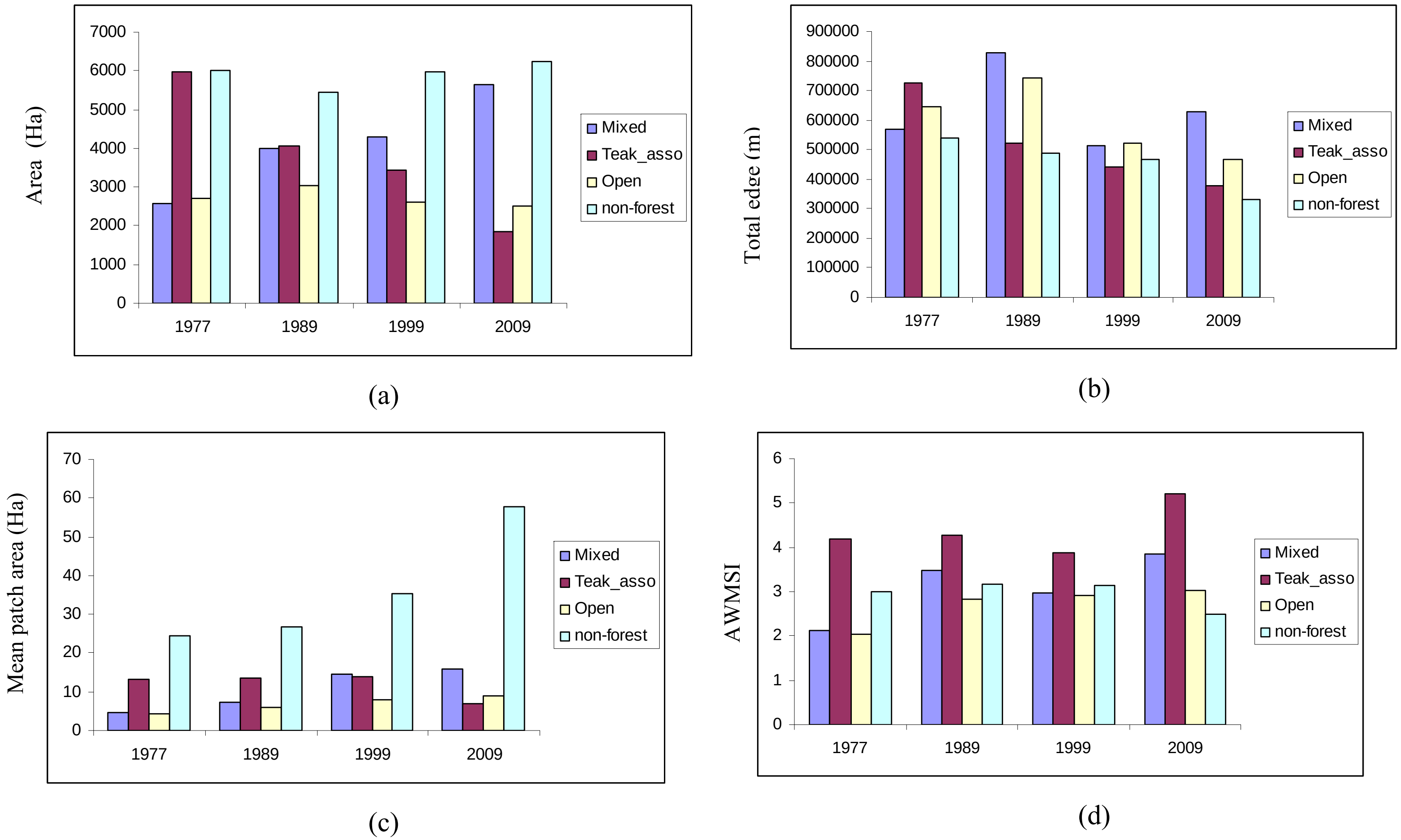


Fig. 5.16 Landscape characterization of Different LULC classes in Category II a) Area (Ha), b) Total edge, c) Mean patch area (Ha), d) Area weighted mean shape index between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh

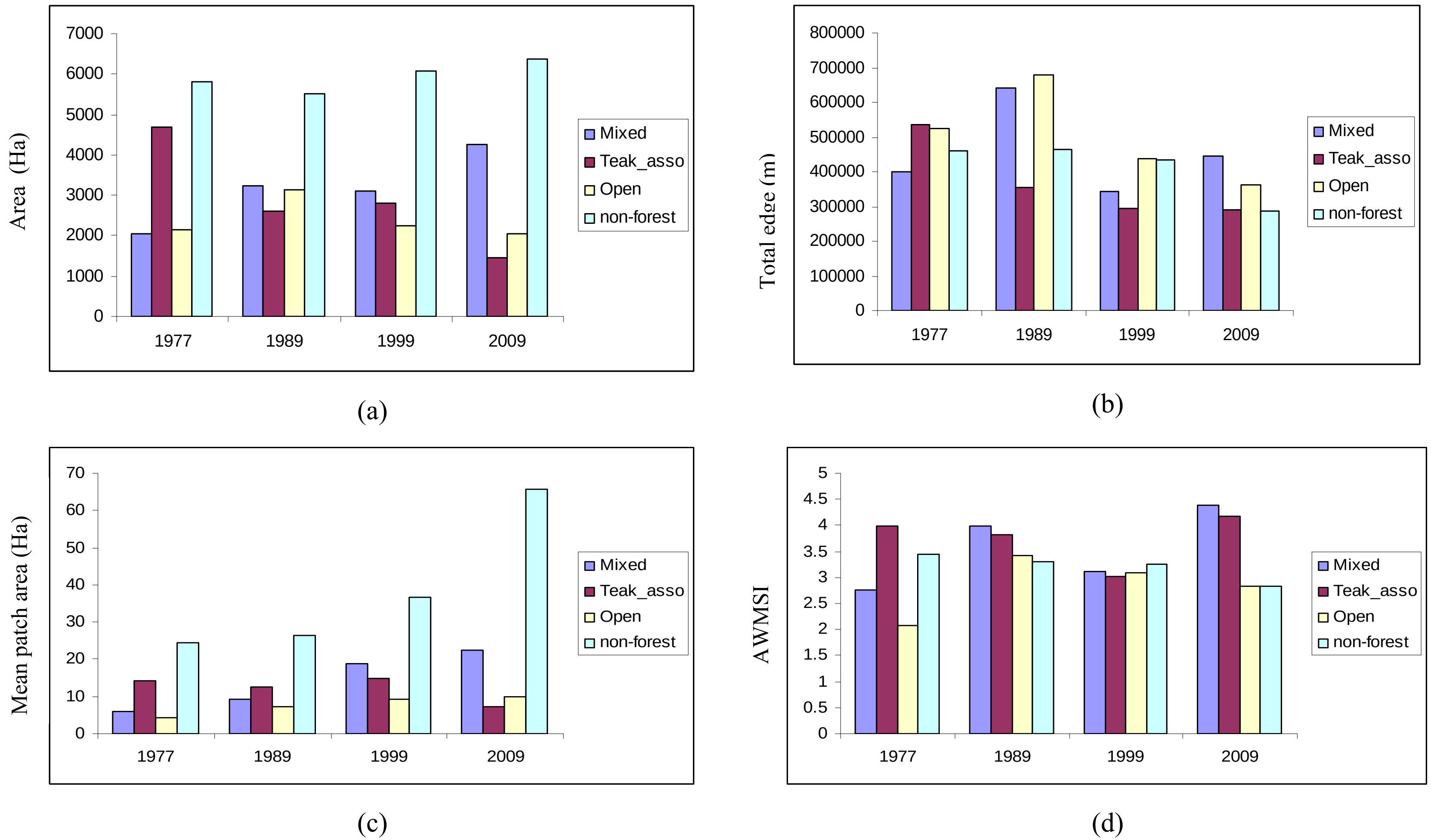
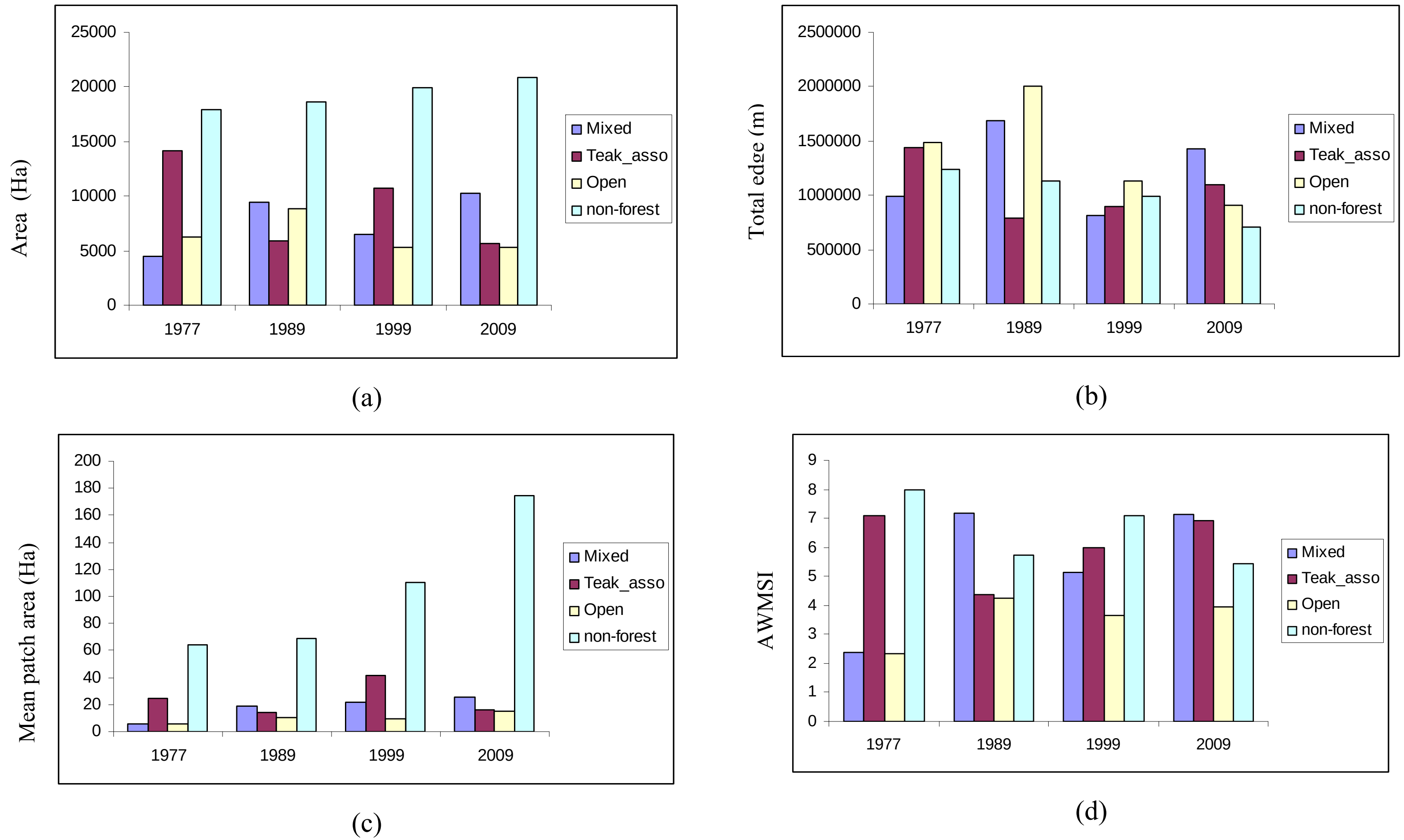


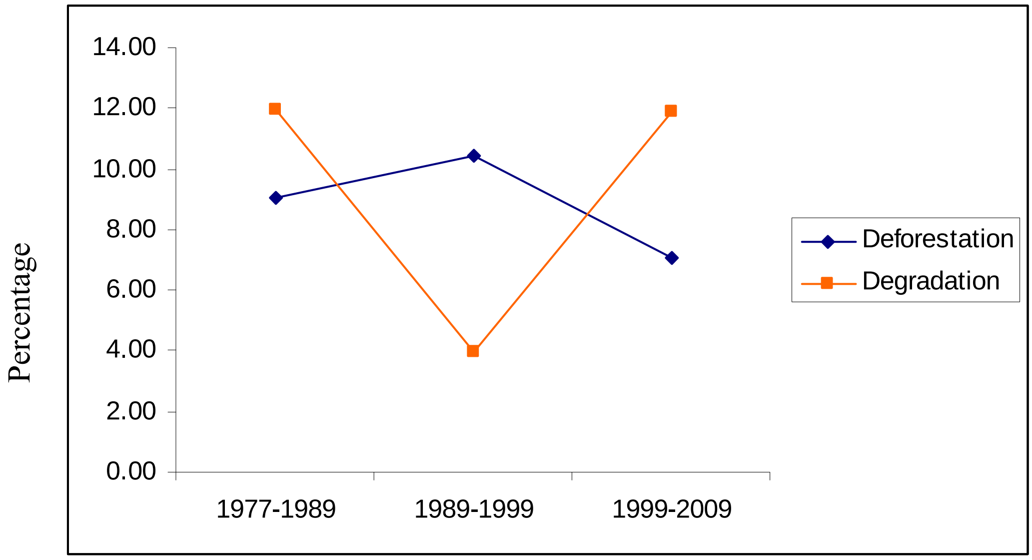
Fig. 5.17 Landscape characterization of Different LULC classes in Category III a) Area (Ha), b) Total edge, c) Mean patch area (Ha), d) Area weighted mean shape index between 1977 and 2009 in Pench Tiger Reserve, Madhya Pradesh



5.3.4.4 *Impact of increase in tourist resorts:*

There were 50 tourism resorts that had come up after 1999 around the park. In the villages with these tourist resorts, degradation of forest had gone down between 1989 and 1999 but again increased after 1999 (Fig. 5.16). The opposite trend was found in deforestation. Most of these resorts maintained the theme to be a wildlife resort, so these resorts actually promoted to keep a forest cover to give the tourists wilderness feelings.

Fig. 5.16 Deforestation and degradation of forest in the villages with tourist resorts



5.3.4.5 *Social-economic, biophysical and proximity factors affecting landscape change*

For Deforestation and Degradation, the GWR results of fitted model (based on least AICc value) were given in Table 5.11 & 5.12. The parameters selected in both the models (least AICc) were VAR_NO_HH, VAR_P_ST, VAR_P_LIT, VAR_TOT_IR, EUC_ROAD AND PROTECT. With GWR, there was a local linear equation for each feature in the dataset. The equation was weighted so that nearby features had a larger influence on the prediction of yi than features that were farther away. Hence it was not appropriate to compute p-values for each coefficient in every one of the local linear equations. Moreover, the increases in adjusted R^2 confirmed that GWR-adjusted models in both the cases explain considerably better the variance of the data to global models (Table 5.10 & 5.11). The GRW models attained an adjusted value of 65%, which is 31% points more than the global model in case of deforestation where as in case of degradation model its 65 % with a 55% points difference than the global model. Other studies reviewed using the same techniques provided results with differences of more than 20% (Clement et al. 2009, Farrow et al. 2005).

Table 5.11 Geographically Weighted Regression model diagnostic statistics for Deforestation

Diagnostic Statistics	Geographically weighted regression(GWR)	Ordinary least square(OLS)
Number of Locations to Fit Model (n)	99	99
Akaike Information Criterion (AICc)	386.818	402.287
Correlation Coefficient (r)	0.867	0.615
Coefficient of Determination (r^2)	0.751	0.378
Adjusted r-square (r^2 Adj)	0.652	0.34
P-value (r^2)	<0.001	<.001

Table 5.12 Geographically Weighted Regression model diagnostic statistics for Degradation

Diagnostic Statistics	Geographically weighted regression (GWR)	Ordinary least square (OLS)
Number of Locations to Fit Model (n)	99	99
Akaike Information Criterion (AICc)	458.15	499.339
Correlation Coefficient (r)	0.866	0.392
Coefficient of Determination (r^2)	0.75	0.135
Adjusted r-square (r^2 Adj)	0.652	0.102
P-value (r^2)	<0.001	<.001

When the GWR results were mapped, the estimated parameter sign for variations in total household, this variable changed throughout the territory especially in the northern and southern villages (Fig. 5.17). Furthermore, when the confidence levels for the t-value were considered, some of the villages in the North and South showed a significant positive correlation, while others in the eastern and western side showed a significant negative correlation. This implied that households in different villages located in villages in northern and southern side were causing deforestation, while numbers of households had no impact in only five villages (Fig. 5.18). In other words, there were villages where inhabitants were practicing some kind of micro-deforestation in order to secure energy supplies; but the difference was that while in some villages the impact of this activity was reflected in deforestation; in others this activity had no direct impact. In those villages which were closer to the communication network and had LPG facilities, the relationship was found negative. It was likely that energy was not obtained solely from fuel wood collection; in contrast, villages where the relationship was found positive, areas were far from LPG distribution network. It would not be right to compare the bio-gas units present in the villages as most of them were non-functional during the study. For the same parameter (VAR_TOT_HH) in the model of degradation, the impact of northern villages were far more than the southern villages (Fig. 5.29 & 5.30) which in turn showed that there was more dependency solely on fuel wood extracted from the forests. The factors which determine proximity to major communication roads (EUC_ROAD) contributed similarly in both the models of deforestation and degradation. As southern and northern villages were far from major roads showed more significant deforestation and degradation than other areas (Fig. 5.25, 5.26, 5.37 and 5.38). Being situated in two tribal districts of Madhya Pradesh, Gond tribes predominates this area. Southern and South-western villages exhibit higher Scheduled tribe population. Villagers in this area were getting good work opportunity either from tourist resorts or from winter capital of Maharashtra, Nagpur due to its proximity. Thus these villages specially those in the south-western region had high positive relation with both deforestation and degradation for the variable Var_P_ST (Fig. 5.19, 5.20, 5.31 & 5.32). Good number of labour families were present in these villages without agricultural lands which probably resulted in a lower per capita irrigated land available in these villages compared to other areas. These villages resulted significant deforestation and degradation for the factor VAR_TOT_IR (Fig. 5.23, 5.24, 5.35 & 5.36) which represented variations in the irrigated land. People here were more dependant on seasonal labour works rather than agriculture thus involving them into more forest utilization to generate secondary income for their households. There were more number of literates in Chhindwara district than Seoni. The variable Var_P_LIT in both the models showed more significant deforestation and degradation in the villages of district Seoni because of lack of literacy. Earlier in this chapter, I presented how deforestation and degradation had happened from protected areas to distant places. The factor PROTECT showed similar kind of trend in a significant way for the models of deforestation and degradation. Distant villages from PTR showed more parameter estimate for deforestation while for the model of degradation though the level of significance decreased as we move further from the protected area but all the villages had higher significance than the deforestation models suggesting that villages closer to the protected area might not be affecting deforestation but they had good contribution on forest degradation (Fig. 5.27, 5.28, 5.39 & 5.40).

Fig. 5.19 Spatial distribution of parameter estimate of the variation in total household in deforestation model

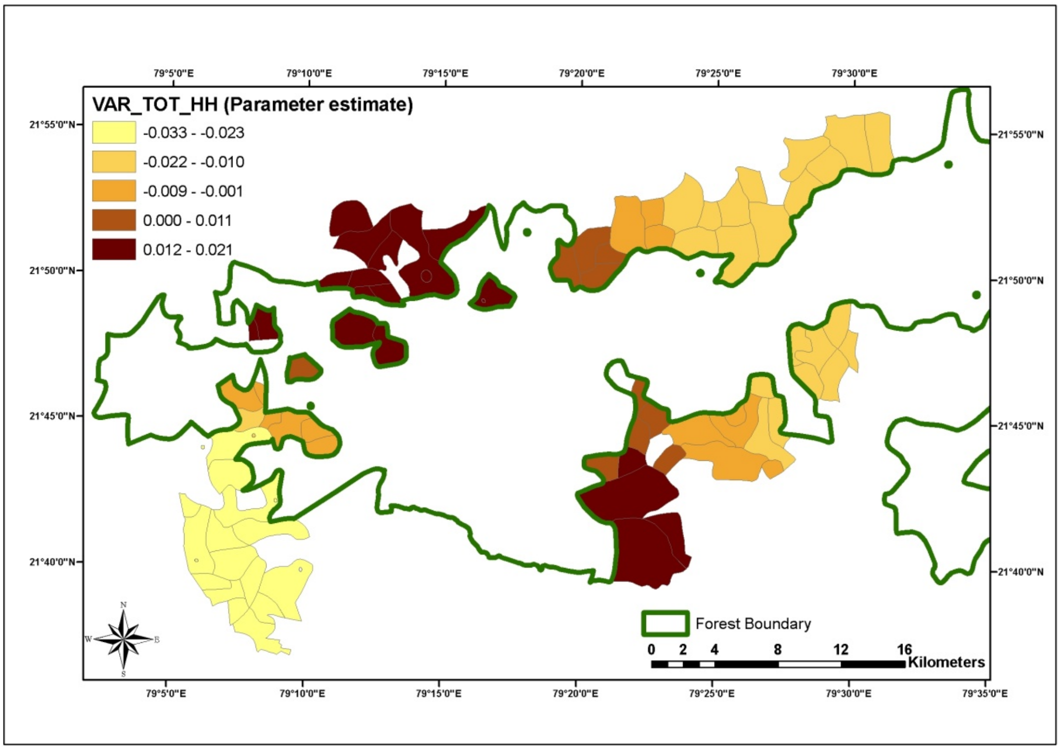


Fig. 5.20 Spatial distribution of pseudo t-values of the variation in total household in deforestation model

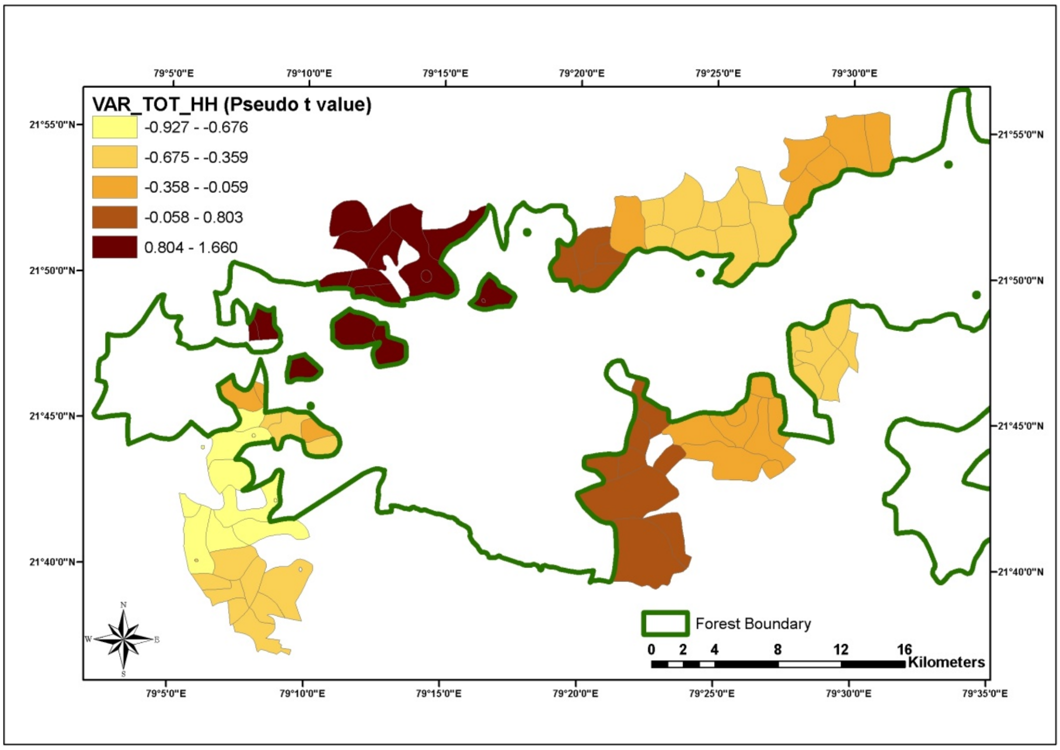


Fig. 5.21 Spatial distribution of parameter estimate of the variation in Scheduled Tribe population in deforestation model

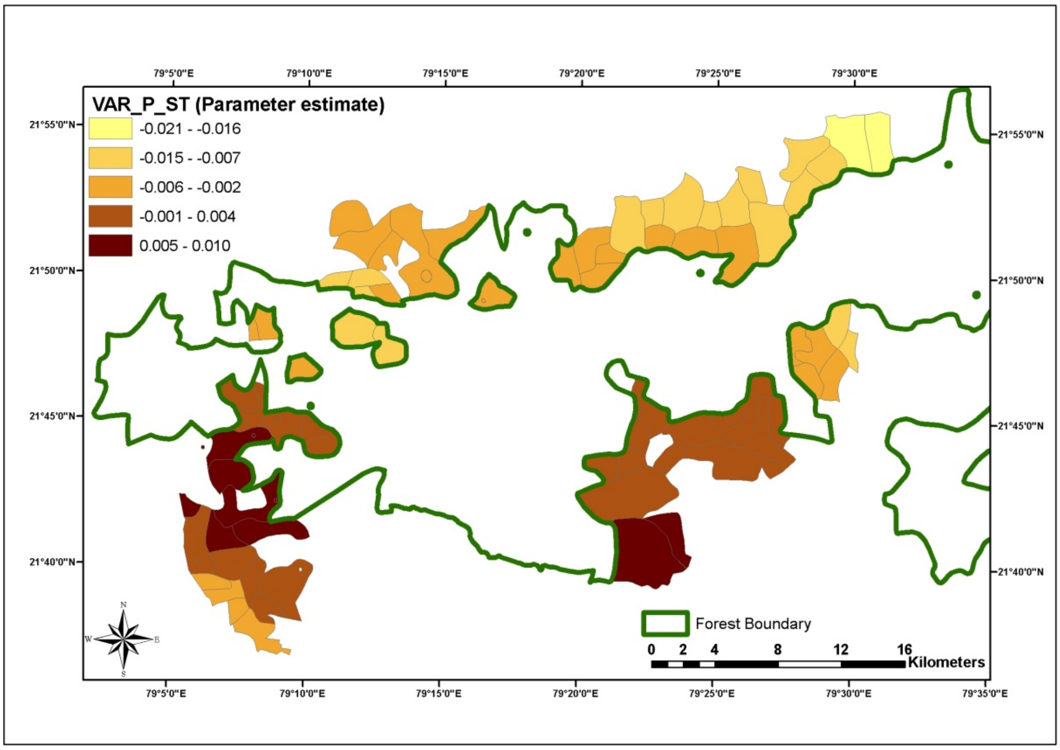


Fig. 5.22 Spatial distribution of pseudo t-values of the variation in Scheduled Tribe population in deforestation model

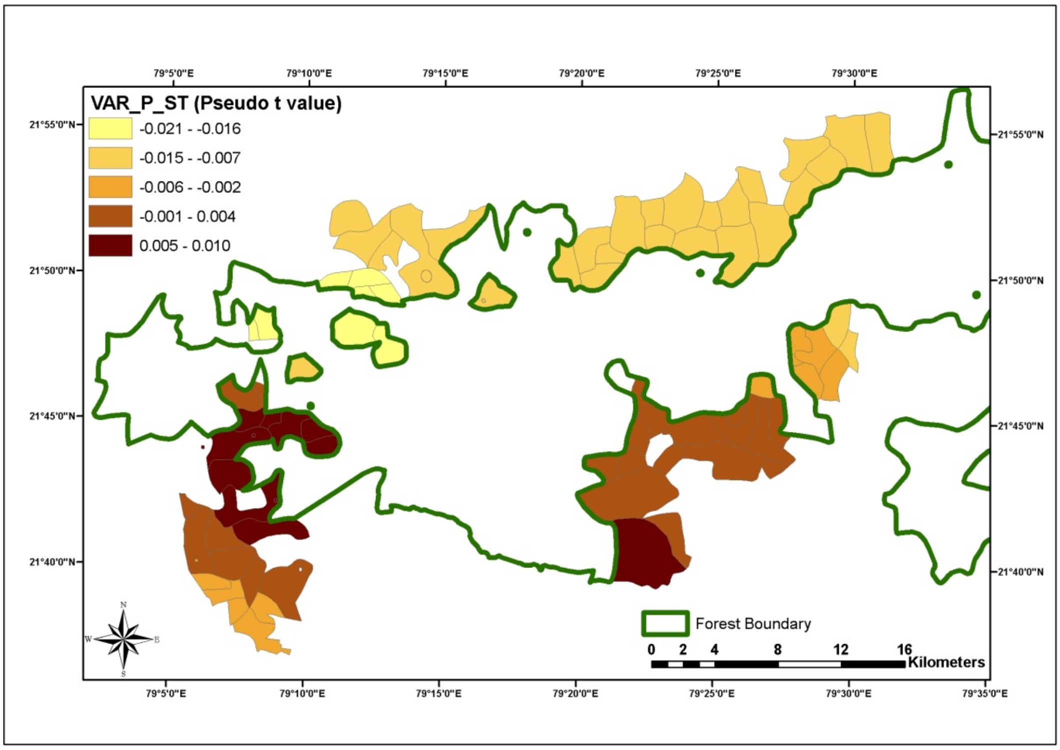


Fig. 5.23 Spatial distribution of parameter estimate of the variation in literate population in deforestation model

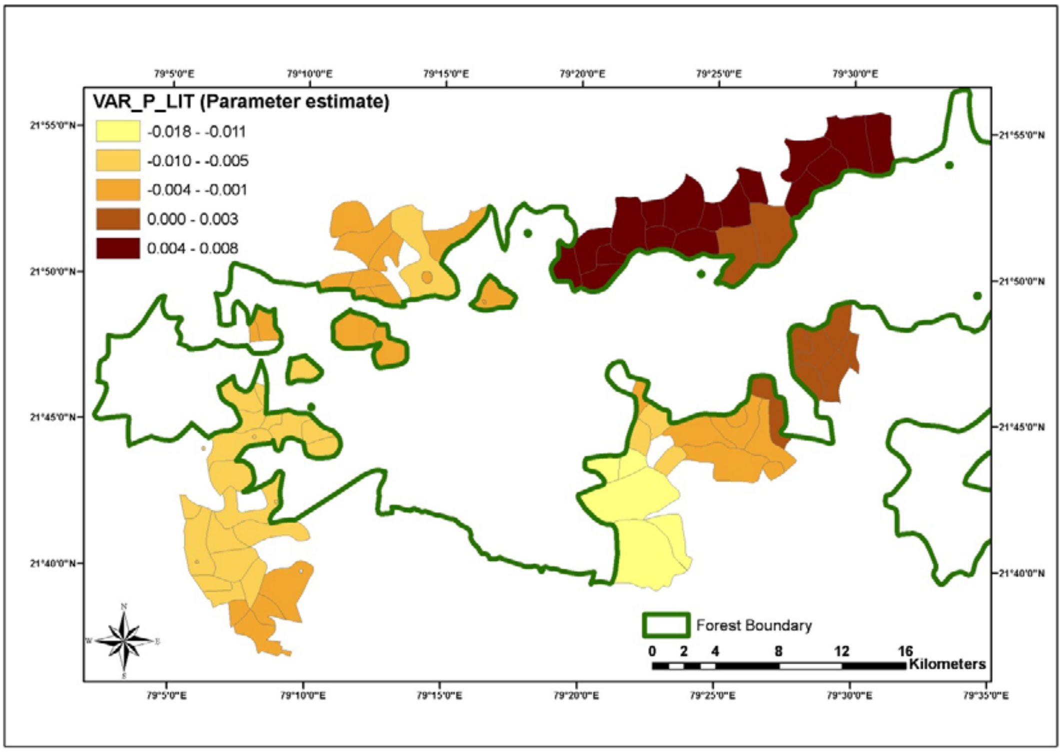


Fig. 5.24 Spatial distribution of pseudo t-values of the variation in literate population in deforestation model

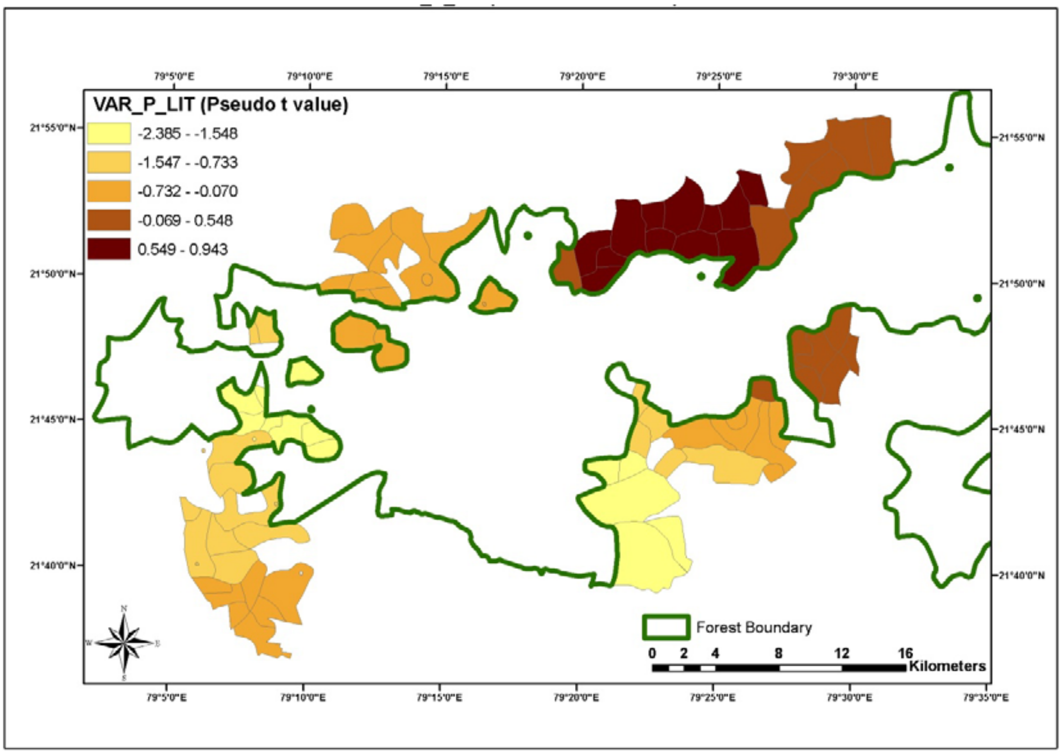


Fig. 5.25 Spatial distribution of parameter estimate of the variation in irrigated land in deforestation model

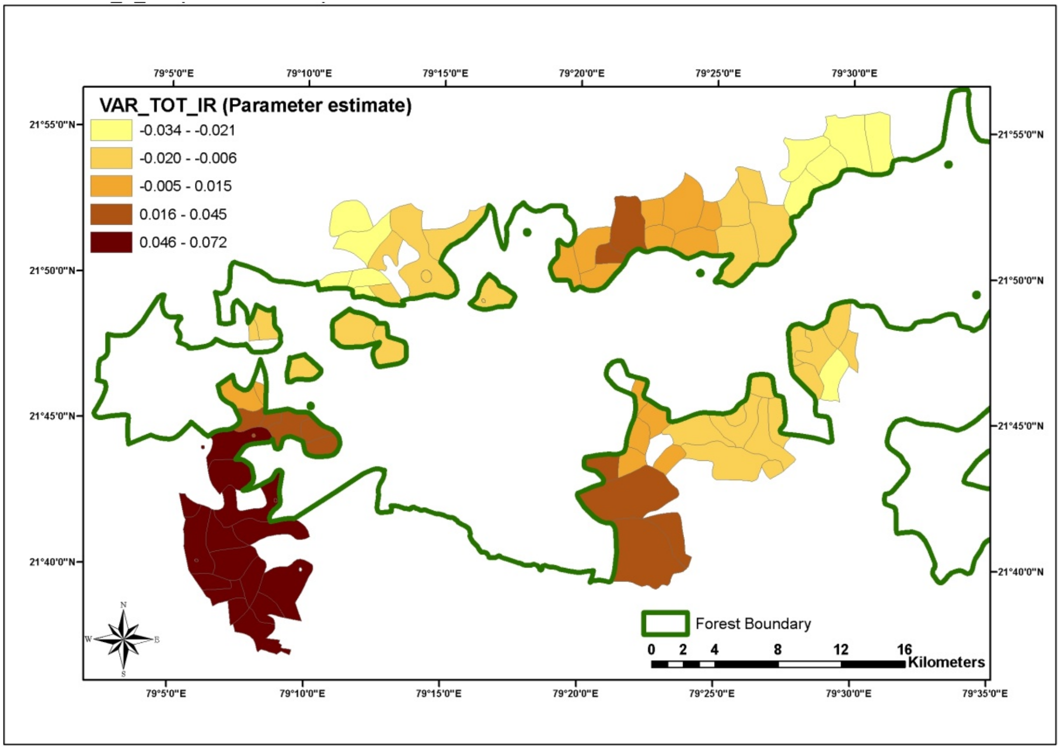


Fig. 5.26 Spatial distribution of pseudo t-values of the variation in irrigated land in deforestation model

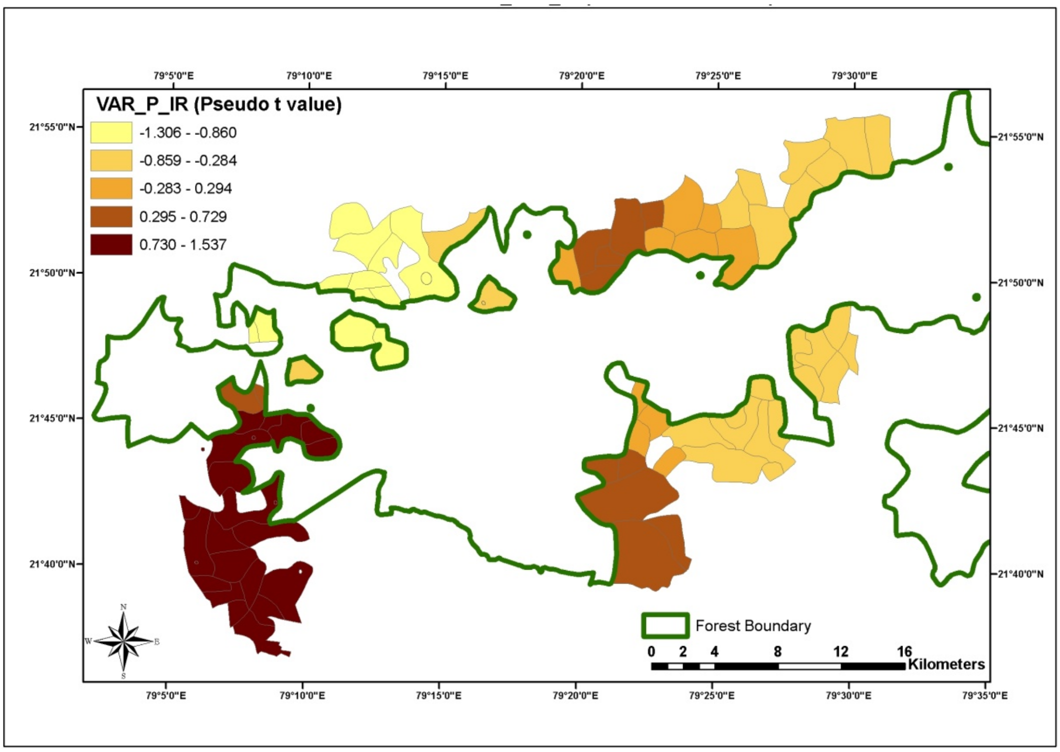


Fig. 5.27 Spatial distribution of parameter estimate of the distance from major roads in deforestation model

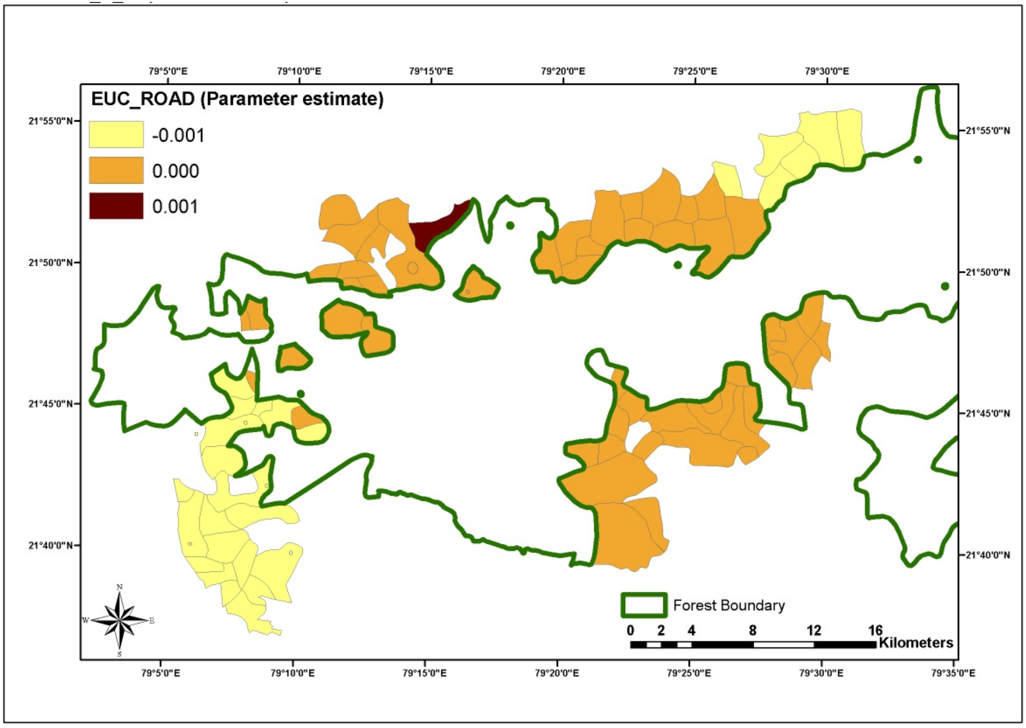


Fig. 5.28 Spatial distribution of pseudo t-values of the distance from major roads in deforestation model

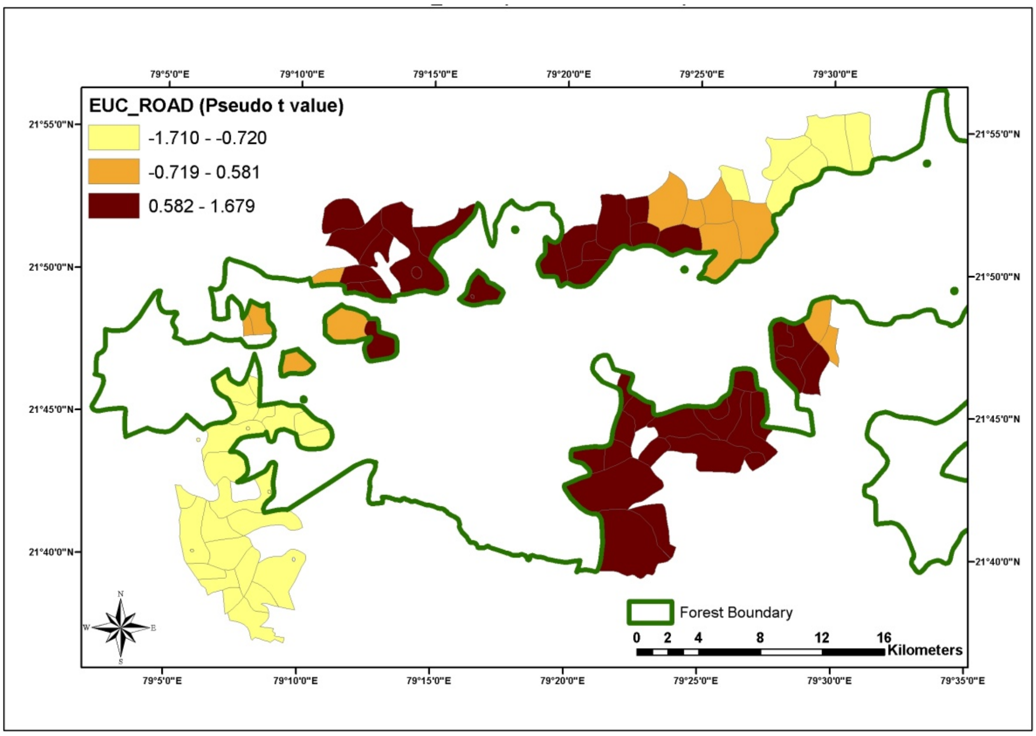


Fig. 5.29 Spatial distribution of parameter estimate of the distance from protected area in deforestation model

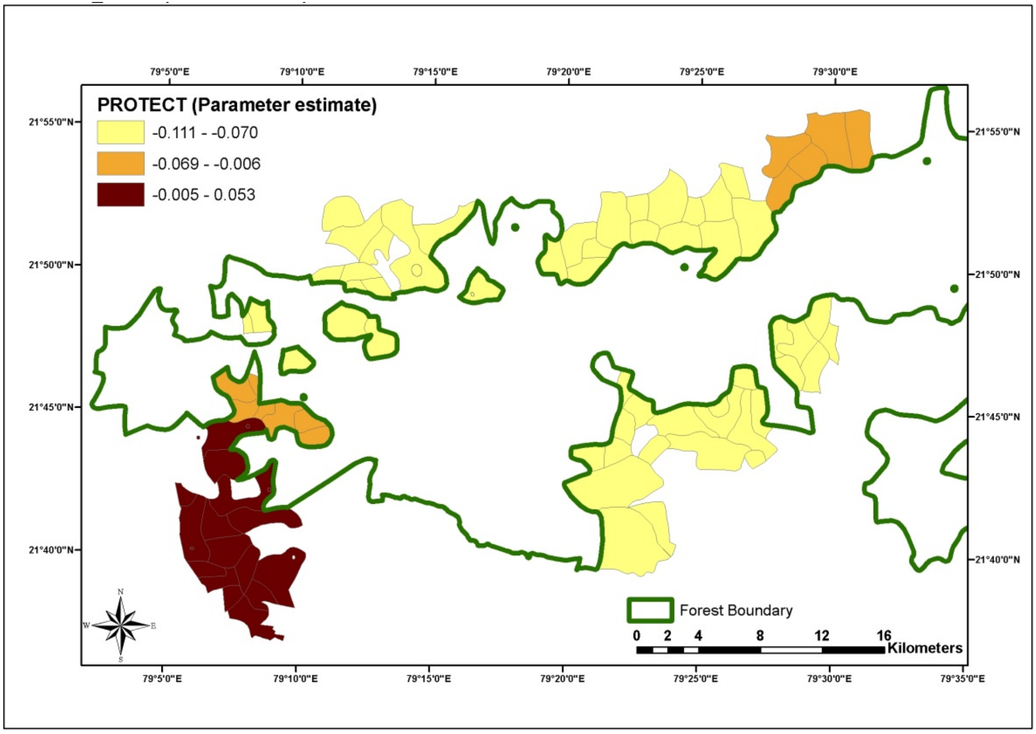


Fig. 5.30 Spatial distribution of pseudo t-values of the distance from protected area in deforestation model

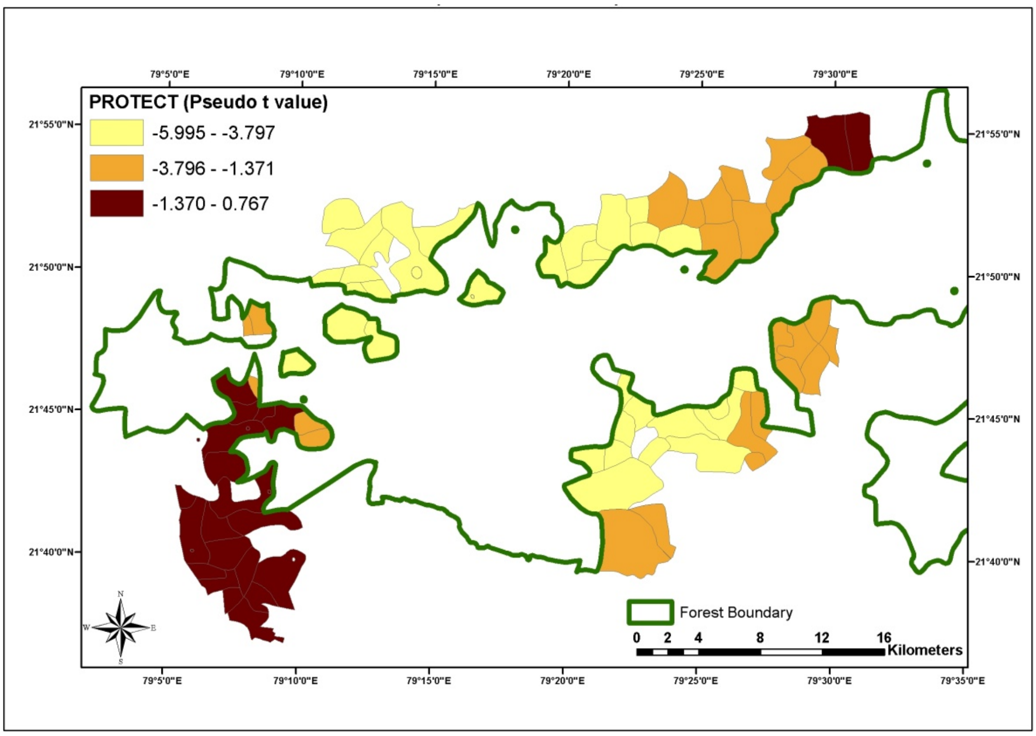


Fig. 5.31 Spatial distribution of parameter estimate of the variation in total household in degradation model

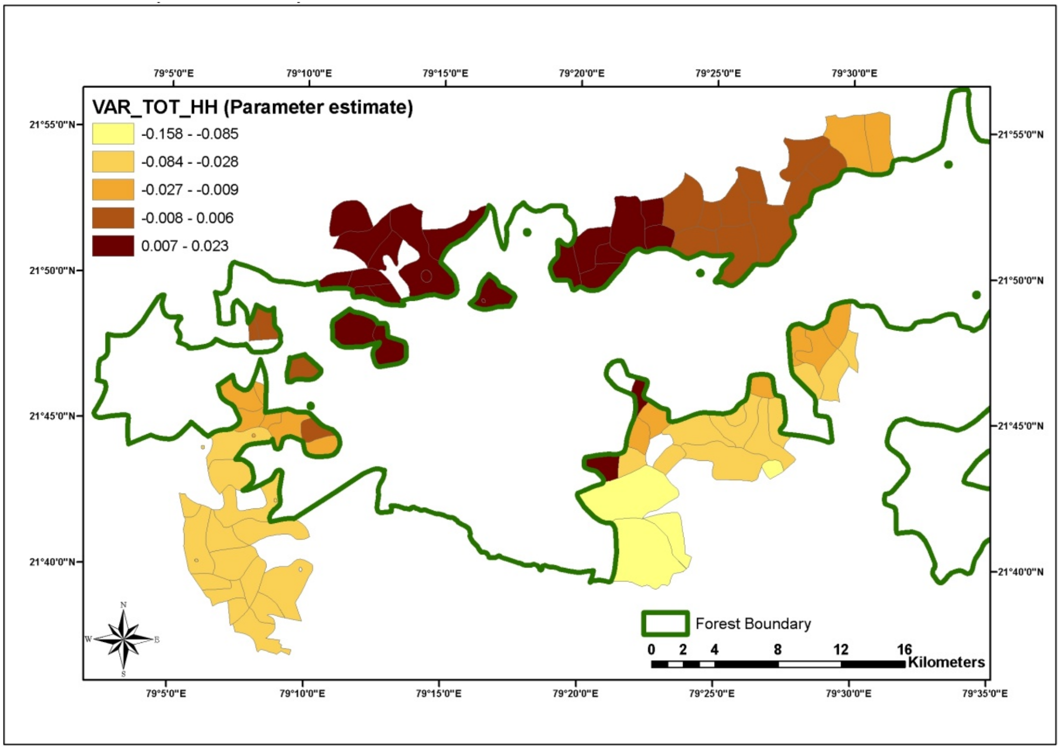


Fig. 5.32 Spatial distribution of pseudo t-values of the variation in total household in degradation model

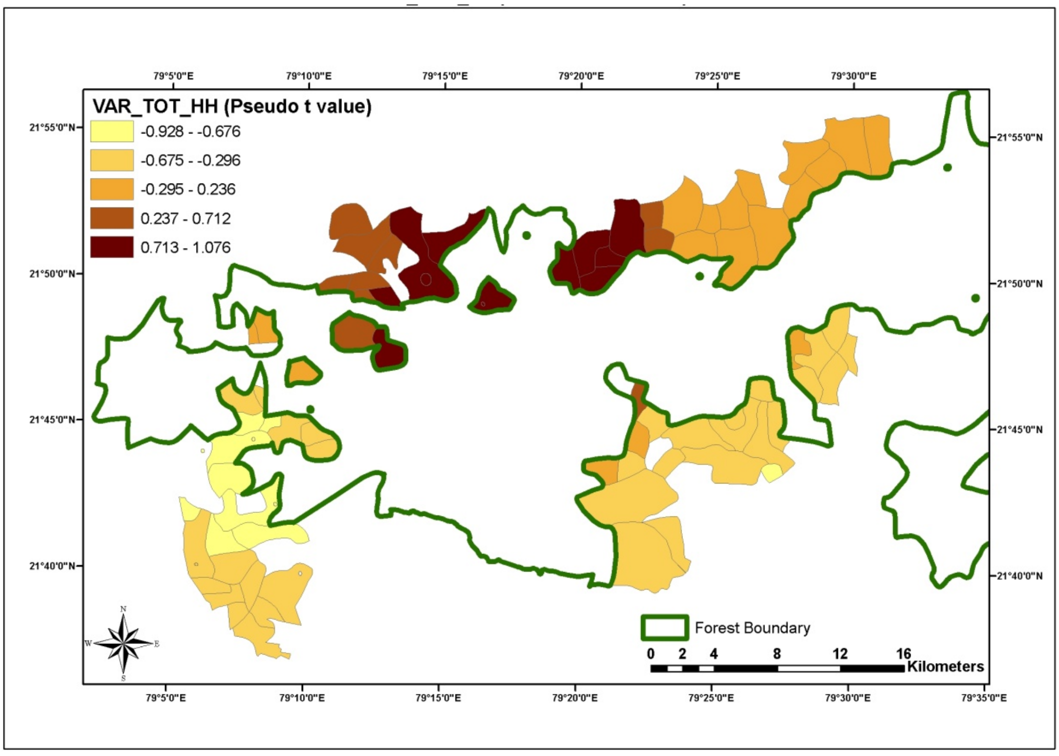


Fig. 5.33 Spatial distribution of parameter estimate of the variation in Scheduled Tribe population in degradation model

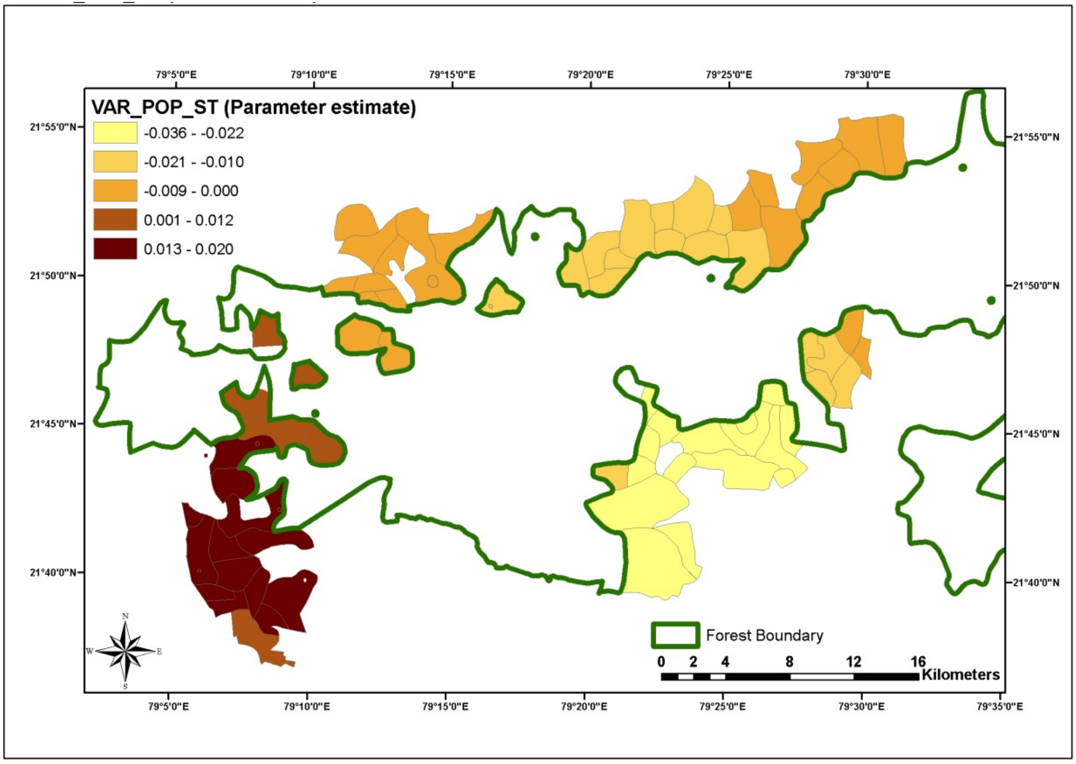


Fig. 5.34 Spatial distribution of pseudo t-values of the variation in Scheduled Tribe population in degradation model

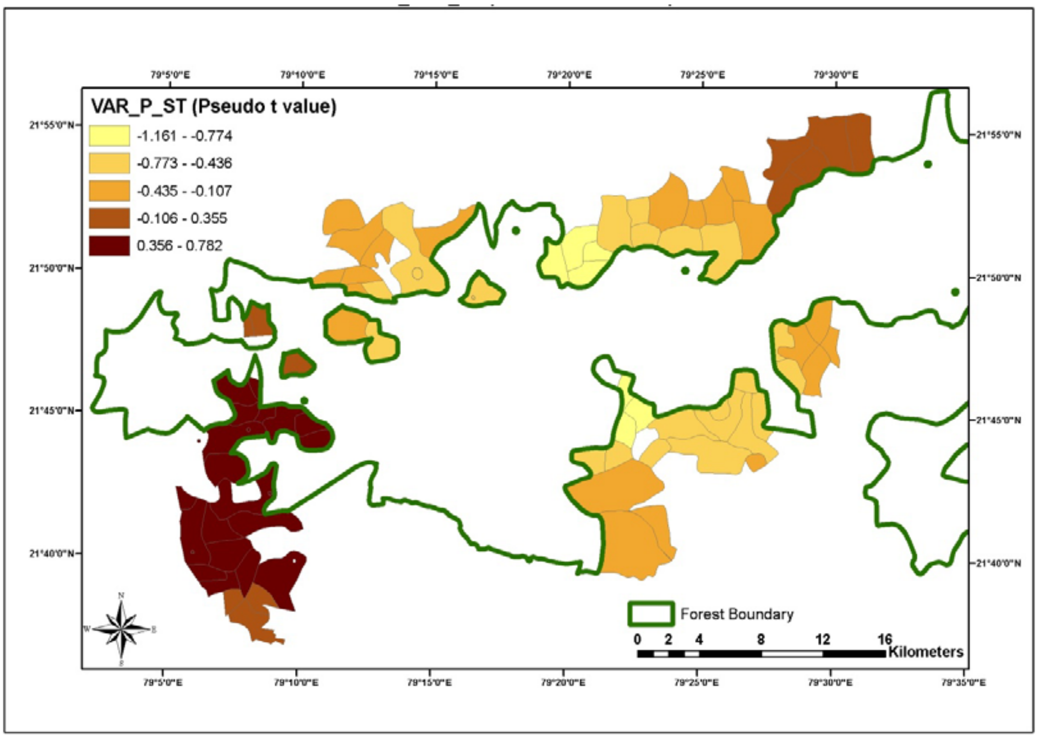


Fig. 5.35 Spatial distribution of parameter estimate of the variation in literate population in degradation model

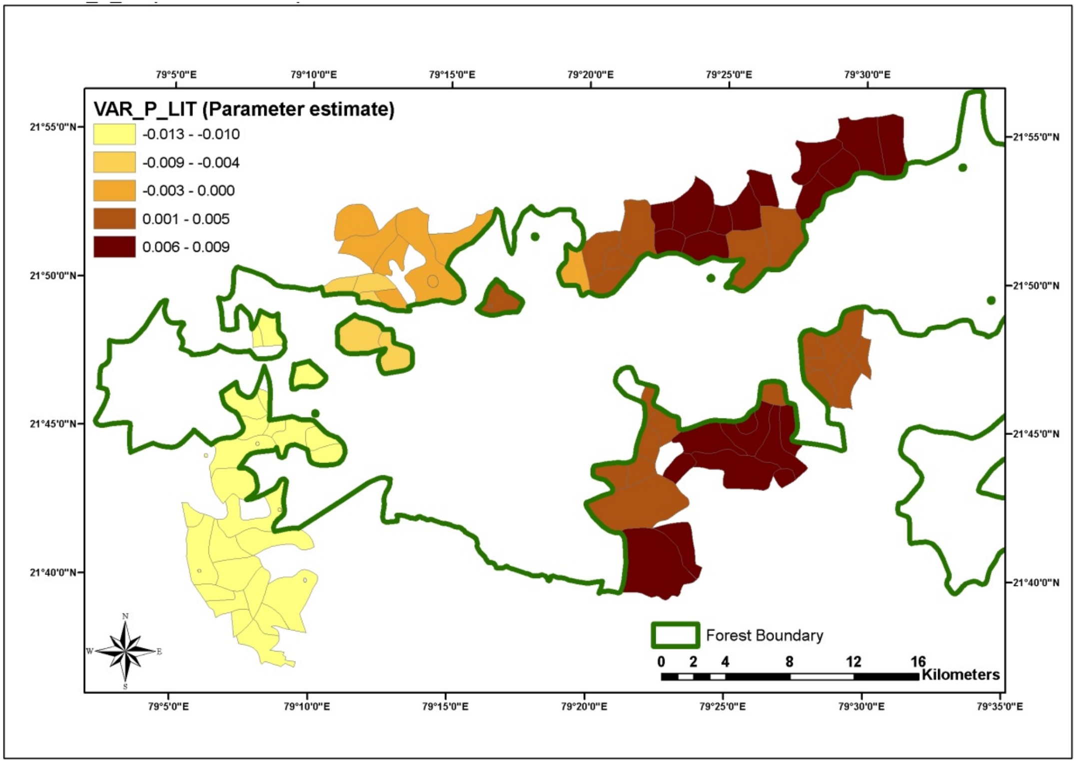


Fig. 5.36 Spatial distribution of pseudo t-values of the variation in literate population in degradation model

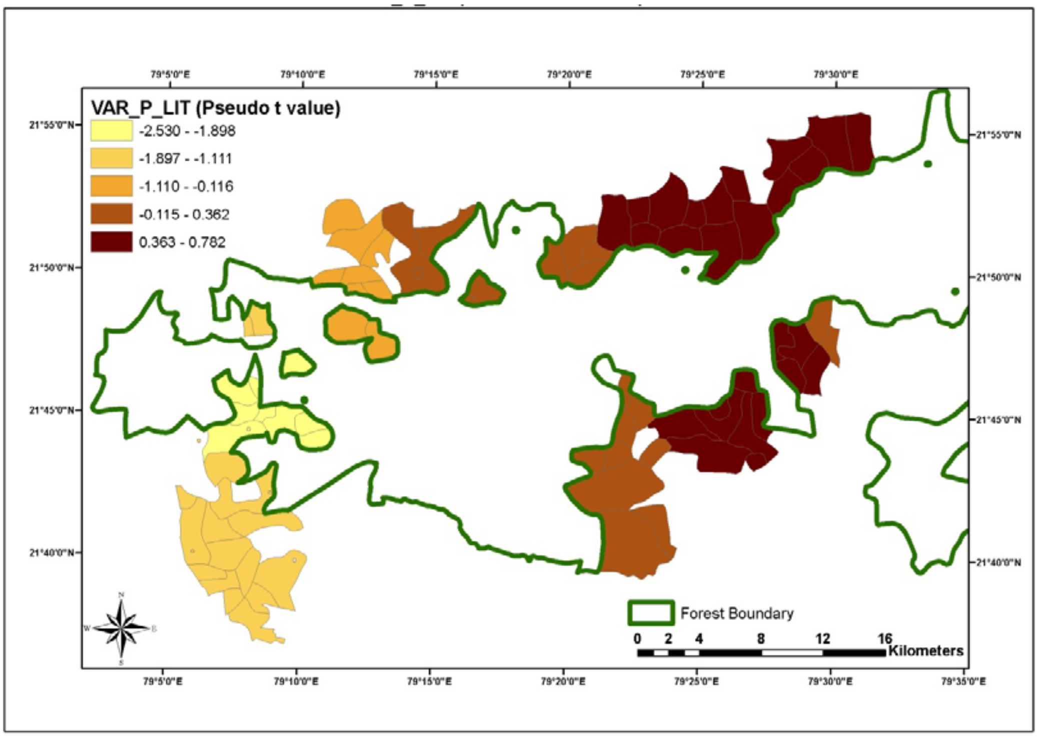


Fig. 5.37 Spatial distribution of parameter estimate of the variation in irrigated land in degradationmodel

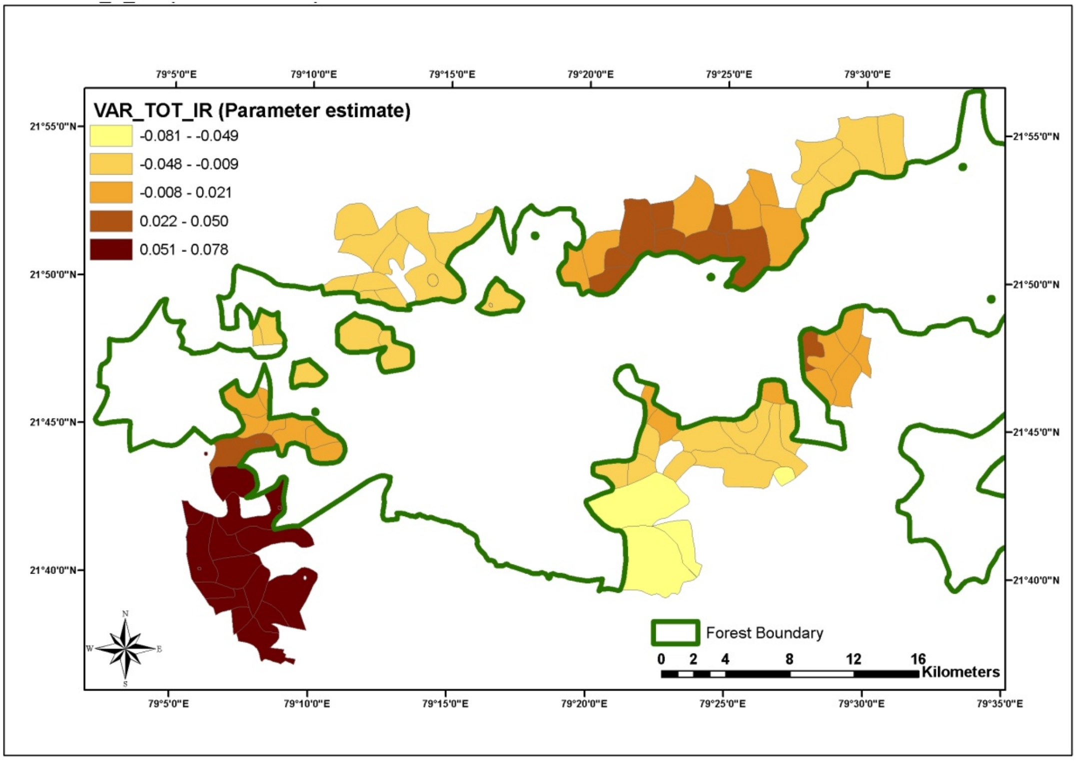


Fig. 5.38 Spatial distribution of pseudo t-values of the variation in irrigated land in degradation model

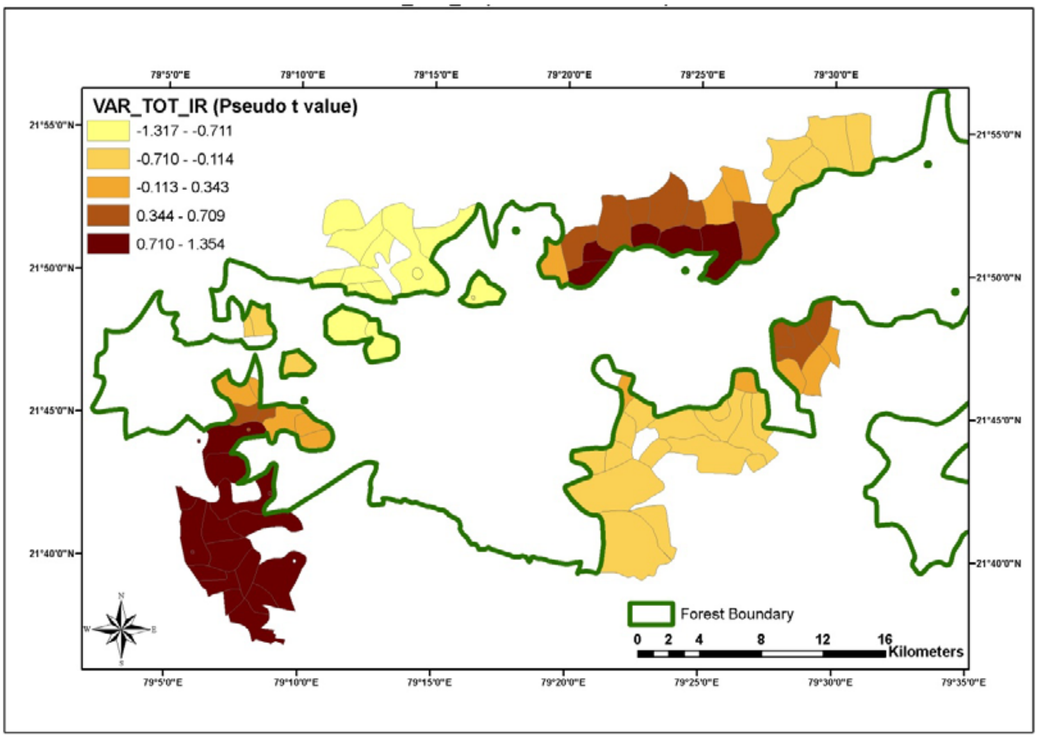


Fig. 5.39 Spatial distribution of parameter estimate of the distance from major roads in degradation model

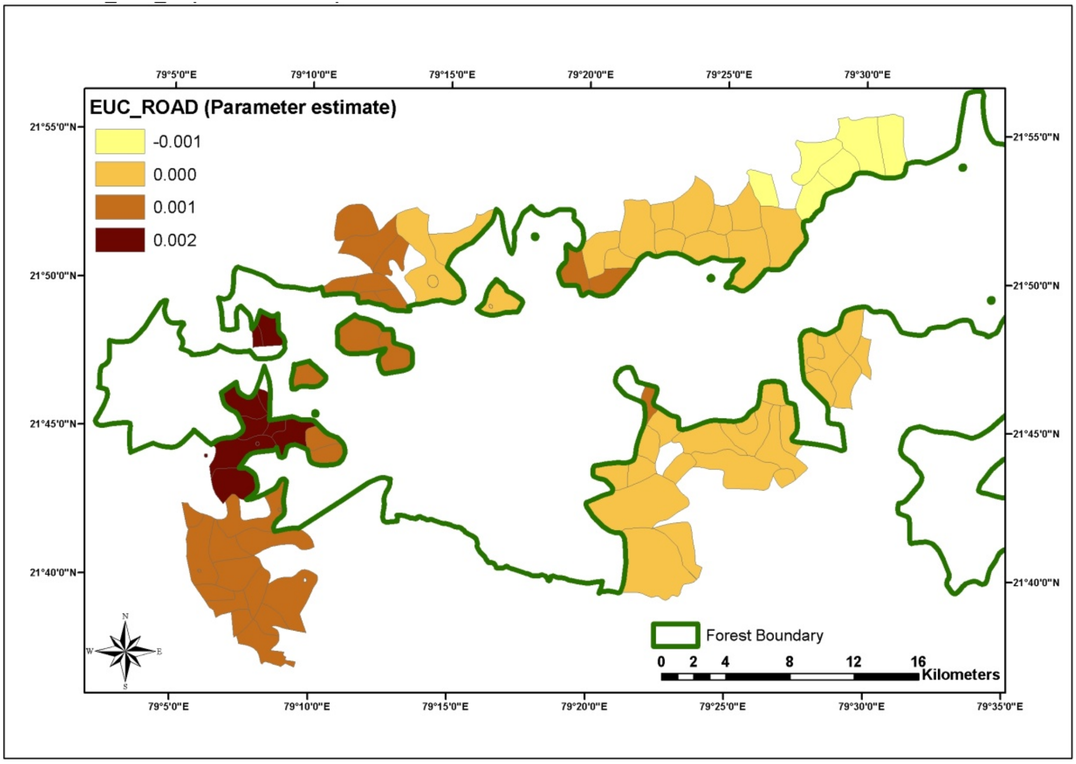


Fig. 5.40 Spatial distribution of pseudo t-values of the distance from major roads in degradation model

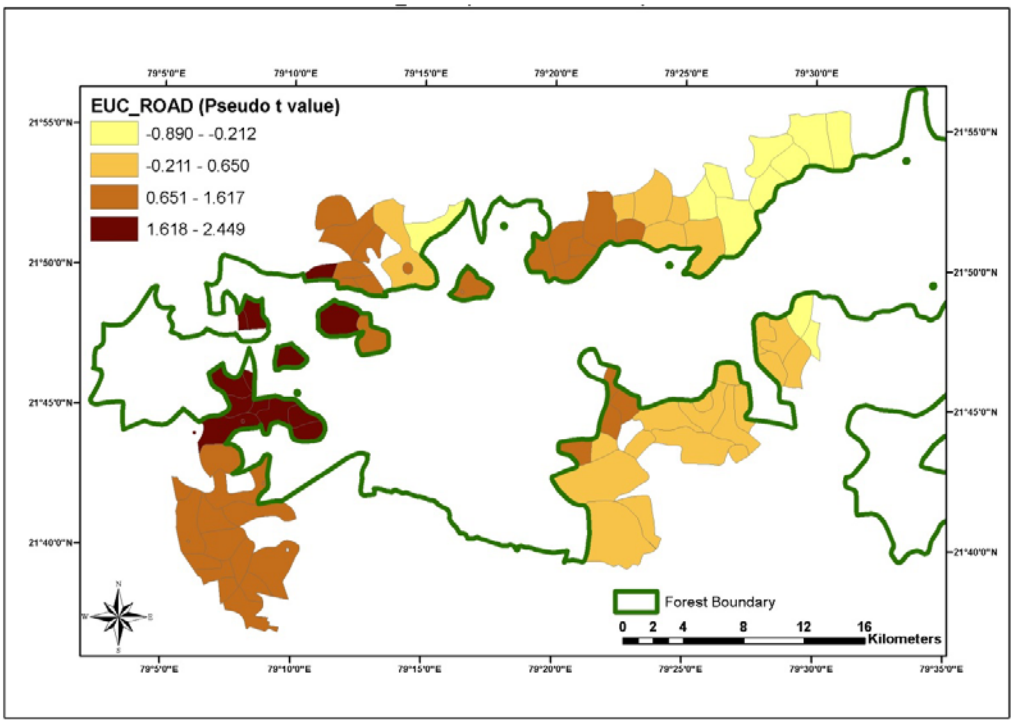


Fig. 5.41 Spatial distribution of parameter estimate of the distance from protected area in degradation model

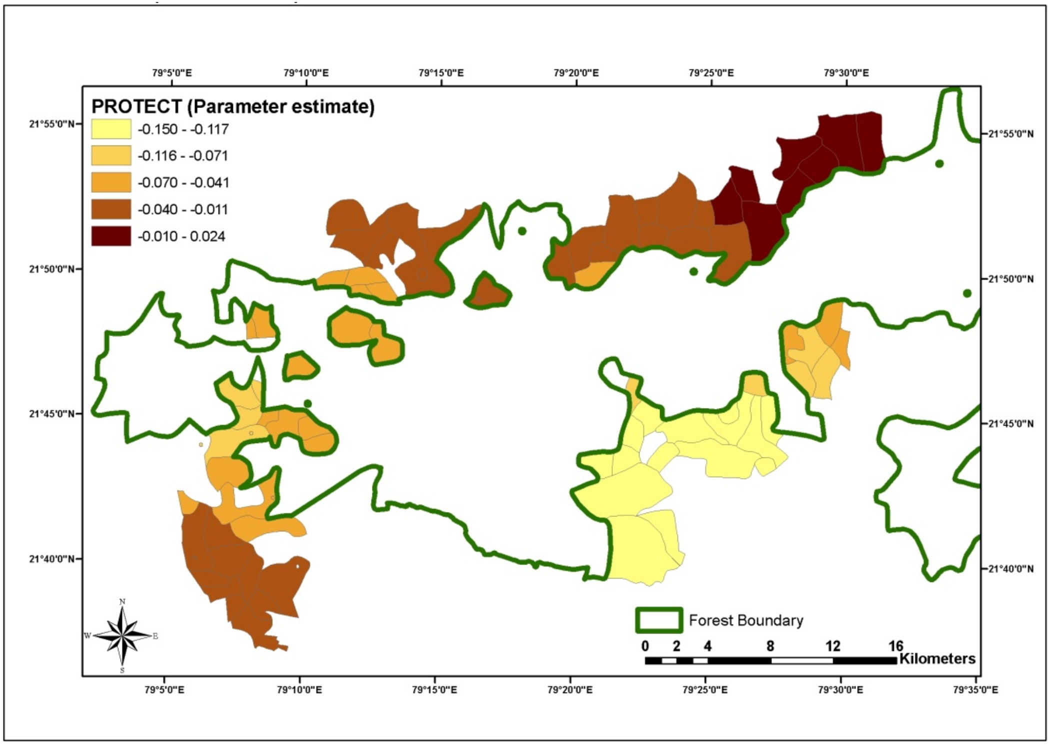
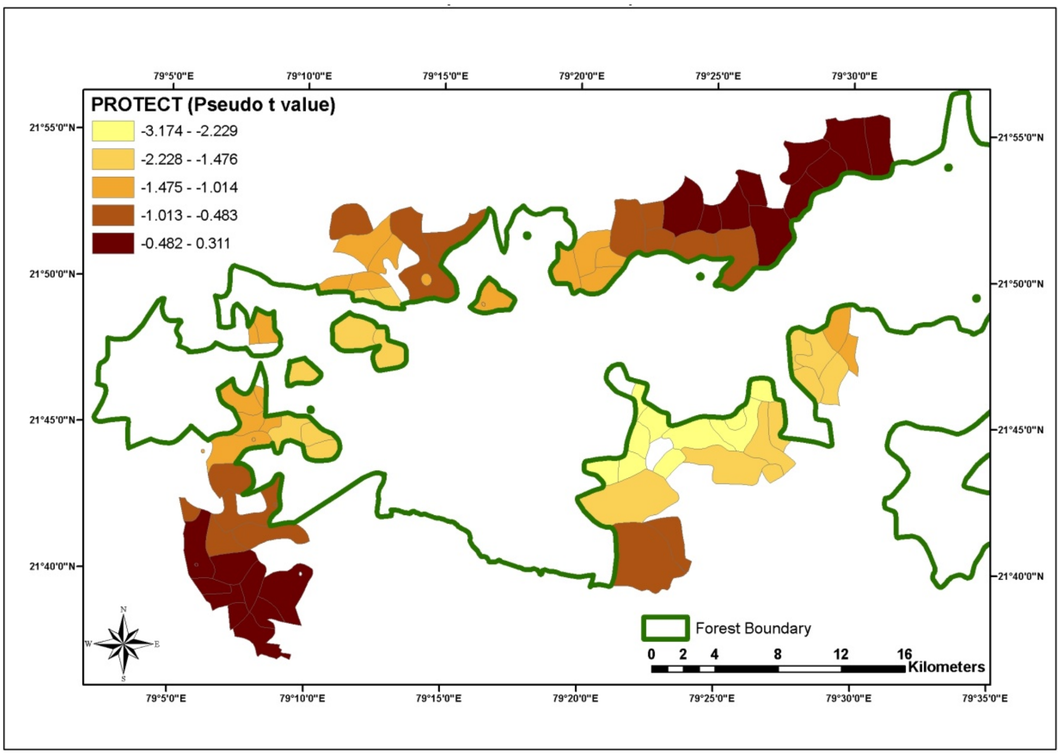


Fig. 5.42 Spatial distribution of pseudo t-values of the distance from protected area in degradation model



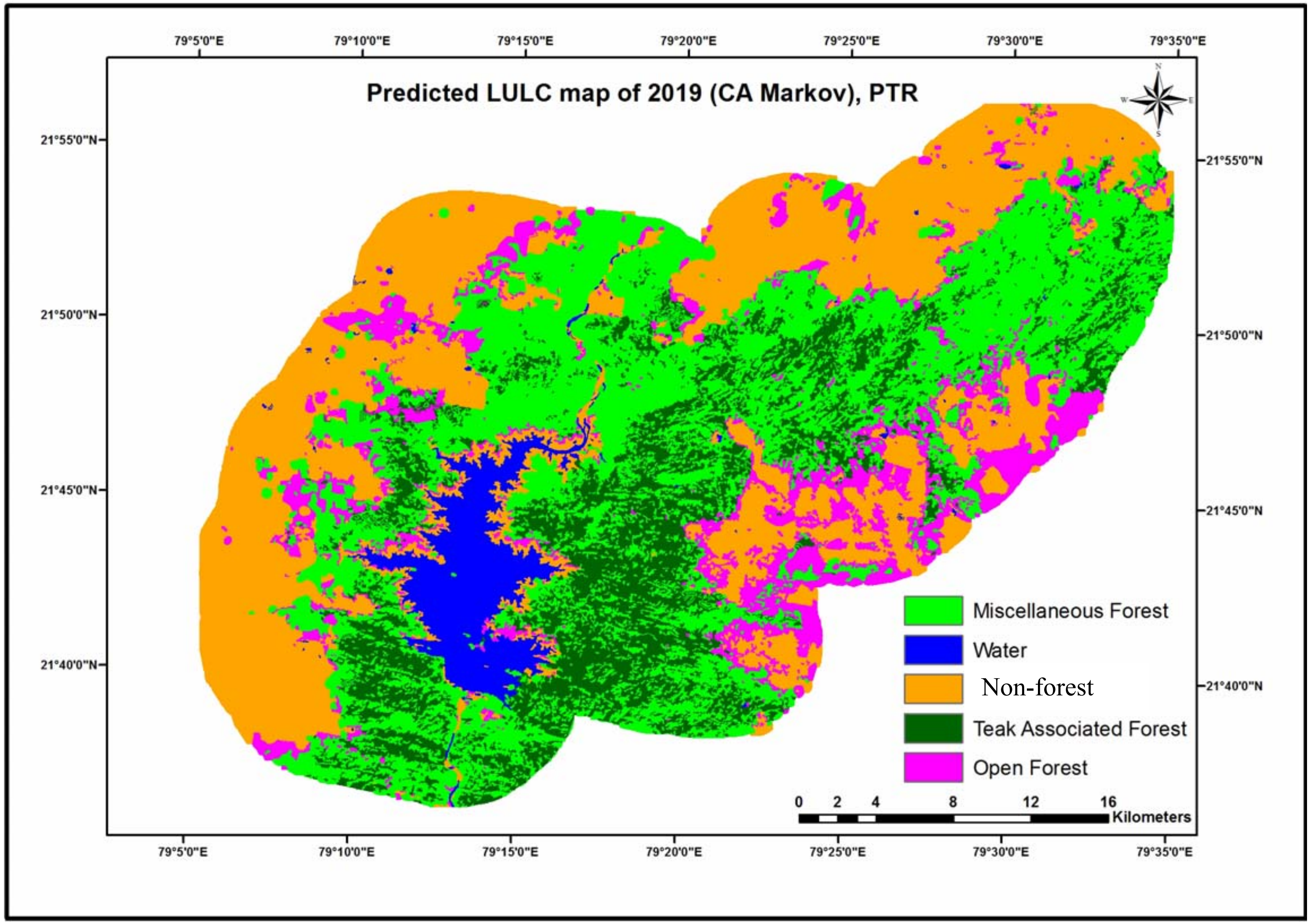
5.3.4.6 Land use land cover prediction by cellular automata model

The land use land cover prediction map of 2019 (Fig. 6.25) had resulted in five classes i.e. Miscellaneous forest, Teak Associated forest, Open forest, Water and Agri-habitation. Miscellaneous forest had turned out to be the largest class (Table 6.21).

Table 5.13 Area under various classes in predicted 2019 LULC map

Class	**Area (Km^2)**
Miscellaneous Forest	413.3
Water	58.9
Non-forest	385.5
Teak	192.5
Open	128.4

Fig. 5.43 Predicted LULC map of 2019 by CA Markov model in and around Pench Tiger Reserve, Madhya Pradesh



5.4 DISCUSSION

Preceded by a global trend of tropical deforestation in the 1980s, many tropical countries witnessed a decline in deforestation rates (FAO 1993 and 2006) with a select few even exhibiting net reforestation (Lugo and Helmer 2004, Rudel 2005, Arroyo-Mora et al. 2005). In the Indian subcontinent in particular, the expansion of forest protection and plantations have led to reforestation (Salam et al. 2000, Lamb and Gilmour 2003, SFR 2007). The present study provided a direct comparison of the effects of strict protection on forest and land-cover changes and thus contributes to the forest management literature. The study area exemplifies a typical case of contrasting management regimes in an area protected for wildlife. This condition enabled us to examine the role of different protective management approaches in preserving forest cover. While we expected to see maintained and/or regenerated forest cover within the park as a result of protection, we also expected greater forest loss over time outside the park, as suggested by many case-studies in the tropics (DeFries et al. 2005). Part of my findings supported other studies showing the effectiveness of parks in maintaining forest cover (Bruner et al. 2001). The findings of the present study had captured the dynamics of those government policies well in terms of protective measures. While the protected area (PA) status of the park became effective from 1977, it still continued to suffer notable forest loss until 1999 especially, in the buffer areas of the park which had continued pressure from the surrounding villages (mainly grazing, NTFP and fuel wood collection). This pre-1999 forest loss and post-1999 forest-cover recovery within the PA could be attributed to the 1983 notification of National Park and 1992 notification of Tiger Reserve by which felling and other timber management activities were banned inside PA, exhibiting the importance of national-level policies in favor of conservation of tiger landscapes.

The present study used NDVI standard normal deviate as a proxy of vegetation health and productivity. NDVI standard normal deviate image differences for the stable forest class showed a decrease in vegetation productivity (Fig. 5.2, 5.3 & 5.4) in later years. This degradation could potentially be due to several factors, e.g. grazing, changes in tree species richness, stand density and canopy cover as a result of felling or plantation activities (Pelkey et al. 2000, Gillespie et al. 2009).

Due to very little forest management intervention for more than 30 years, most of the one or two tree species dominated forest stands (like Teak-associated forests) were converted into mixed forest as shown by the increase in patch area but decrease in number of patches (Fig. 5.6 & 5.7). Uncontrolled extraction of forest resources in terms of fuel wood, fodder, NTFPs, agricultural expansions and utilization of forested lands for grazing left very less forested patch outside PTR where forests were heavily managed for harvesting of timber. While two date change trajectories showed decadal changes in forest covers as a result of changing forest policies, the overall change trajectory drew an overall change scenario experienced in the study area in the last 30 years. The stable forest classes were notably greater than that in any other change classes (Table 5.4). The stable barren class mainly denoted agri-habitational land in this area, which in totally situated outside PTR. The stable water class might be attributed partly to the presence of the Totladoh reservoir in the later images and partly to the precipitation variability resulting in more water in some images. The effect of the dam construction was also evident in the deforestation class, especially within the PA (Fig. 5.5 and Table 5.4). While restoration and upgradation trends were considerably lower in this area, deforestation and degradation trends were interestingly high. The study reported loss of 18.9% forest cover between 1977 and 1989, which was mostly due to the construction of hydroelectric dam and continuous increase in demands of people. The dominance of non-forest land covers in the northern, western and southern boundaries of the park related to the presence of villages in vicinity of the park which were dependent on the forest for fuel wood collection, cattle grazing and other minor forest products.

Villagers travelled most for collection of fuel wood (Mean 4.07 km, SE 0.35) compared to grazing and NTFP collection (Mean 3.28 km, SE 0.24 and Mean 3.3 km, SE 0.23 respectively). It was evident that both deforestation and degradation of forest inside the core area were negligible in the post 1999 period. In the middle area which comes under protected area and extraction radius though deforestation is negligible, registered almost similar trend in degradation of forested areas which could be interpreted as continuous resource extraction process even places inside PA. Its beyond the scope of this study to say which village was contributing how much for this kind of changes but in depth study along the boundary of PTR would definitely prove worthy in improving the quality of the forest. The India Eco-development project (1996-2001) funded by United Nation Development Programme (UNDP), aimed at involving forest dependent communities in sustainable forest management. Among all the villagers that fall within 5 km buffer around PTR, 99 villages were targeted under this project. This new participatory management regime was expected to reduce extraction and grazing pressure on the protected area as well as surrounding buffer by reducing forest dependence for fuel wood (through supply of bio-gas and LPG) and controlled grazing on marked pasture. Yet, researchers and scientists had continually been skeptical about the degree of true participation of the communities and intension of forest officials and public sectors to engage the local people in conservation efforts (woodman 2004, Nayak and Berkes 2008). Woodman (2002) pointed out that the antecedent conditions for the India Ecodevelopment Project were not conductive in the study area because of a lack of experience of such projects and lack of trust between the parties and thus transmission of project ideas, ethos and methodology was severely limited, partially due to resistance to change from both villagers and forest departments. Nevertheless, the concept of involving local people in conserving forest was appealing and with true implementation holds the promise of successful and potentially sustainable forest management.

While two-date change trajectories showed decadal changes in forest covers as a result of changing forest policies, the overall change trajectory drew an overall change scenario experienced by the study area in the last 30 years. While deforestation and degradation were negligible in PA in post 1999 period, reforestation and upgradation trends are quite interesting in pre 1999 period also stabilized in the post 1999 (table 5.9). Outside forested areas showed considerable deforestation and an alarming degradation in post 1999 (Table 5.9). It could be visualized as good protection and management strategies in the post 1999 period almost stabilized changes in the forest inside PA whereas outside forests had higher degradation rates due to imposed ban and strict legislation on cutting trees.

While this study design did not allow me to identify the casual factors of this degradation, this difference in forest quality was important and will hopefully lead to more detailed ecological studies in this region. The differences in forest coverage in and around PTR, Madhya Pradesh most likely reflect the difference in degree of protection.

This study contributed to the land/forest cover change and socio-economic, biophysical and proximity factors affecting it. It was the first large scale forest cover change study in India for entire Tiger Reserve and its surrounding that investigates forest cover change and spatial variation within determinants by applying GWR. This study showed the importance of studying local spatial variation of forest cover in a protected area gathering information at village level with a set of demographic, biophysical and proximity determinants. Finally, this study demonstrates the importance of GWR as a tool for exploring local spatial variation of forest cover change and reducing spatial autocorrelation. This instrument could be used for studies with focus on natural resources in human-dominated landscapes managed for wildlife to reveal information at local level, which could be otherwise neglected. A GWR study should investigate whether local spatial variation was due to the influence of determinants to a response variable, a step which was not often in use though we found it valuable and meaningful. GRW analysis explored the behavior of variables at a local level and revealed significant spatial variability among some of them. This represented a clear enhancement of the understanding offered by a global analysis, rather than obtaining an average coefficient for the entire area, an estimated coefficient for each point analysed was obtained. Furthermore, this method revealed certain aspects of the inter-relationships which did not emerge with traditional global specifications. This implied that the parameter estimates for this regression varied according to geographical location. Therefore, the application of this method made it possible to study the spatial stability of the global model coefficients. It was found that the coefficients of many variables were spatially non-stationary and that the models produced using GWR describe the data significantly better than the global model (OLS).

India has a network of 660 protected areas that includes 99 national parks covering an area of 39,048km^2 (1.19% of the country) (National Wildlife Database, 2009). This network was created to help conserve a significant part of the country's biodiversity. The basic approach of park management in India has been exclusionary based on the assumption that permanent human settlement within or in near vicinity of the park degrades the ecosystem through resource extraction, which has been supported by several case studies (Barve et al. 2005, Karanth et al. 2006, Davidar et al. 2007). In the present study, the park suffered from less deforestation after it was declared a national park. The actual scenario, even in the absence of the intervention, could have been something different than that predicted in this study. I attempted to capture the trend of changes in land use/ land cover and predicted future conditions in the landcape. With continuous increase in human population, forests in India are not only experiencing multiple fold increase in pressure but changing in much faster rate than anticipated in all tropical countries.

Chapter-6 Habitat Suitability Modeling

6.1 Introduction

Competition between human activities and wildlife is becoming more intense due to habitat destruction, leading to the decline of wildlife species. Effective wildlife conservation needs to reduce the friction between human and wildlife activities by identifying areas suitable for wildlife, and by reducing human intervention in these areas. For this purpose, mapping of suitable habitat is very important for wildlife conservation and ecosystem management. The actual geographical distribution of species as Habitat Suitability (HS) map is the result of the analysis of species–environment relationships (Dormann et al. 2007). Species distribution lies well within the optimal range of environmental factors (Kormondy 2003). It is, therefore, useful for ecological modelers to design a methodological algorithm to compute HS by incorporating most of the environmental factors with presence–absence data or only with presence data to develop a more precise estimate.

Ecological background and habitat definition are essential knowledge for HS modelling. Within the trophic levels of the food web in an ecosystem, organisms differ from each other in terms of population sizes, in terms of their roles as producer, prey, competitor, predator, etc., and also in terms of other biotic interactions. Species affect each other directly or indirectly depending on their relationship. Data based on field observation automatically include ecological autocorrelation among species (Betts et al. 2006, Dormann et al. 2007, Lichstein et al. 2002) and must reflect species relationships and interactions. The availability of ecological components in terms of the quality and quantity of both physical factors and chemical conditions, on the other hand, determines the distribution pattern of plants, animals and microbes (Pirot et al. 2000).

The 'ecological niche' is an important concept in HS modelling. It has been developed on the basis of the relationship between a species and its environment. Earlier scientists preferred an autecological and physiological approach to the niche (Austin 1992), while later writers focused more on trophic levels or food web theory (Guisan and Thuiller 2005). The ecological niche concept was first introduced by

Grinnell (1917), who argued that every species has its own physiological, morphological and behavioral profile, which makes it suitable to occupy particular spaces offered by nature. Elton (1927) described niche as an integration of the interactions of species with their biotic environment in terms of food and enemies, excluding abiotic factors (Meyer 2007). Hutchinson (1957), on the other hand, developed the concept of niche as the sum of all environmental factors acting on the organism; the niche is thus defined as a region of a *n*-dimensional hypervolume. He also mentioned that under constant conditions, competitive relationships reduce the size of the fundamental niche to the size of a realized niche (Pulliam 2000, Meyer 2007). According to Dennis et al. (2003), niche is: (1) the place or living space, where an organism lives, (2) a place comprising a set of resources, consumables and utilities for the maintenance of an organism, (3) a form of behavior that appears to be essentially innate (Robinson and Bolen 1984), and which leads to the selection of an appropriate habitat in which an animal is most likely to survive and reproduce. The availability of resources and utilities such as food, shelter, concealment, and refuge constitutes the carrying capacity of a suitable site (Capen et al. 1986, Caughley and Sinclair 1994, Phumiphakphun 1999, Schamberger and O'Neil 1986, Titeux 2006). Tolerance (Scalet et al. 1997) is another inherent factor of species, which has an influence on their distributive capacity (Whittaker et al. 1973).

Environmental factors can be divided into two main groups: (1) environmental requirements of species under the influence of limiting factors, (2) environmental impacts on species such as disturbances and perturbations affecting environmental systems (Guisan and Thuiller 2005).

Williams (2003) categorized HS models based on the original data of species into (1) presence–absence models and (2) presence models, and explained further that species data are employed extensively in habitat modeling and that most modeling methods use statistical tools, particularly multiple regressions. Guisan et al. (2006) argued that ecological modeling can be improved by including individual species' distribution as a bottom-up approach. They also proposed how to make better predictions of biogeography, and determined a framework to predict HS more efficiently by: (1) linking to ecological theory, (2) using existing data and already generated information, (3) incorporating spatial technique, (4) including ecological and environmental interactions, (5) evaluating the errors and uncertainties of the process and (6) predicting distribution of communities.

The issue was that we did not know why certain species occur in certain places, and we did not know which environmental factor had an influence on the presence of species in each location. Environmental parameters (EnvPs) such as physical factors, biological factors (Guisan and Thuiller 2005, Guisan and Zimmermann 2000, Williams and Araujo 2000) and human factors have always been put into the model at the same time to analyze HS either through presence–absence models such as Generalized Linear Modeling (GLM) (McCullagh and Nelder 1989), Discriminant Function Analysis (Davis 1986), Generalized Additive Modeling (GAM) (Hastie and Tibshirani 1986), Artificial Neural Networks, and Classification and Regression tree (CART) or other presence models such as Maximum Entropy Method (MaxEnt) (Phillips et al. 2006) and especially, Ecological Niche factor analysis (ENFA model). Greaves et al. (2006), for instance, used GLM for estimating HS of the New Zealand long-tailed bat (*Chalinolobus tuberculata*)with six EnvPs, and obtained a correct classification rate value of 0.56, and predictive power values of 0.45 and 0.1 for presence and absence, respectively. Cassinello et al. (2006) used ENFA with 31 EnvPs for estimating HS of aoudad (*Ammotragus lervia*) obtained a correct classification rate value of 0.6, etc. Both of the studies excluded environmental categorization and species–human interaction factors in HS modeling.

Based on the assumption that species must be affected by each feature in terms of their behavior, movement and activities, HS modeling incorporating all EnvPs at the same time, may result in lower predicting power. Environmental impacts and trophic effects (Arditi et al. 2005) such as competition, predation and other ecological interactions (Pulliam 2000, Titeux 2006) as well as perturbations by humans (Guisan and Zimmermann 2000, Guisan and Thuiller 2005), however, have not been incorporated into modeling to a comparable extent, despite the fact that they play an extremely important role in determining HS. In this study, these factors were incorporated into HS modeling for complete ecological modeling.

6.1.1 Chital (*Axis axis*):

Chital is an endemic species of south Asia, occurring in India, Sri Lanka, Nepal and Bangladesh (Prater 1934, Schaller 1967). They are found in a variety of forest types in India viz. dry deciduous, moist deciduous, thorn and mangrove forests. The introduced chital population in Andaman Islands is found in evergreen forests.

Chital are known to feed on more than 160 species of plants (Schaller 1967, Johnsingh and Sankar 1991). Schaller (1967) showed that grass/herb formed the bulk of the feed of chital, while Mishra (1982) considered chital primarily a grazer. Sankar (1994) found that chital was a grazer as long as green grasses were available (monsoon and post-monsoon seasons), but switched over to fallen leaves, flowers and fruits in winter. Chital form one of the important preys of top carnivores as is evident from studies in Kanha (Schaller 1967), Bandipur (Johnsingh 1983), Rajaji National Park (Johnsingh et al. 1993), Sariska (1994), Pench (Biswas and Sankar 2002) and Ranthambore (Bagchi et al. 2003).

6.1.2 Sambar (*Rusa unicolor*):

Sambar (*Rusa unicolor*) is the largest deer species native to South and South-East Asia. Adult sambar stags weigh between 225 and 320 kg. It has an exceedingly wide geographical distribution that includes India, Myanmar, Sri Lanka, extending through the Malay countries, and eastward to the Philippines and beyond (Prater 1971). Within India sambar occur in the tropical thorn forests of Gujarat and Rajasthan, in the moist deciduous forests throughout peninsular India, in the pine and oak forests at the Himalayan foothills, and in the evergreen and semi-evergreen forests of north-eastern India. Sambar had been observed to feed on more than 139 species of plants (Schaller 1967, Johnsingh and Sankar 1991). Sambar would graze or browse depending upon the forage available at any given point of time. The estimated annual home range of sambar stags was nearly 15 km^2, whereas that of hinds was nearly 3 km^2 (Sankar 1994). The preference of sambar for heavy cover has already been recorded (Schaller 1967, Johnsingh 1983). Sambar predation is mainly by tiger, leopard and dhole (Schaller 1967, Johnsingh 1983, Karanth and Sunquist 1995, Sankar 1994, Biswas and Sankar 2002, Bagchi et al. 2003). Sambar are predominantly forest-dwellers, favouring the cover of trees, venturing out into the open mainly at night, and late at dusk or early dawn. They usually rest the whole of the daylight hours (Schaller 1967).

6.1.3 Wild Pig (*Sus scrofa*):

Wild pigs are ungulates native to Eurasia. The wild pigs occupy a wide variety of habitats, from semi-desert to tropical rain forests, temperate woodlands, grasslands and reed jungles, and often venturing into agricultural land to forage (Prater 1971). They are omnivorous, living on crops, roots, tubers, fruits and carrion. The stomach and fecal matter analysis indicated that vegetable matter, fruits, seeds, roots and tubers, constituted about 90% of the diet (Prater 1971, Spitz 1986). Wild pigs form an important part in the diets of tiger, leopard and dhole.

6.1.4 Tiger (*Panthera tigris*):

Tiger is the largest Felid classified into nine subspecies including three extinct ones. Tigers once ranged widely across Asia, from Turkey in the west to the eastern coast of Russia. Over the past 100 years, they have lost 93% of their historic range, and have been extirpated from southwest and central Asia, from the islands of Java and Bali, and from large areas of Southeast and Eastern Asia. Today, they range from the Siberian taiga to open grasslands and tropical mangrove swamps. The remaining six tiger subspecies have been classified as endangered by IUCN. The global population in the wild is estimated to number between 3,062 to 3,948 individuals, with most remaining populations occurring in small pockets that are isolated from each other. Major reasons for population decline include habitat destruction, habitat fragmentation and poaching (Chundawat et al. 2011). The extent of area occupied by tigers is estimated at less than 1,184,911 km^2 (457,497 sq mi), a 41% decline from the area estimated in the mid-1990s (Sanderson 2006). Tiger habitats will usually include sufficient cover, proximity to water, and an abundance of prey. Bengal tigers live in many types of forests, including wet, evergreen, the semi-evergreen of Assam and eastern Bengal; the mangrove forest of the Ganges Delta; the deciduous forest of Nepal, and the thorn forests of the Western Ghats. In the wild, tigers mostly feed on larger and medium sized animals. Sambar, chital and wild pig are the favoured prey of tiger in India.

6.1.5 Leopard (*Panthera pardus*):

The leopard is a member of the Felidae family and the smallest of the four "big cats" in the genus *Panthera*. The leopard was once distributed across eastern and southern Asia and Africa, from Siberia to South Africa, but its range of distribution has decreased radically because of hunting and loss of habitat. There are nine sub-species recognized by IUCN (Hanschel 2011, Uphykina 2001). It is now chiefly found in sub-Saharan Africa; there are also fragmented populations in the Indian subcontinent, Sri Lanka, Indochina, Malaysia, Indonesia, and China (Hanschel 2011). Leopards live mainly in grasslands, woodlands, and riverine forests. They are usually associated with savanna and rainforest, but leopards are exceptionally adaptable: in the Russian Far East, they inhabit temperate forests where winter temperatures reach a low of −25 °C (−13 °F) (Uphykina 2001). Major prey species for leopard are chital, sambar and wild pig.

6.1.6 Dhole or Indian Wild Dog (*Cuon alpines*):

The dhole or Indian Wild Dog is a species of canid native to South and Southeast Asia. The dhole is a highly social animal, living in large clans which occasionally split up into small packs to hunt. It primarily preys on medium-sized ungulates, which it hunts by tiring them out in long chases, and kills by disemboweling them. Prey species for dholes in India include chital, sambar, muntjac, mouse deer, wild pig, cattle, goats and common langur (Achariya 2007, Durbin et al. 2011). Dholes are primarily diurnal hunters, hunting in the early hours of the morning. In some areas, dholes are sympatric to tigers and leopards. Competition between these species is mostly avoided through differences in prey selection, although there is still substantial dietary overlap observed (Karanth and Sunquist 1995). Dholes once ranged throughout most of South, East and Southeast Asia, extending from the Tien Shan and Altai Mountains and the Primorsky Krai southward through Mongolia, Korea, China, Tibet, Nepal, India, and south-eastwards into Myanmar and Indochina, Thailand, Malaysia, Sumatra and Java (Hunter 2011). Dhole inhabits forest, forest grassland mosaic and montane scrublands from peninsular India to Eastern Himalaya.

6.2 METHODOLOGY

Chital (*Axis axis*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*) among the herbivore species and among carnivores, tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*) were chosen for large mammal habitat suitability (HS) modeling. Very few sightings of gaur (*Bos gaurus*) restricted me to do habitat suitability modeling for this species. The ENFA model was applied to analyze the study species HS.

6.2.1 ENFA model:

The ENFA model was designed on the basis of Hutchinson's niche concept (Hutchinson 1957), which focuses on presence only data. It is widely accepted because it does not need absence data which often are not available or difficult to sample, even if the sampling is systematic. Absence data, however, seem to reflect closer links with unsuitable habitat (Jimenez-Valverde et al. 2007, Tole 2005). Hirzel et al. (2002) explained that absence data may be arranged into two types: (1) species are absent from suitable habitat because they cannot be detected and (2) species are absent from habitat that is truly unsuitable. ENFA compares the Environmental parameters (EnvPs) of species distribution and global distribution. The ecological niche of a species is normally a subset of its global distribution. Hirzel et al. (2002) have determined the following two parameters: (1) the difference of mean between species distribution and global distribution, called "marginality", which is shown in Eq. (6.1):

$$M = \frac{|mG - mS|}{1.96\sigma G} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6.1)$$

M is the marginality for a species expressed by the fact that the species mean differs from the global mean. *mG* is the mean of global distribution. *mS* is the mean of species distribution. σ*G* is the variance of the global distribution. The ratio between variance of global distribution and species distribution, called "specialisation", which is shown in Eq. (6.2). The specialisation of a species is expressed by the fact that the species variance is lower than the global variance. Specialisation indicates how restricted the species' niche is in relation to the study area (Hirzel et al. 2002):

$$S = \frac{\sigma G}{\sigma S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6.2)$$

S is the specialisation of a species and σ*S* is the variance of species distribution. Eqs. (6.1) and (6.2) is given here mainly to explain the principle of ENFA. For overall marginality of all EnvPs, ENFA is computed in Biomapper as:

$$M = \sqrt{\frac{\sum_{i=1}^{v} m_i^2}{1.96}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6.3)$$

The coefficient *mi* of the marginality factor expresses the marginality of a species for each EnvP in units of variance from the global distribution. Along the *mi*, Hirzel et al. (2002) explain that the signs (minus and plus) of the coefficients indicate whether the suitable habitat is found above or below the average value of each EnvP. *M* is the marginality of all EnvPs. The large value of *M* indicates that species range is different from average condition of all EnvPs. ENFA also calculated overall specialisation in Biomapper as

$$S = \sqrt{\frac{\sum_{i=1}^{v} (\sigma_{Gi}/\sigma_{Si})^2}{v}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

S is in range from1 to infinity, with the niche becoming narrower as *S* increases (Bryan and Metaxas 2007). σ*Gi* is variance of the global distribution of EnvP *i* while σ*Si* is variance of the species distribution of EnvP *i*. *v* is the number of EnvPs. The ENFA model uses raster grid maps containing continuous values of EnvPs. The specialisation factors were produced as uncorrelated factors by maximizing the ratio of variance of global distribution and of species distribution (*S*). These specialization factors were constructed by alternately removing and restoring each EnvP (Hirzel et al. 2002), until all EnvPs were extracted. This process is similar to PCA (principal component analysis). HS maps build on a count of all cells of species distribution that are situated as far as or farther apart from the median than the cells of each specialisation factor. This count is normalized in such a way that the suitability index ranges from 0 to 100 (Estrada-pena et al. 2006, Hirzel et al. 2002, Zaniewski et al.

2002). The suitability of any cell of global distribution is calculated from its situation relative to the species distribution on all selected specialisation factors, which were selected as first few factors. ENFA takes 100% of the marginality, as well as some proportion of specialisation factors into account for computing the HS index. Biomapper 3.2 (Hirzel et al. 2004) as a GIS-statistic program was designed to process according to the ENFA concept in order to facilitate the generation of HS maps (Zaniewski et al. 2002).

6.2.2 Dataset of wildlife species, human activities/visitations and human-induced events

Three to five km carnivore sign survey (Jhala et al. 2008) (total effort = 252 km) for major carnivore species (tiger, leopard, wild dog) by recording their signs (pugmark, scat, scrape, rake, direct sighting) and two km line transects for major wild ungulate species (chital, sambar, wild pig) were walked (total effort = 168 km) in all 43 beats of the study area (Fig. 6.0) , which had been collected during 2007-2009 in PTR in winter (November to February). Data on carnivore signs and wild ungulate sightings were converted to encounter rates per kilometer. These encounter rates were mapped at beat level. Data on human disturbance signs such as signs of lopping, wood cutting, number of trails and livestock dung were collected in 10 m radius plots at every 400 m on the line transects. These data was also mapped at beat level. The distribution map of tiger, leopard, wild dog, chital, sambar, wildpig were prepared in ArcGIS 9.2 (ESRI Inc.) by using GIS technique and was transformed to Boolean map in Idrisi based on 1 km X 1 km square pixels covering PTR and its five km buffer.

6.2.3 Dataset of environmental parameters

GIS layers such as beat boundary, streams and roads were digitized from Survey of India (SOI) toposheets. These GIS layers were generated to produce the EnvP maps as environmental variables. The EnvPs were arranged based on similarity of mechanisms and, in addition to that, on species–human interactions (Guisan et al., 2006). Three main features were categorized. Altogether 35 EnvPs, which consist of 18 geographical and resource parameters, 11 human disturbance and 6 species interaction parameters (Table 6.1). All EnvPs, to serve as input into ENFA model, must be in the form of quantitative maps, which contain continuous values such as slope and elevation. Therefore, qualitative maps like vegetation types were generated and transformed into Boolean maps in Idrisi. Distance measurement was applied to produce parameter maps by using Euclidian distance. All EnvP maps must be prepared in the form of idrisi format.

Table 6.1 Details of variables used in different habitat suitability models

Variables in species Interaction model	**Variables in geographical-resource model**
Chital encounter rate	Percentage High canopy
Sambar encounter rate	Percentage Medium canopy
Wild pig encounter rate	Percentage Low canopy
Tiger encounter rate	Percentage No canopy
Leopard encounter rate	Percentage Agriculture
Wild dog encounter rate	Percentage *Cliestanthus colinus*
Variables in human disturbance model	Percentage Miscellaneous forest
Lopping signs	Percentage Open forest
Cattle dung	Percentage Riverine forest
Livestock seen	Percentage Submergence
People seen	Percentage Teak dominated forest
No. of Trails	Percentage Teak-lagerstromia forest
No. of Wood cutting signs	Percentage Teak-mixed forest
Distance from road	Elevation
Distance from village	Slope
	Distance from water

6.2.3.1 Species interaction

This feature has been added to HS modelling to include the effect of perturbations by other species (Guisan et al. 2006). It is generally not used as input for habitat modeling because of the lack of data on other species in a study site. This feature was categorized into two groups: encounter rates of competitor species and encounter rates of predator/prey species. Parameters for this feature were generated by dividing PTR and its five Km buffer into 1 kmX 1 km fishnet grids. GIS technique was used to analyze the species encounter data.

6.2.3.2 Human disturbance factors

This feature influences species through disturbances and pressures, causing the animals to retreat to interior places. Human factors include (1) human disturbance signs, (2) distance to villages and (3) distance to roads. Data on human disturbance signs like signs of lopping, wood cutting, grass- bamboo cutting, number of human trails, livestock dung and people seen were collected in 10 m radius plots at every 400 m on the line transects laid in every beat for ungulate encounter rate estimation. These data was also mapped at beat level. The mean value was extracted by the same 1 kmX 1 km square pixels.

6.2.3.3 Geographical and resource features

This feature has been used early in habitat modeling. It describes the landscape characteristics and their effect on the movement and the geographical region of a species. This study has defined geographical features as follows: (1) Elevation and slope generated ASTER GDEM 30 m resolution data downloaded from http://www.gdem.aster.ersdac.or.jp/ , (2) Distance to waterhole: Euclidean distance function was used to generate this geo-parameter, (3) Land use/cover classes and forest density classes (discussed in Chapter 3 in details) and (4) Normalized Difference Vegetation Index: this was generated from Infra red (IR) and near IR bands of the multi-spectral Landsat TM satellite imagery.

6.2.4 HS map by model averaging:

HS mapping for target species was done in two steps to produce HS map: (A) Using ENFA model to produce 3 HS maps by separate niche analysis according to the three sets of features, i.e. species interaction features, geographical and resource feature and human disturbance features (model 1–model 3). Marginality and specialisation were computed separately for each model. This method is the key point for HS analysis according to the influence of each feature. Each HS map indicates and provides suitable habitat in the form of (1) geographical/resource region where species prefer to live, (2) region for species to retreat from human disturbances and (3) preference/avoidance for species due to interaction with other species. (B) The next step was model averaging (model 4) which was performed to include all EnvPs by averaging the HS values of model 1 to model 3 as 3-dimensional hypervolumes of HS according to the three features by using the marginality of three HS as an axis. This model can explain the relationship between niche and species distribution according to Pulliam (2000), who proposed four theoretical models by interpreting *2*-dimensional environments: (1) the *fundamental niche* of Grinell, where species occupy a suitable area and are absent in unsuitable areas; (2) the *realized niche* of Hutchinson, where competition may lead to species being absent from a suitable area; (3) the source–sink dynamic whereby conditions for a species to satisfy its requirements are favorable or sufficient in the source habitat, and unfavorable or insufficient in the sink habitat, (4) the dispersal limitation situation in which a species can sometimes be absent from suitable habitat.

6.2.5 Model evaluation

The approaches of model 1 and model 3 performed with ENFA differed from each other methodologically with respect to the manner of inputting the EnvPs. Model 4 is the result of integrating the average HS values of model 1–model 3. All HS maps contain the probability values of HS between 0 and 100. All the models were compared. The Absolute Validation Index (AVI) and the Contrast Validation Index (CVI), which is provided in Biomapper, were used to evaluate all result models. CVI can be calculated by AVI-AVI0 when AVI0 (AVIzero) is the proportion of all pixels with HS > 50, with the CVI always lower than the AVI. A good model should have a high value of both AVI and CVI in the sense that AVI should have value >0.6 and CVI > 0.3 (Hirzel et al. 2004).

6.2.6 Habitat classification

The HS map of different species were classified into four habitat types: highly suitable habitat (HS values >60), moderate suitable habitat (40 <HS values <=60), low suitable habitat (20 <HS values <=40) and unsuitable habitat (HS values are <=20). Suitable habitat contains most of the essential conditions of the three EnvP features, and is sufficient for species to survive and to reproduce. The suitability values decrease from moderate suitable to low suitable and to unsuitable habitat until some essential conditions are no longer sufficient for species.

6.2.7 Predicted HS of different species with cellular automata model predicted land use land cover

ENFA was used to predict future habitat suitability of tiger, leopard, wild dog, chital, sambar and wild pig. Predicted 2019 land use land cover map was used in these models. To compare the changes in different suitability classes between present and 2019 HS, present model was also run with 2009 land use land cover map only.

6.3 RESULTS

6.3.1 HS model for Chital:

Incorporating the presence data of chital (n = 530), has resulted in the three HS map (model 1 to model 3) for species interaction, human disturbances and geographical–resource factors respectively (Fig. 6.1-6.3). The proportion of explainable information in model 1 to 3 are 89%, 95% and 84% respectively. The overall marginality (M) for model 1 to 3 are 0.75, 0.56 and 1.23 respectively and the overall specialisation (S) are 0.94, 2.36 and 1.345 respectively. This indicates that chital preferred habitat that are different from the average conditions in PTR, and that chital requires a quite specific range of habitats. Positive sign of marginality means that chital preferred higher average than the global mean. Accordingly, chital preferred to stay nearly with sambar (0.779) and wild pig (0.59) (table 6.2). Chital did not preferred areas with high lopping (-0.268), high cattle presence (-0.212) and high human disturbance in terms of wood cutting (-0.316).

Table 6.2 Marginality and Specialisations of different variables in HS models of Chital

Variables	Marginality	Specialisation1	Specialisation2	Specialisation3
Chital species Interaction model (Model 1)				
Leopard encounter rate	-0.043	-0.999	-0.006	0
Wild dog encounter rate	0.098	-0.001	-0.034	0.058
Tiger encounter rate	0.184	0.001	-0.981	0.032
Sambar encounter rate	**0.779**	-0.036	0.151	-0.612
Wild pig encounter rate	**0.59**	-0.024	0.113	0.788
Chital human disturbance model (Model 2)				
Lopping	-0.268	0.13	-0.983	0.693
Cattle dung	-0.212	0.11	-0.019	0.216
Livestock seen	-0.015	-0.172	0.002	-0.454
People seen	0.04	0.03	0.043	0.471
Trail	0.233	0.055	0.005	0.01
Wood cutting	**-0.316**	0.059	0.006	0.025
Distance from road	**0.485**	0.603	-0.147	-0.187
Distance from village	**0.702**	0.755	0.097	0.096

Chital geographical-resource model (Model 3)

Agriculture	-0.207	0.058	0.015	0.118
High canopy	**0.313**	0.022	-0.017	0.032
Medium canopy	**0.428**	0.051	0.029	0.045
Low canopy	**0.321**	0.331	-0.048	0.675
No canopy	0.029	-0.007	0.007	-0.066
Cliestanthus colinus	0.072	0.003	0.001	0.003
Elevation	**0.307**	-0.826	-0.195	-0.173
Miscellaneous forest	0.267	0.044	0.018	0.128
Open forest	0.111	0	0.011	-0.005
Riverine forest	-0.012	0.003	-0.014	-0.012
Slope	-0.147	-0.338	0.364	0.522
Submergence	0.087	0.016	0.019	0.024
Teak dominated forest	**0.411**	0.094	0.01	-0.012
Teak-lagerstromia forest	0.172	0.013	0.01	-0.062
Teak-mixed forest	0.269	-0.026	0.012	-0.024
Distance from water	0.133	0.273	0.907	-0.407

Chital preferred areas away from road (0.485) and village (0.702). It avoided agricultural areas (-0.207). It had no bias towards any canopy density area but preffered teak-dominated forest (0.411). Pench has undulating terrain. Chital though preferred elevated areas (0.307) but avoided steep slope (-0.147) to a certain limit. The large numbers of specialisation were found on leopard encounter (-0.999 on Spec.1), sambar (-0.612 on spec. 3), wildpig (0.788 on spec.3), lopping on spec. 2 (-0.983) and spec. 3 (0.693), distance from road (0.603 on spec.1) and distance to village (0.755 on spec.1), low canopy in spec.1 (0.331) and spec. 3 (0.675), slope in spec.1 (-0.338), spec.2 (0.364) and spec.3 (0.522), distance from water in spec.2 (0.907) and in spec.3 (-0.407). This showed that the distribution of chital could deviate from optimal values with respect to these parameters (Hirzel et al. 2002). ENFA was performed again to produce HS maps of chital according to each categorized environmental parameters (EnvPs) (model 1 to model 3, see Fig. 6.1 to 6.3). The *M* and *S* were also computed. The *M* of model 1 to model 3 were 0.746, 0.566 and 1.228 respectively, while the *S* are 0.939, 2.366 and 1.345 respectively (Table 6.2). The HS map which was created by inputting only geographical and resource features (*M*= 1.228) differred from the average geographical conditions of

PTR. The difference was the largest of *M* when compared with *M* of other condition such as species interaction (*M*=0.746) and human disturbance (*M*=0.566). On the other hand, *S* indicated that conditions for chital in PTR for resource and geographical features (*S* = 1.228) were better than species interaction (*S* = 0.939) and human disturbance conditions (*S* = 2.366). *M* and *S* of each model reflected the size of suitable habitat in different aspects. The integrated-ENFA model (model 4) includes all EnvPs by model averaging (model 1 to model 3) as presented in the HS map in Fig. 6.4. The averaging model did not receive the *M* and *S* similar to general ENFA model. However, model 4 needed model 1 to model 3, as the background on explainable information.

Fig. 6.1 Habitat suitability map of Chital based on species interaction

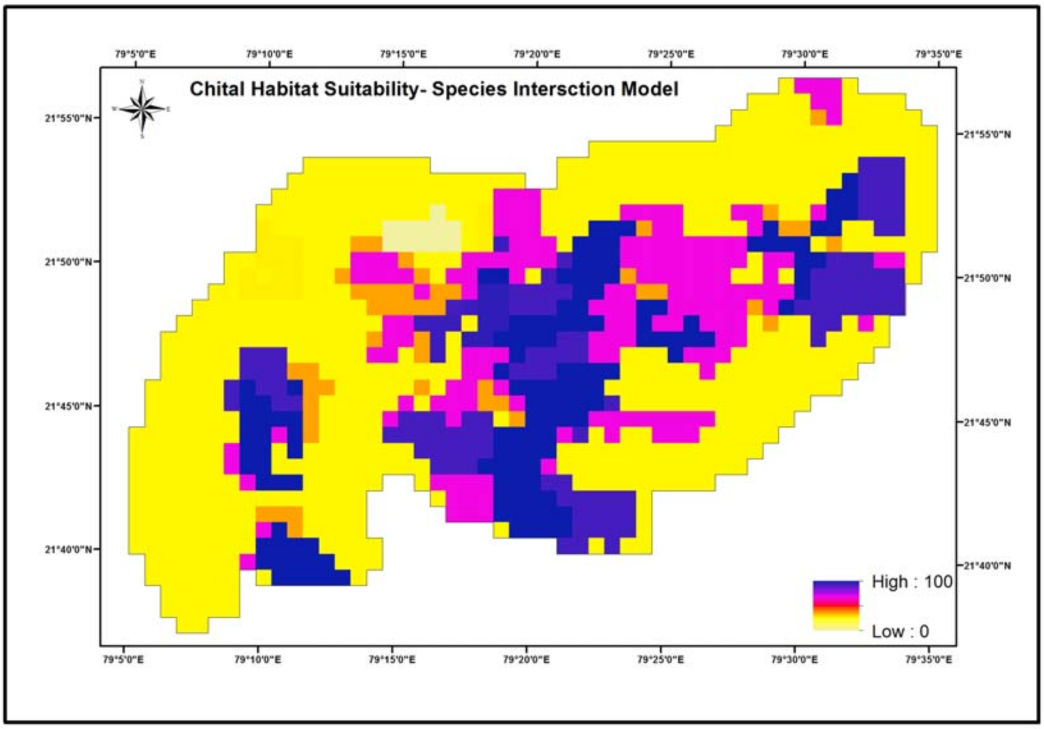


Fig. 6.2 Habitat suitability map of Chital based on Human disturbance

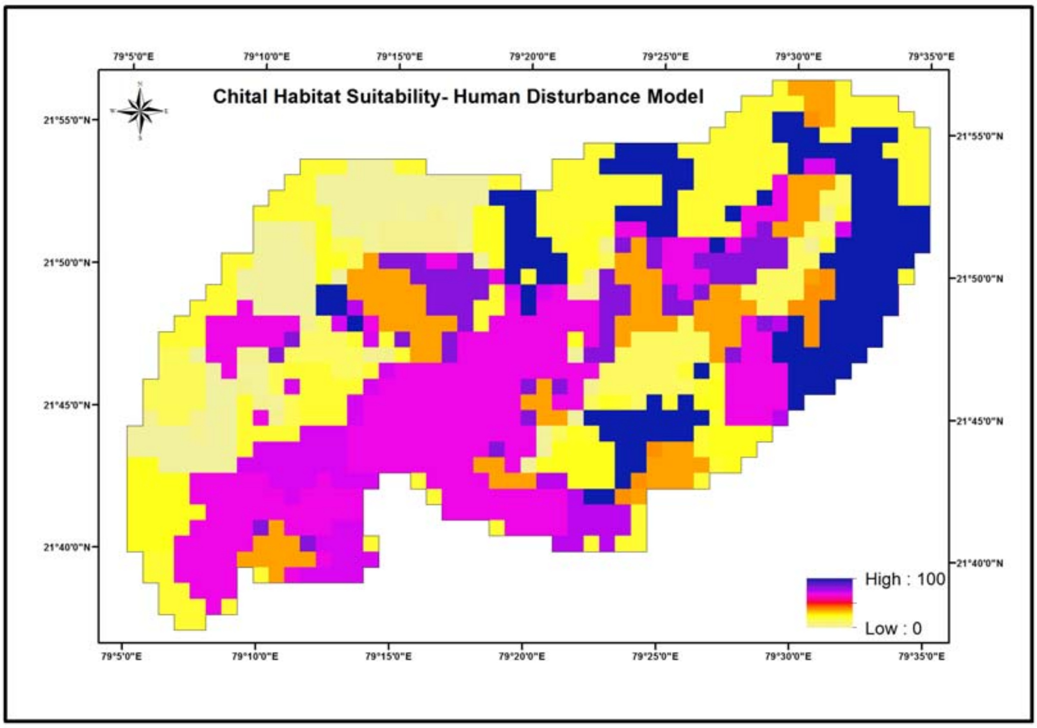


Fig. 6.3 Habitat suitability map of Chital based on resource and geographical features

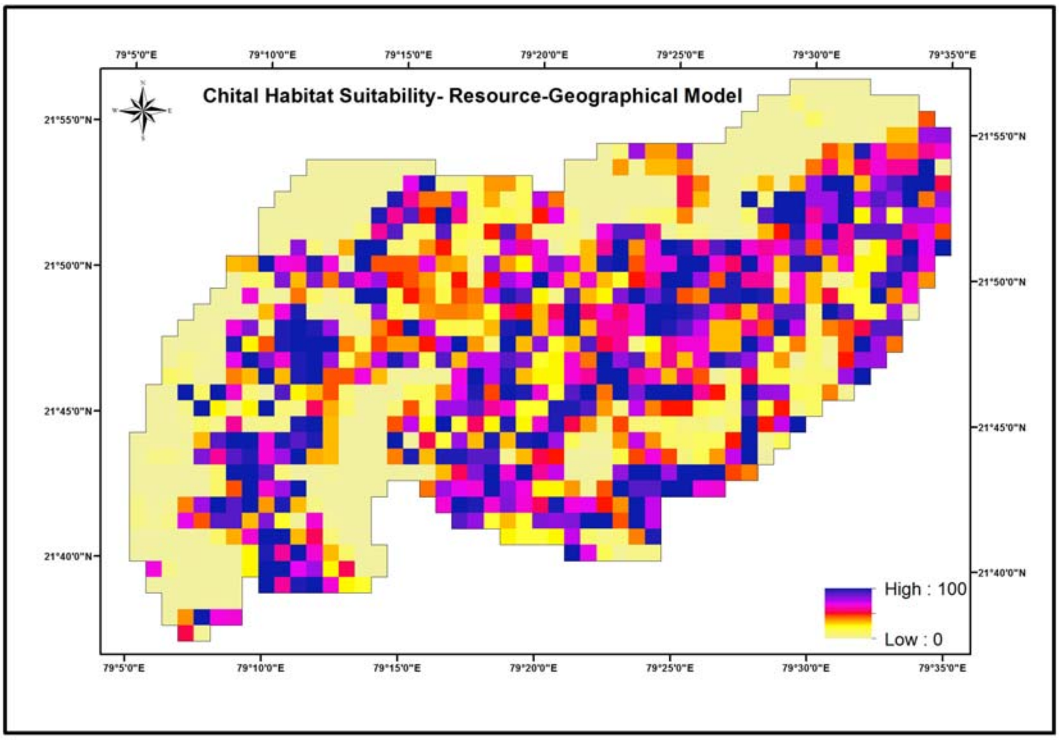
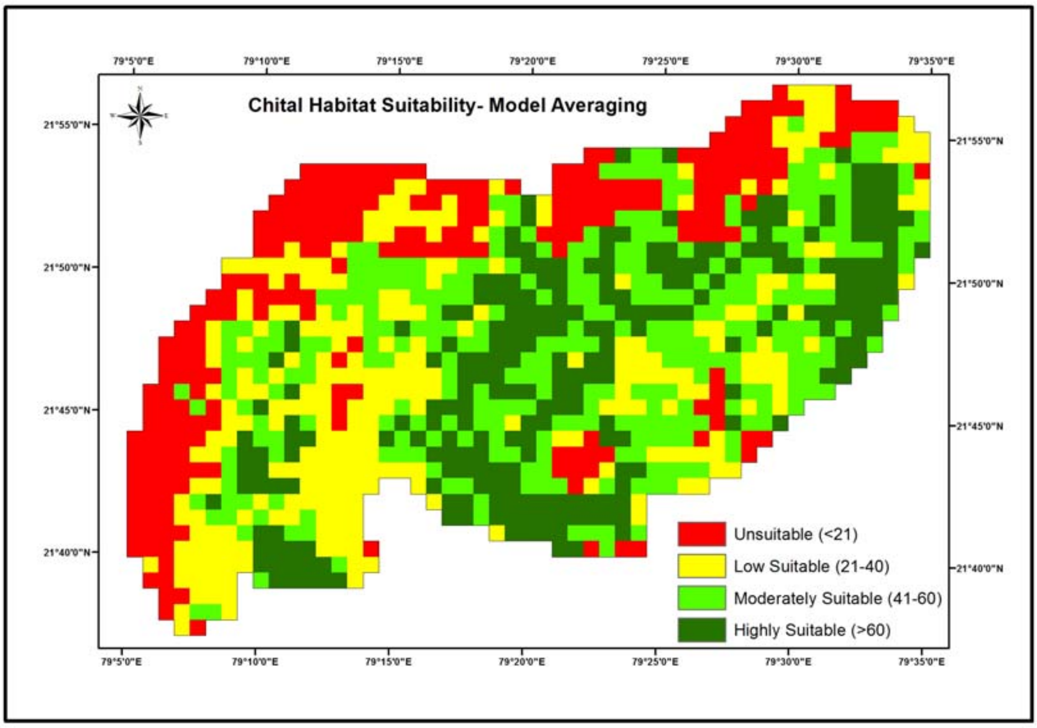


Fig. 6.4 Habitat suitability map of Chital based on model averaging



The chital HS model validation results (Table 6.3) showed that Model 4 attains the highest value of AVI and CVI with 0.715 and 0.399. The other models: i.e. Species interaction (model 1), human disturbance model (model 2) and geographical-resource model (model 3) attained AVI with 0.675, 0.609 and 0.602 respectively and attained CVI with 0.367, 0.32, and 0.378 respectively. Therefore, the validating test showed that model 4 has the highest values of AVI and CVI, and matches better than other models. The area under highly suitable, moderately suitable, low suitable and unsuitable classes for chital are 256 Km^2, 270 Km^2, 315 Km^2 and 256 Km^2 respectively (Table 6.4).

Table 6.3 Summary of validating model of all HS models for chital

Model No.	Habitat Suitability Model	AVI	AVI0	CVI
1	Chital Species Interaction model	0.675	0.308	0.367
2	Chital Human Disturbance Model	0.609	0.289	0.32
3	Chital Resource-geographical model	0.602	0.224	0.378
4	Chital model averaging	0.715	0.316	0.399

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.4 Area under each Habitat suitability category for chital in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	**Area (Km^2)**
Highly Suitable	256
Moderately suitable	315
Low suitable	270
Unsuitable	247

6.3.2 HS model for Sambar:

Sambar presence (n= 503) resulted into three HS models based on species interaction (Model5), human disturbance (Model6) and geographical and resource factors (Model7) (Fig. 6.5-6.7). The proportions of explained information in Model 5 to 7 were 80%, 95% and 83% respectively. *M* for model 5 to 7 were 0.756, 0.572 and 1.3 respectively and overall *S* were 0.693, 2.442 and 1.397 respectively. Positive marginality indicated that sambar preferred habitat higher than the global mean i.e. better than average condition in PTR. Similarly sambar shared habitats with chital (0.764) and wild pig (0.614). Predator species had almost no significant impact on sambar habitat preference.

Table 6.5 Marginality and Specialisations of different variables in HS models of Sambar

Sambar Species Interaction model (Model 5)

Variables	**Marginality**	**Specialisaion1**	**Specialisation2**	**Specialisation3**
Chital encounter rate	**0.764**	-0.742	0.109	0.134
Leopard encounter rate	-0.059	0.546	0.774	-0.977
Wild dog encounter rate	0.101	-0.03	-0.02	-0.019
Wild pig encounter rate	**0.614**	-0.386	0.027	-0.164
Tiger encounter rate	0.157	0.038	-0.623	0

Sambar human disturbance model (Model 6)

Variables	Marginality	Specialisation1	Specialisation2	Specialisation3
Lopping	-0.265	0.796	-0.949	0.092
Cattle dung	-0.225	0.08	-0.032	0.27
Livestock seen	-0.1	-0.107	-0.001	-0.674
People seen	-0.053	0.031	0.064	0.64
Trail	0.155	0.027	0.012	-0.002
Wood cutting	**-0.397**	-0.035	-0.008	0.034
Distance from road	**0.429**	0.36	-0.26	-0.208
Distance from village	**0.708**	0.465	0.163	0.102
Sambar Geographical-resource model (Model 7)				
Agriculture	-0.087	-0.133	0.424	0.477
High canopy	0.272	-0.007	0.014	0.083
Medium canopy	**0.382**	-0.052	0.118	0.094
Low canopy	**0.358**	-0.372	-0.028	0.505
No canopy	-0.036	0.037	-0.14	-0.245
Cliestanthus colinus	0.051	-0.005	0.001	-0.004
Elevation	0.27	0.888	-0.695	0.193
Miscellaneous forest	**0.343**	-0.085	-0.083	-0.075
Open forest	0.035	0.002	0.022	0.072
Riverine forest	0.006	-0.007	-0.004	0.232
Slope	0.294	0.042	0.023	-0.113
Submergence	0.02	-0.026	0.037	0.056
Teak dominated forest	**0.382**	-0.088	0.113	-0.064
Teak-lagerstromia forest	0.278	0.004	0.022	-0.037
Teak-mixed forest	0.254	0.017	0.025	-0.063
Distance from water	0.274	-0.181	0.53	-0.561

Sambar prefered undisturbed habitat (Lopping: -0.265, Cattle dung: -0.225, wood cutting: -0.397) and areas away from villages (0.708) and road (0.429). It also preferred medium (0.382) and low canopy (0.358) areas in PTR as most of the area is covered by these two classes. Similarly it preferred Miscellaneous (0.343) and Teak dominated forests (0.382). Large numbers of specializations were found in chital encounter rate (-0.742 on spec.1), leopard encounter rate (spec.1: 0.546, spec.2: 0.774, scpec.3: -0.977), wild pig in spec.1 (-0.386), tiger encounter rate in spec.2 (-0.623), lopping (spec.1: 0.796, spec.2: -0.949), distance from village on spec.1 (0.465), agriculture (spec.1: 0.424, spec.2: 0.477), low canopy on spec.3 (0.505), elevation (spec.1: 0.888, spec.2: -0.695), distance from water (spec.2: 0.53, spec.3: -0.561). Sambar HS could deviate from its optimum value with respect to these parameters. Three HS maps (Fig. 6.5-6.7) were produced by ENFA. The overall *M* were 0.756, 0.572 and 1.3 respectively and *S* were 0.693, 2.442 and 1.397 respectively for model 5 to 7. Similarly like chital, models for sambar also showed that Geographical and resource features (Model 7) were better than other two models as per *S* of the respective models. The final HS map (Fig. 6.8) was created by model averaging (Model 5- to 7).

Fig. 6.5 Habitat suitability map of Sambar based on species interaction

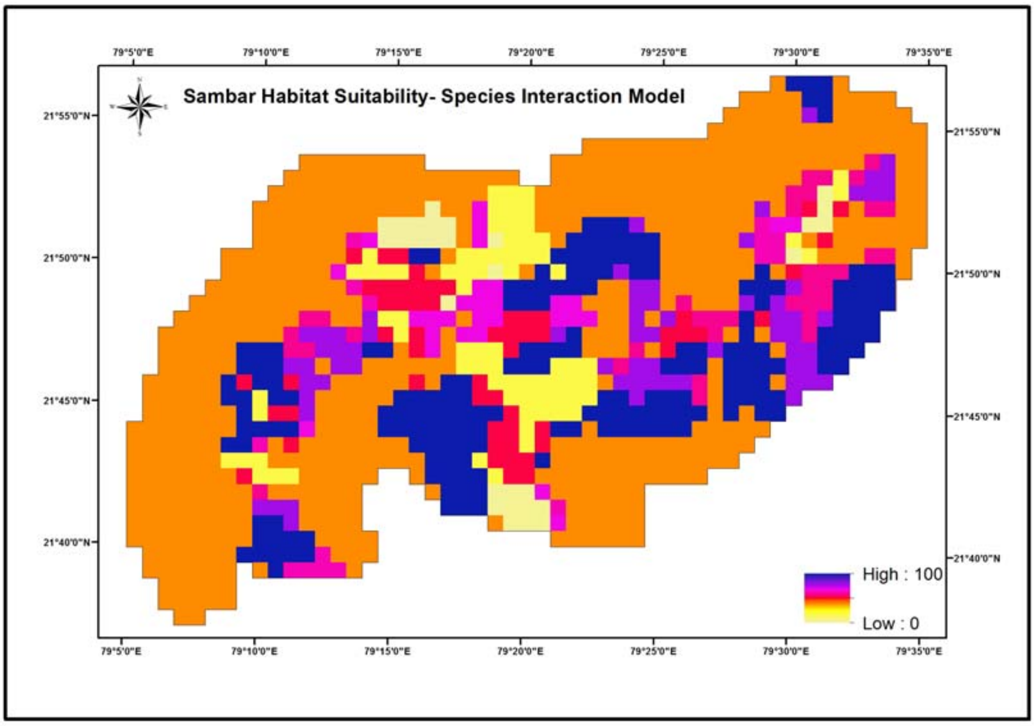


Fig. 6.6 Habitat suitability map of Sambar based on Human disturbance

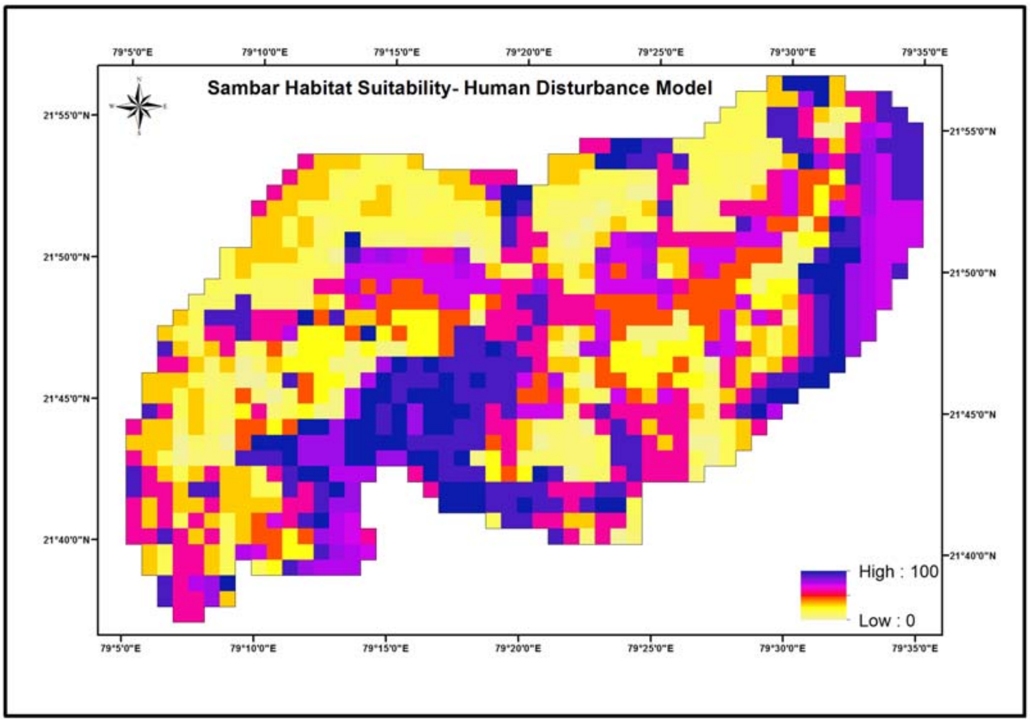


Fig. 6.7 Habitat suitability map of Sambar based on resource and geographical features

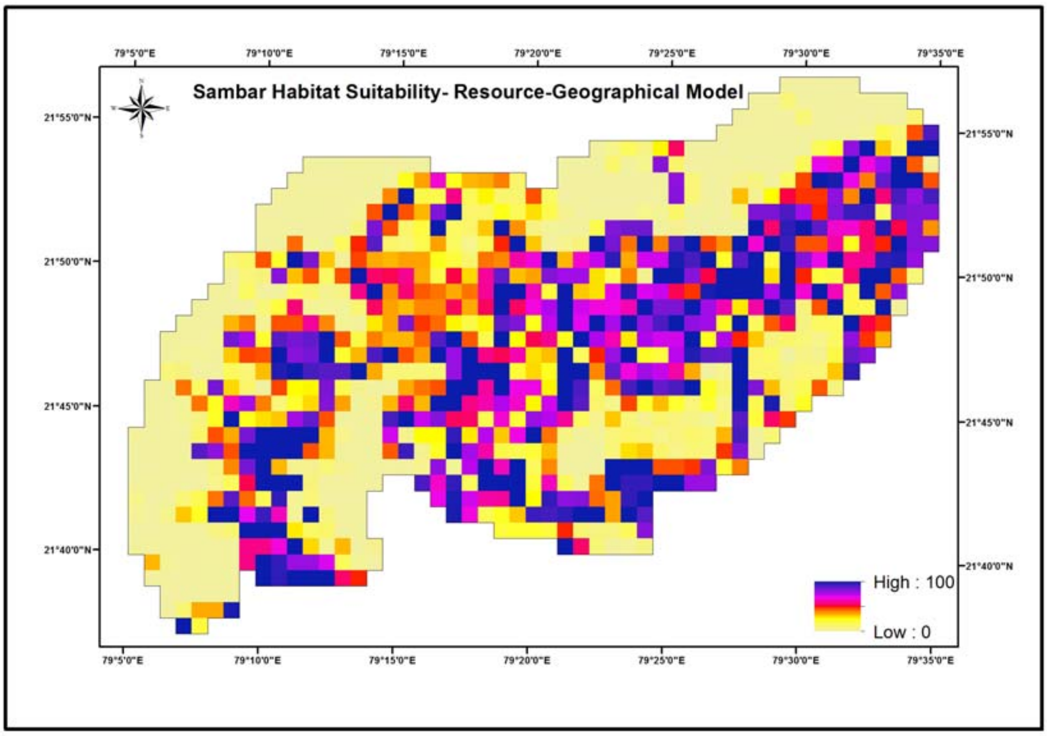
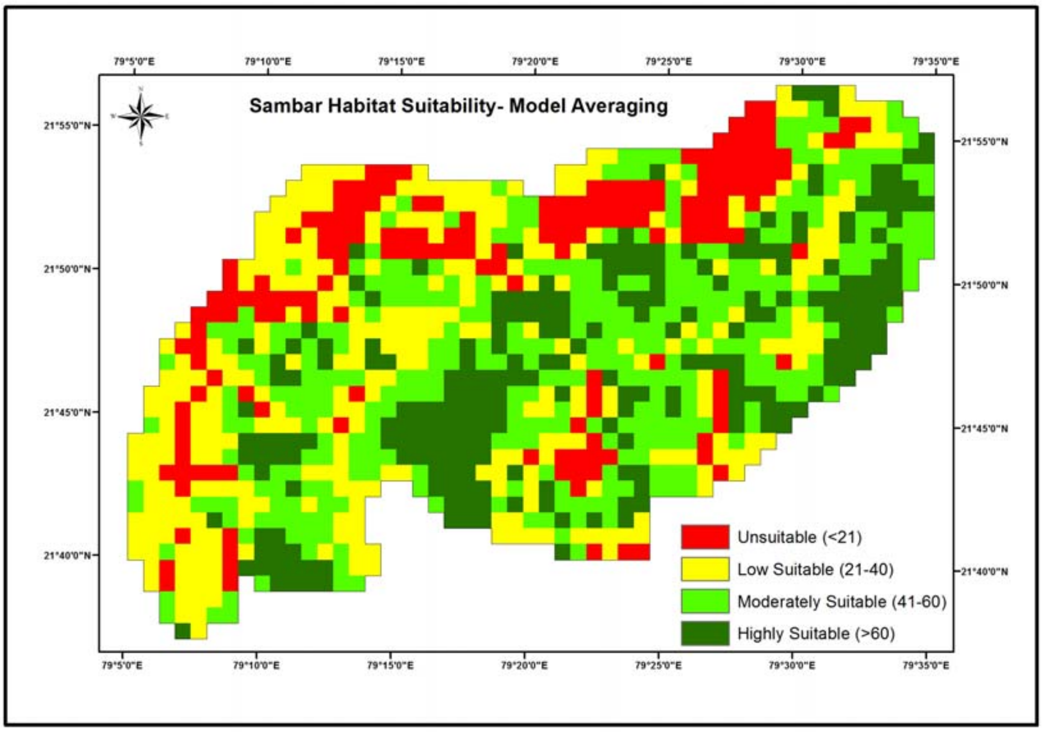


Fig. 6.8 Habitat suitability map of Sambar based on model averaging



Model 8 attained highest value of AVI and CVI of 0.689 and 0.382 respectively, compared to AVI (0.644, 0.619 and 0.635) and CVI values (0.355, 0.317 and 0.33) of model 5-7 (Table 6.6). This showed that model 8 was the best fit model. The area under highly suitable was 245 Km^2, moderately suitable 348 Km^2, low suitable 317 Km^2 and unsuitable 178 Km^2 respectively for sambar in PTR (Table 6.7).

Table 6.6 Summary of validating model of all HS models for Sambar

Model No.	Habitat Suitability Model	AVI	AVI0	CVI
5	Sambar Species Interaction model	0.644	0.289	0.355
6	Sambar Human Disturbance Model	0.619	0.302	0.317
7	Sambar Resource-geographical model	0.635	0.305	0.33
8	Sambar model averaging	0.689	0.307	0.382

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.7 Area under each Habitat suitability category for sambar in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	Area (Km^2)
Highly Suitable	245
Moderately suitable	348
Low suitable	317
Unsuitable	178

6.3.3 HS model for Wild pig:

Presence data of wild pig (n= 417) resulted into three HS models (Model 9-11) for species interaction, human disturbance and resource-geographical factors (Fig. 6.9-6.11). The proportions of explained information in these three models were 80%, 97% and 81% respectively. Overall *M* in these models were 0.761, 0.616 and 1.33 respectively and *S* in these models were 0.707, 2.916 and 1.32 respectively. This indicated that resource and geographical features were found to be more suitable for wild pig than other features in PTR. Positive signs of *M* indicated that Wild pig preferred higher average of EnvPs than the global mean.

Table 6.8 Marginality and Specialisations of different variables in HS models of Wild Pig

Wild Pig Species Interaction model (Model 9)

Variables	Marginality	Specialisation1	Specialisation2	Specialisation3
Chital encounter rate	**0.743**	0.029	-0.13	0.66
Leopard encounter rate	-0.034	0.999	-0.006	-0.002
Sambar encounter rate	**0.634**	0.02	0.406	-0.722
Tiger encounter rate	0.171	-0.004	-0.903	-0.207
Wild dog encounter rate	0.122	-0.001	-0.057	0.021

Wild Pig human disturbance model (Model 10)

Variables	Marginality	Specialisation1	Specialisation2	Specialisation3
Lopping	-0.24	-0.626	-0.919	0.99
Cattle dung	-0.165	-0.076	-0.005	-0.006
Livestock seen	-0.241	0.059	-0.253	-0.064
People seen	-0.239	0.013	0.258	0.066
Distance from road	**0.334**	-0.511	-0.137	0.089
Trail	0.016	-0.028	0.009	-0.002
Distance from village	**0.645**	-0.579	0.081	-0.051
Wood cutting	**-0.522**	-0.04	0.005	-0.006

Wild Pig Geographical-resource model (Model 11)

Agriculture	-0.108	-0.129	0.501	-0.381
High canopy	0.246	-0.012	0.02	0.028
Medium canopy	**0.372**	-0.039	0.041	-0.167
Low canopy	0.35	-0.274	0.179	0.579
No canopy	-0.051	0.016	-0.158	0.053
Cliestanthus colinus	0.064	-0.005	0.003	0
Elevation	0.267	0.89	-0.652	0.236
Miscellaneous forest	0.297	-0.047	0.003	0.136
Open forest	0.026	-0.004	0.021	-0.046
Riverine forest	0.003	0.006	-0.009	0.091
Slope	0.292	0.028	-0.029	-0.203
Submergence	0.036	-0.02	0.064	0.014
Teak dominated forest	**0.422**	-0.124	0.02	-0.564
Teak-lagerstromia forest	**0.303**	-0.002	0.014	-0.025
Teak-mixed forest	0.274	0.015	-0.014	-0.11
Distance from water	0.261	-0.31	0.509	0.179

Wild pig preferred areas with chital (0.743) and sambar (0.634) presence. It also preferred areas distant from road (0.334), distant from village (0.645), less wood cutting areas (0.522), areas with medium canopy (0.372), teak dominated forest

(0.422) and teak Lagerstroemia forest (0.303). Large numbers of specializations were located in chital encounter rate (0.66 on spec.3), leopard encounter rate (0.999 on spec.1), sambar encounter rate (0.406 on spec.2), tiger encounter rate (-0.903 on spec.2), lopping (spec.1: -0.626, spec.2: -0.919, spec.3: -0.99), distance from road (-0.511 on spec.1), distance from village (-0.579 on spec.1), agriculture (spec.2: -0.501, spec.3: -0.381), low canopy (0.579 on spec.3), teak dominated forest (-0.564 on spec. 3) and distance from water (spec.1: -0.31, spec.2: 0.509). Any change in these observed factors is likely to affect the HS of wild pig in PTR.

Fig. 6.9 Habitat suitability map of Wild Pig based on species interaction

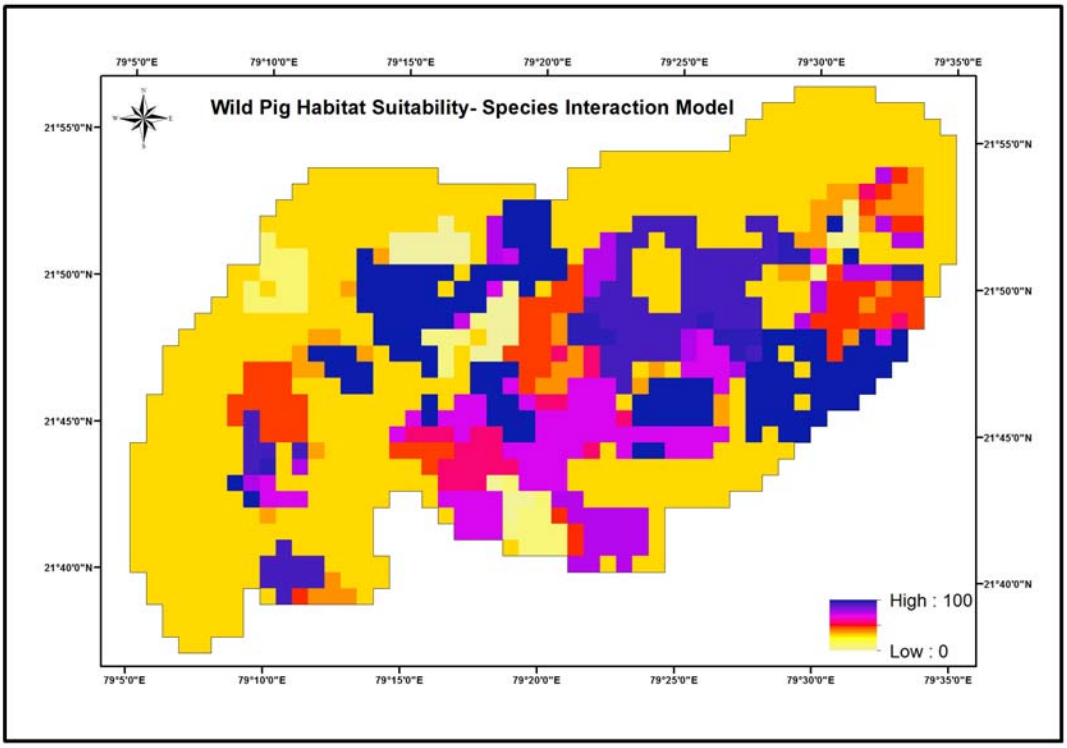


Fig. 6.10 Habitat suitability map of Wild Pig based on Human disturbance

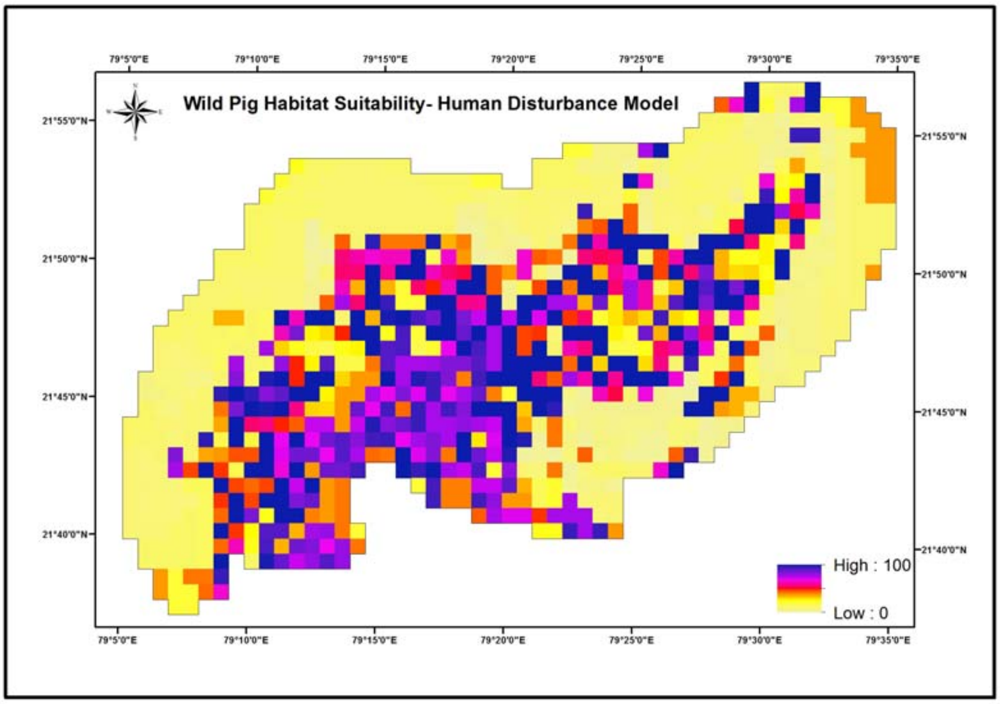


Fig. 6.11 Habitat suitability map of wild pig based on resource and geographical features

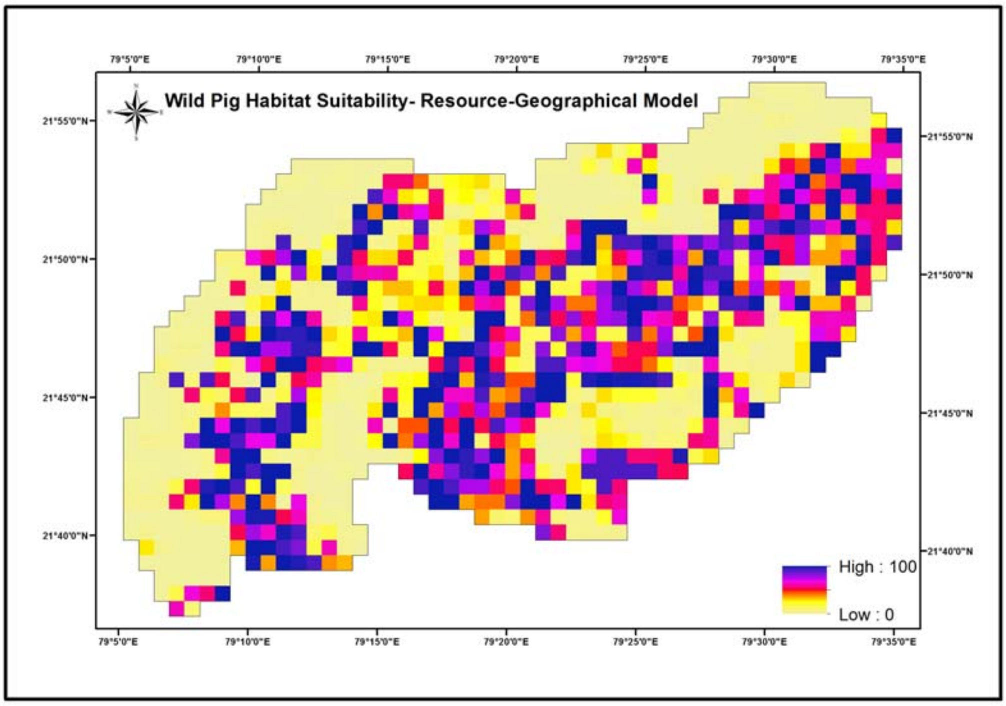
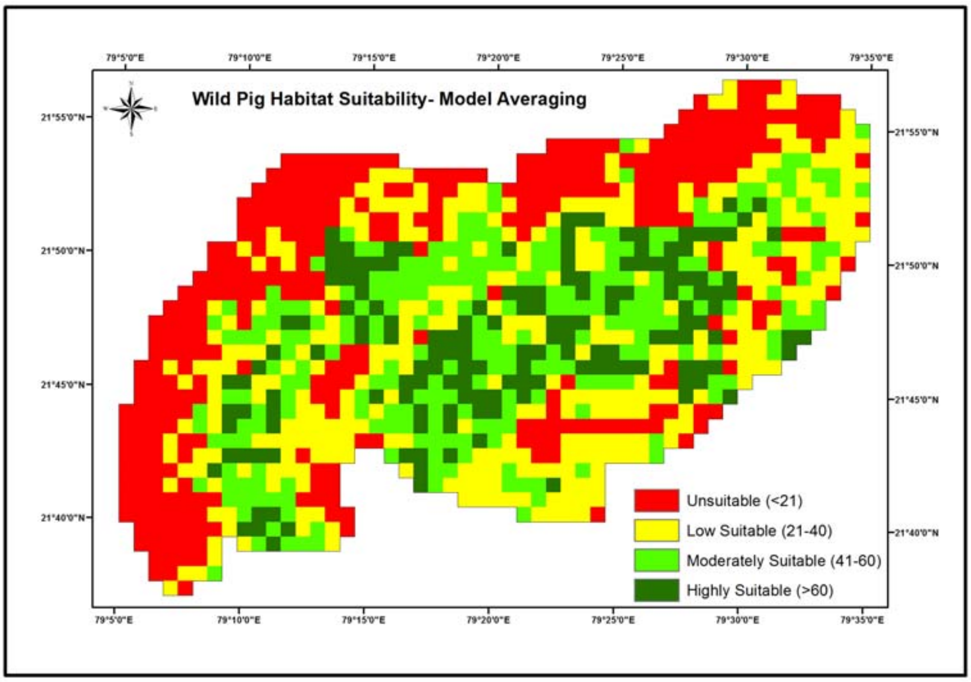


Fig. 6.12 Habitat suitability map of wild pig based on model averaging



The integrated HS model (model 12) was developed by model averaging (Fig. 6.12). This model attained highest AVI (0.645) and CVI (0.34) values when validated (Table 6.9). Areas under highly suitable, moderately suitable, low suitable and unsuitable categories were 160 Km^2, 251 Km^2, 328 Km^2 and 349 Km^2 respectively for wild pig in PTR (Table 6.10).

Table 6.9 Summary of validating model of all HS models for wild pig

No.	Habitat Suitability Model	AVI	AVI0	CVI
1	Wild Pig Species Interaction model	0.609	0.288	0.321
2	Wild Pig Human Disturbance Model	0.607	0.291	0.316
3	Wild Pig Resource-geographical model	0.611	0.287	0.324
4	Wild Pig model averaging	0.645	0.305	0.34

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.10 Area under each Habitat suitability category for wild pig in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	**Area (Km^2)**
Highly Suitable	160
Moderately suitable	251
Low suitable	328
Unsuitable	349

6.3.4 HS model for Tiger:

Tiger presence data (n= 452) resulted into three HS models (model 13-15) for species interaction, human disturbance and resource-geographical features (Fig. 6.13-6.15). The proportions of explainable information in these models were 85%, 96% and 91% respectively. Overall *M* were 0.89, 0.636 and 1.402 respectively and *S* were 0.938, 2.87 and 2.017 respectively. This indicated that tiger preferred habitat that were different from average conditions of PTR and it required very specific range of habitat. This difference was found largest for geographical-resource features (*M* = 1.402). On the other hand, *S* indicated that conditions for tiger in PTR for human disturbance (*S*=2.87) was better than species interaction (*S*=0.938) and geographical-resource features (*S*=2.017).

Table 6.11 Marginality and Specialisations of different variables in HS models of Tiger

Tiger Species Interaction model (Model 13)

Variables	**Marginality**	**Specialisation1**	**Specialisation2**	**Specialisation3**
Chital encounter rate	**0.59**	-0.021	0.633	-0.599
Leopard encounter rate	-0.03	-1	-0.001	-0.003
Sambar encounter rate	**0.526**	-0.017	-0.772	-0.221
Wild dog encounter rate	0.093	0	0.032	0.132
Wild pig encounter rate	**0.604**	-0.014	0.048	0.758

Tiger human disturbance model (Model 14)

Lopping	**-0.226**	-0.46	-0.99	-0.701
Cattle dung	-0.092	-0.039	0.039	0.017
Livestock seen	**-0.336**	0.113	-0.097	0.489
People seen	**-0.333**	-0.02	-0.019	-0.518
Trail	-0.073	-0.044	0	-0.009
Wood cutting	**-0.493**	-0.046	0.006	0.005
Distance from raod	**0.33**	-0.507	-0.089	0.007
Distance from village	**0.6**	-0.716	0.021	-0.016

Tiger Geographical-resource model (Model 15)

Agriculture	-0.109	-0.061	-0.359	-0.473
High canopy	0.232	-0.027	-0.01	0.019
Medium canopy	**0.368**	-0.041	-0.015	-0.172
Low canopy	**0.358**	-0.516	-0.134	0.355
No canopy	-0.048	-0.009	0.088	0.059
Cliestanthus colinus	0.057	-0.006	-0.004	0
Elevation	0.265	0.843	0.755	0.1
Miscellaneous forest	**0.301**	-0.068	-0.014	0.088
Open forest	0.054	0.004	-0.01	-0.034
Riverine forest	0.033	-0.024	0.022	0.03
Slope	0.293	0.047	-0.009	-0.149
Submergence	0.03	-0.001	-0.04	0.025
Teak dominated forest	**0.416**	-0.087	-0.104	-0.545
Teak-lagerstromia forest	**0.319**	0.013	-0.008	-0.005
Teak-mixed forest	0.279	0.03	0.008	-0.094
Distance from water	0.249	0.027	-0.512	0.517

Tiger preferred habitats with chital (0.59), sambar (0.526) and wild pig (0.604) presence. It avoided areas with high human disturbances (Livestock seen: -0.336, people seen: -0.33, wood cutting: -0.493). It preferred distant areas from road (0.33) and distant areas from villages (0.6), medium (0.368) and low (0.358) canopy areas, miscellaneous forest (0.301), teak dominated forest (0.416), Teak Lagerstroemia forest (0.319). Large numbers of specializations were observed in chital encounter rate (0.633 on spec.2), sambar encounter rate (-0.722 on spec.2), wild pig encounter rate (0.758 on spec.3), lopping (spec.1: -0.46, spec.2: -0.99, spec.3 -0.701), livestock seen (0.489 on spec.3), people seen (-0.518 on spec.3), distance to road (-0.507 on spec.1), distance to village (-0.706 on spec.1), agriculture (spec.2: -0.359, spec.3: 0.473), low canopy (spec.1: -0.516, spec.3: 0.355), teak dominated forest (-0.545 on spec.3) and distance to water (spec.2: -0.512, spec.3: 0.517). Tiger HS may deviate from its optimal value with respect to these parameters.

Fig. 6.13 Habitat suitability map of Tiger based on species interaction

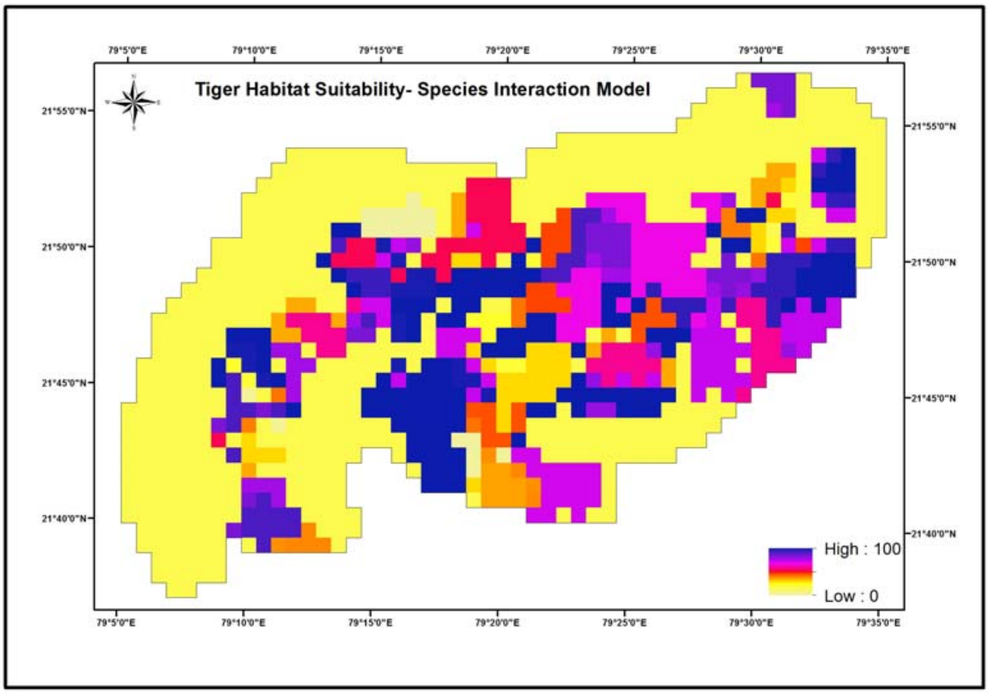


Fig. 6.14 Habitat suitability map of Tiger based on Human disturbance

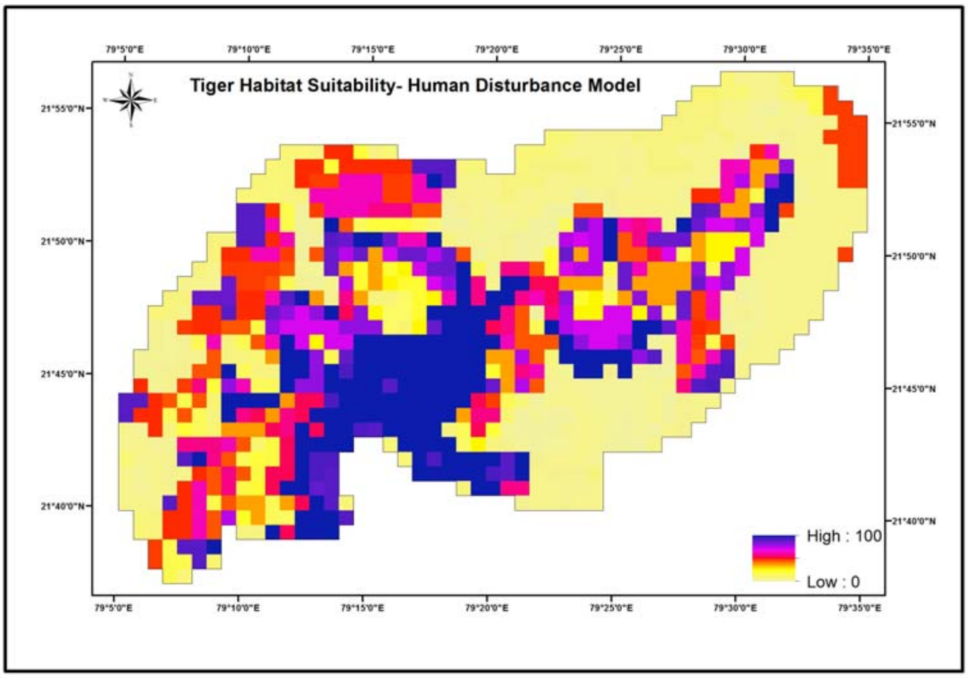


Fig. 6.15 Habitat suitability map of Tiger based on resource and geographical features

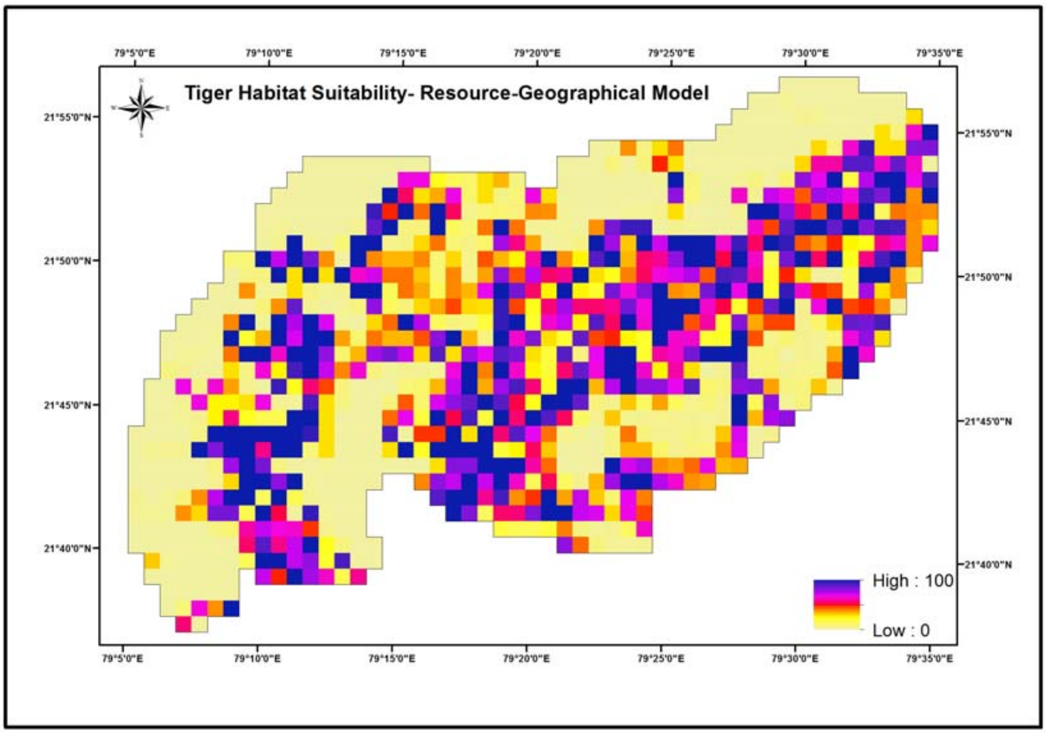
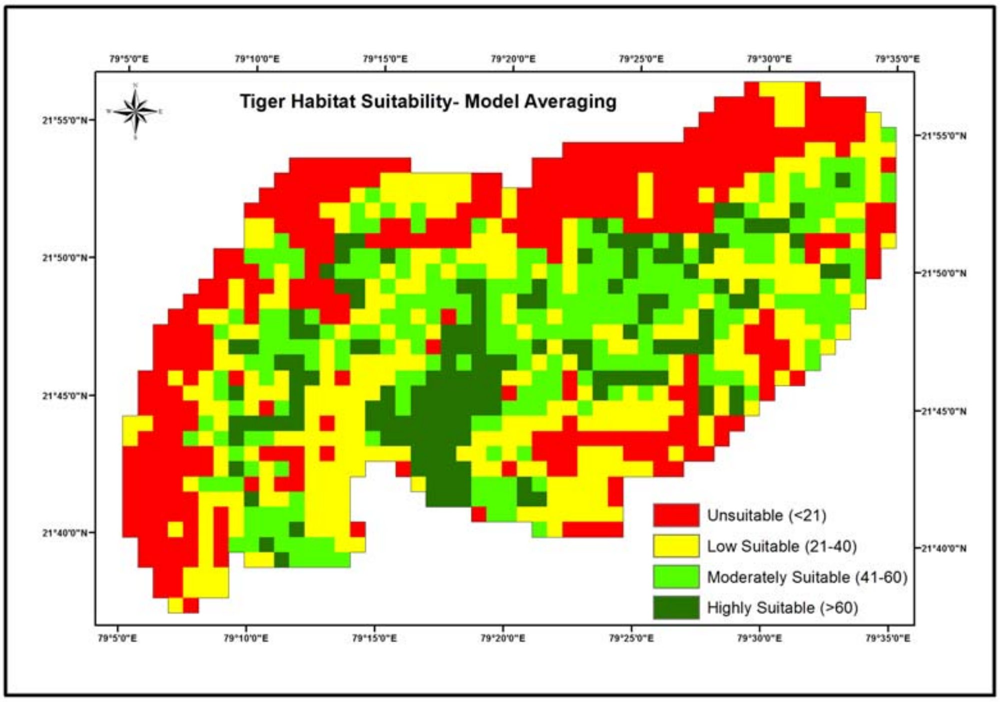


Fig. 6.16 Habitat suitability map of Tiger based on model averaging



Model 16 (Fig. 6.16) was created by model averaging from model 13 to 15. All the models were tested for validation. The AVI and CVI values of model 16 were 0.666 and 0.353 respectively (Table 6.13) which were higher than the AVI (model 13: 0.634, model 14: 0.624, model 15: 0.645) and CVI values (model 13: 0.328, model

14: 0.313, model 15: 0.347). The areas under highly suitable, moderately suitable, low suitable and unsuitable classes were 152 Km^2, 254 Km^2, 328 Km^2 and 354 Km^2 respectively for tiger in PTR (Table 6.14).

Table 6.12 Summary of validating model of all HS models for Tiger

No.	Habitat Suitability Model	AVI	AVI0	CVI
1	Tiger Species Interaction model	0.634	0.306	0.328
2	Tiger Human Disturbance Model	0.624	0.311	0.313
3	Tiger Resource-geographical model	0.645	0.298	0.347
4	Tiger model averaging	0.666	0.313	0.353

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.13 Area under each Habitat suitability category for Tiger in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	Area (Km^2)
Highly Suitable	152
Moderately suitable	254
Low suitable	328
Unsuitable	354

6.3.5 HS model for Leopard:

Leopard presence data (n= 437) had resulted in the creation of three HS models (model 17 -19) for species interaction, human disturbance and resource-geographical features (Fig. 6.17-6.19). Proportions of explainable information of these models were 79%, 965 and 88% respectively. *M* for these models were 0.753, 0.647 and 1.359 and *S* were 0.791, 3.037 and 1.681 respectively. Leopard preferred higher average of EnvPs than the global mean. Conditions for leopard in PTR for human disturbances was found to be better than species interaction and resource-geographical features.

Table 6.14 Marginality and Specialisations of variables in HS models of leopard

Variables	**Marginality**	**Specialisation1**	**Specialisation2**	**Specialisation3**
Leopard Species Interaction model (Model 17)				
Chital encounter rate	**0.566**	-0.063	-0.631	-0.663
Sambar encounter rate	**0.521**	-0.497	0.727	-0.06
Wild dog encounter rate	0.1	0.095	-0.022	0.112
Wild pig encounter rate	**0.616**	0.281	-0.089	0.697
Tiger encounter rate	0.138	0.813	0.255	-0.244
Leopard human disturbance model (Model 18)				
Lopping	-0.065	0.068	0.025	-0.392
Cattle dung	-0.292	-0.709	0.696	-0.143
Livestock seen	-0.292	-0.319	-0.718	-0.003
People seen	0.26	-0.585	0.007	0.779
Trail	**-0.603**	-0.045	-0.009	0.009
Wood cutting	-0.087	0.002	-0.011	0.035
Distance from road	**0.483**	-0.213	-0.013	-0.44
Distance from village	**0.391**	-0.033	0.009	-0.155
Leopard Geographical-resource model (Model 19)				
Agriculture	-0.116	0.029	0.387	0.332
High canopy	0.223	0.025	0.015	-0.027
Medium canopy	**0.364**	0.03	0.009	0.133
Low canopy	**0.36**	0.454	0.155	-0.578
No canopy	-0.05	0.024	-0.106	-0.038
Cliestanthus colinus	0.059	0.005	0.005	-0.001
Elevation	0.262	-0.874	-0.745	-0.19
Miscellaneous forest	0.291	0.07	0.013	-0.112
Open forest	0.046	-0.005	0.007	0.038
Riverine forest	0.03	0.013	-0.037	-0.057
Slope	0.287	-0.071	0.009	0.222
Submergence	0.034	0.003	0.05	-0.027
Teak dominated forest	**0.429**	0.11	0.096	0.589
Teak-lagerstromia forest	**0.315**	-0.01	0.008	0.003
Teak-mixed forest	0.287	-0.023	-0.013	0.121
Distance from water	0.252	0.063	0.496	-0.265

Leopard preferred habitats with chital (0.566), sambar (0.521) and wild pig presence (0.616). It preferred areas with less human trails (-0.603), distant areas from road (0.483), distant areas from villages (0.391), medium (0.364) and low canopy areas (0.36), Teak dominated forest (0.429) and Teak Lagerstroemia (0.315) forests. Optimal HS of leopard is expected to deviate with respect to following parameters, chital encounter rate (spec.2: -0.631, spec.3: -0.663), sambar encounter rate (0.497 on spec.1), wild pig encounter rate (0.697 on spec.3), lopping (-0.392 on spec.3), cattle dung (spec.1: -0.709, spec.2: 0.696), livestock seen (spec.1: -0.319, spec.2: -0.718), people seen spec.1: -0.585, spec.3: 0.779), agriculture (spec.2: 0.387, spec.3: 0.332), low canopy (spec.1: 0.454, spec.3: -0.578), Teak dominated forest (0.589 on spec.3) and distance to water (0.496 on spec.2).

Fig. 6.17 Habitat suitability map of Leopard based on species interaction

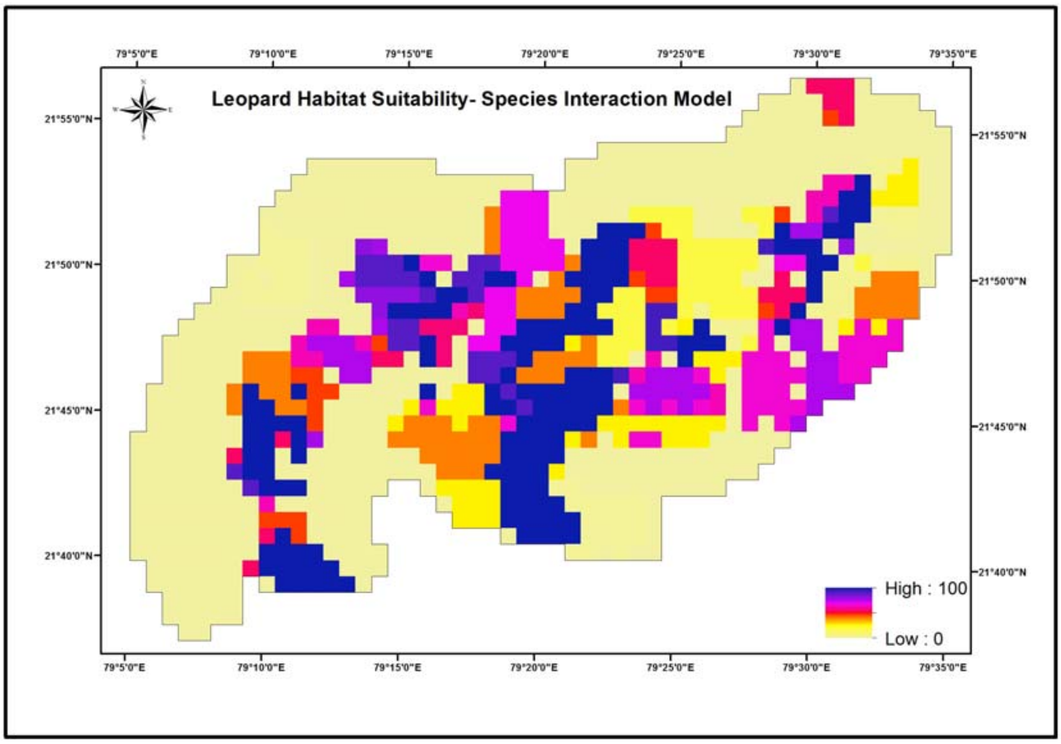


Fig. 6.18 Habitat suitability map of Leopard based on Human disturbance

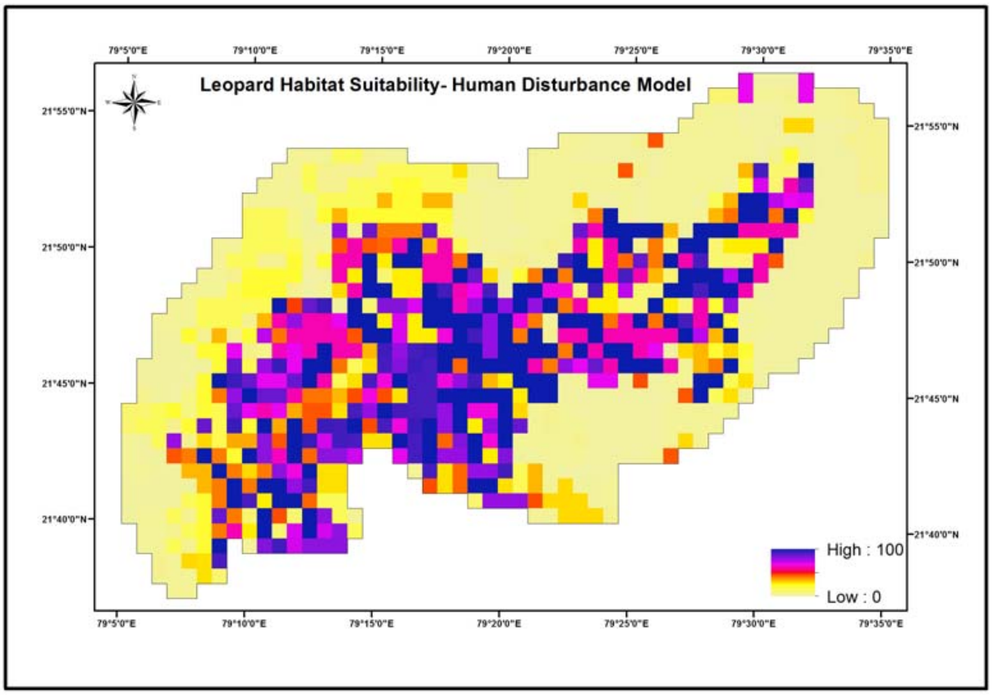


Fig. 6.19 Habitat suitability map of Leopard based on resource and geographical features

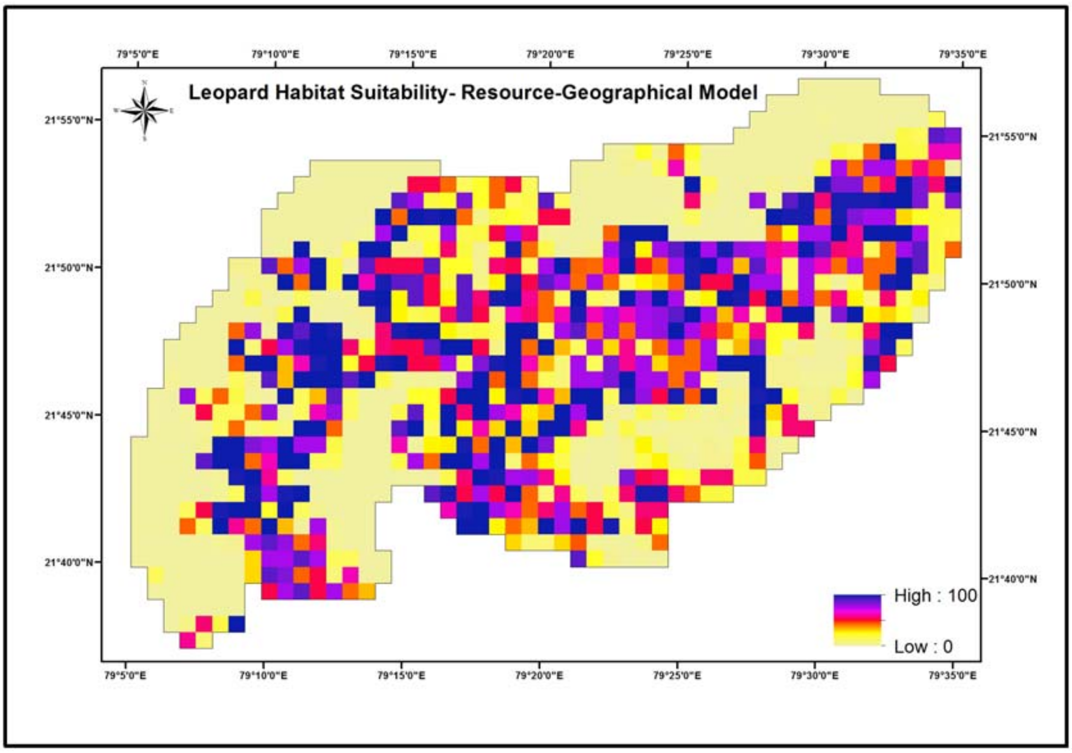
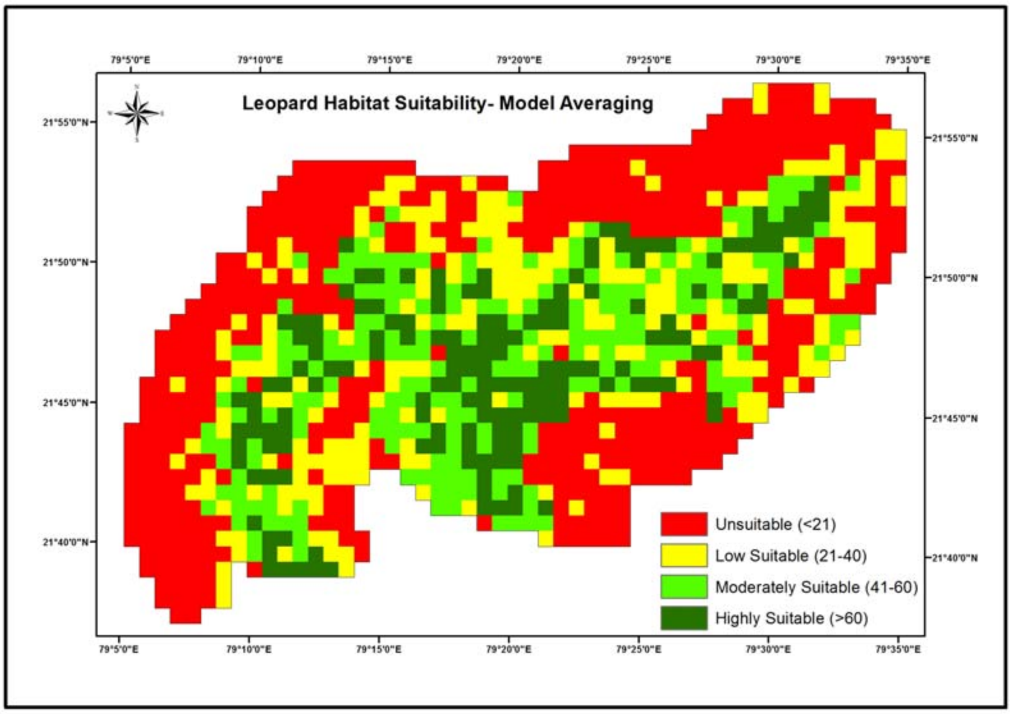


Fig. 6.20 Habitat suitability map of Leopard based on model averaging



Model 20 (Fig. 6.20) was generated by model averaging of model 17 to model 19. Validation of model 20 gave highest AVI (0.699) and CVI (0.392) (Table 6.16) values compared to other models (AVI: 0.653, 0.645 and 0.608 respectively; CVI: 0.35, 0.308, 0.327). The areas under highly suitable, moderately suitable, low suitable and unsuitable were 167 Km^2, 211 Km^2, 233 Km^2 and 477 Km^2 respectively for leopard in PTR (Table 6.17).

Table 6.15 Summary of validating model of all HS models for Leopard

No.	Habitat Suitability Model	AVI	AVI0	CVI
1	Leopard Species Interaction model	0.653	0.286	0.367
2	Leopard Human Disturbance Model	0.645	0.325	0.32
3	Leopard Resource-geographical model	0.608	0.23	0.378
4	Leopard model averaging	0.699	0.307	0.392

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.16 Area under each Habitat suitability category for Leopard in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	**Area (Km^2)**
Highly Suitable	167
Moderately suitable	211
Low suitable	233
Unsuitable	477

6.3.6 HS model for Wild dog:

Incorporating the presence data of wild dog (n= 241) had resulted in the creation of three HS models (model 21-23) for species interaction, human disturbance and resource-geographical features (Fig. 6.21-6.23). In these models, the proportions of explainable information were 91%, 95% and 88% respectively. Overall *M* were 0.853, 0.629 and 1.38 and overall *S* were 1.61, 2.952 and 1.835 respectively. This indicated that though the difference between the mean and the global distribution was found to be highest in resource-geographical feature model but conditions for wild dog in PTR was best in terms of human disturbance compared to other two.

Table 6.17 Marginality and Specialisations of different variables in HS models of wild dog

Wild Dog Species Interaction model (Model 21)

Variables	**Marginality**	**Specialisation1**	**Specialisation2**	**Specialisation3**
Leopard encounter rate	-0.014	-1	-0.002	0.002
Chital encounter rate	**0.631**	-0.01	-0.721	0.132
Sambar encounter rate	**0.478**	-0.01	0.421	0.676
Wild pig encounter rate	**0.584**	-0.005	0.503	-0.55
Tiger encounter rate	0.18	0.003	-0.223	-0.472

Wild Dog human disturbance model (Model 22)

Lopping	-0.232	-0.652	-0.982	-0.948
Cattle dung	-0.14	-0.086	0.088	-0.028
Livestock seen	**-0.296**	0.062	-0.039	-0.133
People seen	**-0.291**	0.081	-0.085	0.198
Trail	-0.205	-0.028	0.005	0.007
Wood cutting	**-0.46**	-0.03	0.009	0.009
Distance from raod	**0.32**	-0.538	-0.13	-0.176
Distance from village	**0.631**	-0.515	0.048	0.115

Wild Dog Geographical-resource model (Model 23)

Agriculture	-0.102	0.077	0.319	-0.446
High canopy	0.24	0.017	0	0.067
Medium canopy	**0.368**	0.027	0.033	-0.092
Low canopy	**0.362**	0.422	0.013	0.262
No canopy	-0.025	0.008	-0.094	0.014
Cliestanthus colinus	0.005	-0.001	0.003	0.016
Elevation	0.271	-0.884	-0.736	-0.157
Miscellaneous forest	**0.303**	0.078	0.009	-0.062
Open forest	0.028	-0.007	0.018	0.035
Riverine forest	0.035	0.006	-0.021	0.062
Slope	0.261	-0.036	0.033	0.073
Submergence	0.053	0.009	0.044	0.02
Teak dominated forest	**0.419**	0.127	0.096	-0.503
Teak-lagerstromia forest	**0.301**	-0.009	0.015	-0.017
Teak-mixed forest	**0.301**	-0.028	0.011	-0.12
Distance from water	0.262	0.093	0.577	0.642

Wild dog preferred habitat with chital (0.631), sambar (0.478) and wild pig (0.584), areas with less livestock (-0.296), people (-.0.291), areas with less wood cutting (-0.46), distant areas from road (0.32) and village (0.631), areas with medium (0.368) and low canopy (0.362), miscellaneous forest (0.303), teak dominated forest (0.419), teak lagerstroemia forest (0.301) and teak mixed forest (0.301). Optimal HS of wild dog is expected to deviate with respect to following parameters, chital encounter rate (-0.721 on spec.1), sambar encounter rate (spec.2: 0.421, spec.3: 0.676), wild pig encounter rate (spec.2: 0.503, spec.3: -0.55), lopping (spec.1: -0.652, spec.2: -0.982, spec.3: -0.948), distance from road (-0.538 on spec.1), distance from village (-0.515 on spec.1), agriculture (spec.2: 0.319, spec.3: -0.446), low canopy (0.422 on spec.1) and distance from water (spec.2: 0.577, spec.3: 0.642).

Fig. 6.21 Habitat suitability map of Wild Dog based on species interaction

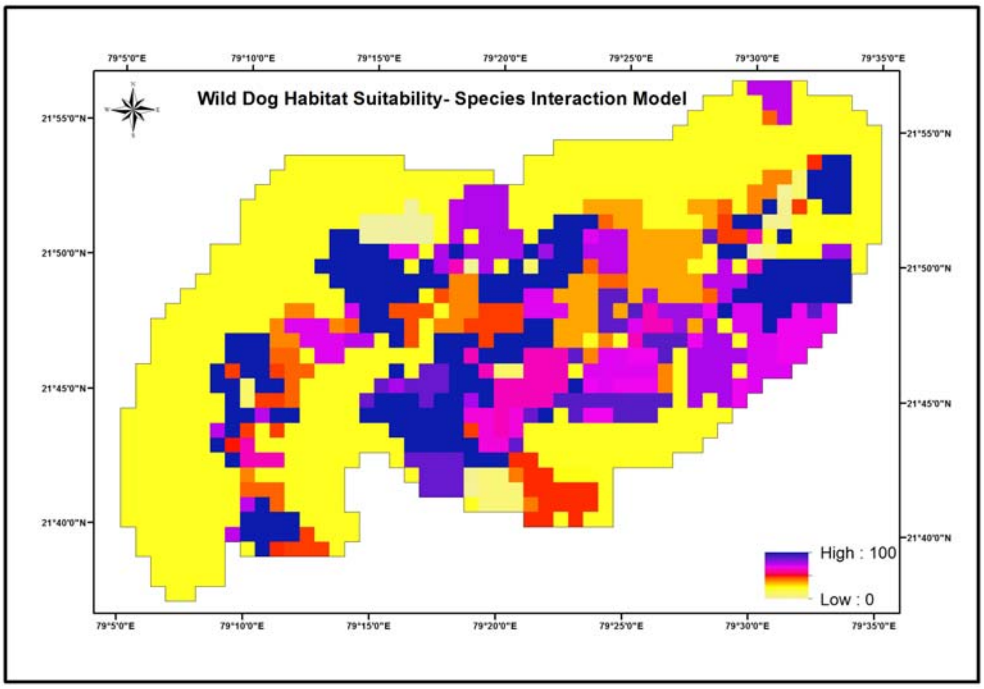


Fig. 6.22 Habitat suitability map of Wild Dog based on Human disturbance

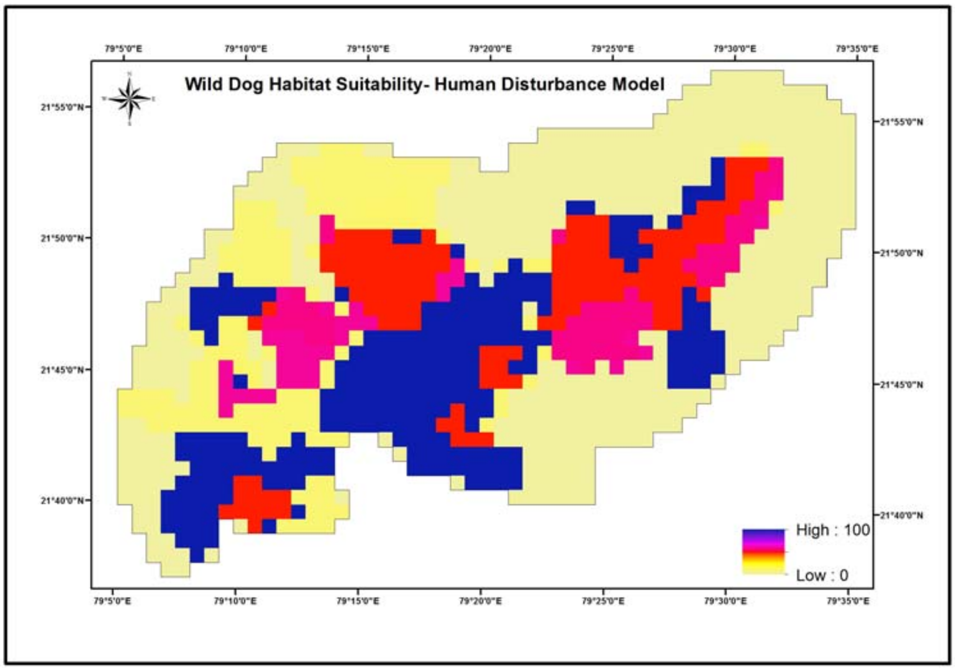


Fig. 6.23 Habitat suitability map of Wild Dog based on resource and geographical features

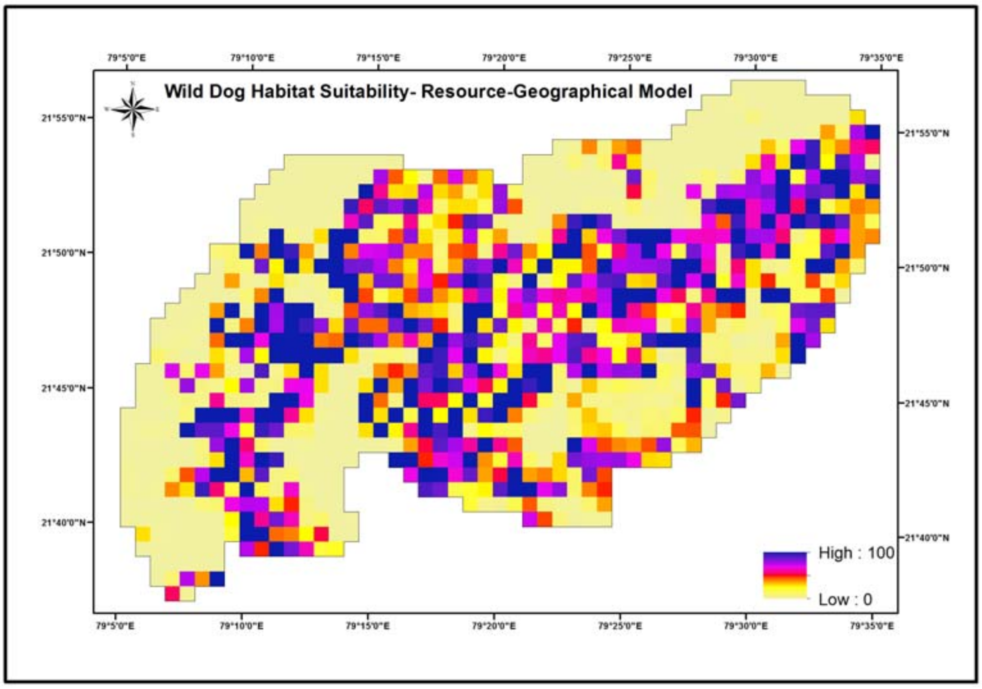
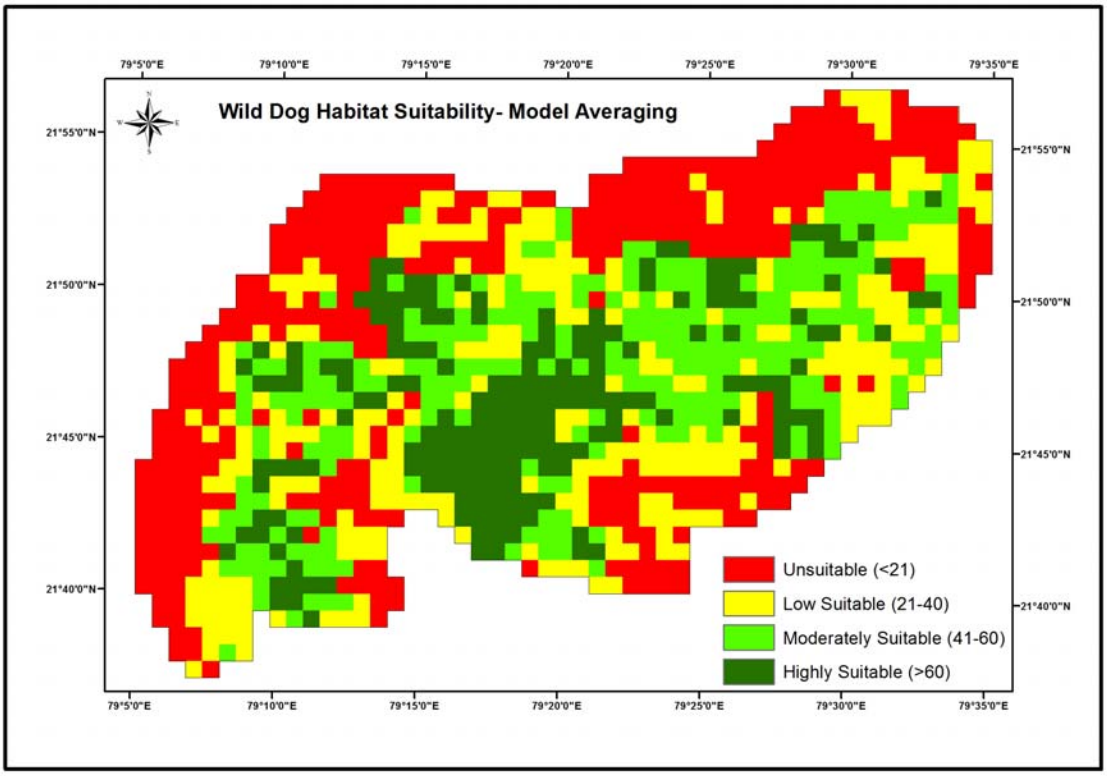


Fig. 6.24 Habitat suitability map of Wild Dog based on model averaging



Model 24 (Fig. 6.24) was generated by model averaging of model 21 to model 23. Validation of model 24 gave highest AVI (0.688) and CVI (0.376) (Table 6.19) values compared to other models (AVI: 0.664, 0.631 and 0.602 respectively; CVI: 0.361, 0.344, 0.305). The areas under highly suitable, moderately suitable, low suitable and unsuitable were 192 Km^2, 249 Km^2, 279 Km^2 and 371 Km^2 respectively for wild dog in PTR (Table 6.20).

Table 6.18 Summary of validating model of all HS models for wild dog

No.	Habitat Suitability Model	AVI	AVI0	CVI
1	Wild dog Species Interaction model	0.664	0.303	0.361
2	Wild dog Human Disturbance Model	0.631	0.287	0.344
3	Wild dog Resource-geographical model	0.602	0.297	0.305
4	Wild dog model averaging	0.688	0.312	0.376

AVI (prop. of validation cells with HS > 50), AVI0 (Prop. of all cell with HS > 50), CVI (CVI =AVI−AVI0)

Table 6.19 Area under each Habitat suitability category for wild dog in Pench Tiger Reserve, Madhya Pradesh

Habitat suitability classes	Area (Km^2)
Highly Suitable	196
Moderately suitable	249
Low suitable	272
Unsuitable	371

6.3.7 Changes in Habitat suitability with present and predicted land cover

Results on habitat suitability modeling by ENFA, presented in this section was modeled only with few land cover classes and hence they were not compared with results of ENFA models discussed earlier in this chapter.

6.3.7.1 Predicted suitability area comparison between 2009 and 2019 for chital

A significant decrease was visible for highly suitable areas for chital in 2019 compared to 2009 in the study area (Table 6.22). Decrease in high suitable areas and increase in moderate suitable area showed degradation of habitat suitability for chital. Similarly results registered decrease in low suitable area and increase in unsuitable areas for this species.

Table 6.20 Area Comparison of habitat suitability classes between 2009 and 2019 for chital in Pench Tiger Reserve, Madhya Pradesh

Class	**2009 (Km^2)**	**2019 (Km^2)**
Unsuitable	509	522
Low suitable	141	129
Moderately suitable	108	157
Highly suitable	330	280

6.3.7.2 Predicted suitability area comparison between 2009 and 2019 for sambar

For sambar there was an increase in the highly suitable area observed between 2009 and 2019 but moderately and low suitable areas decreased with an increase in unsuitable areas in PTR (Table 6.23).

Table 6.21 Area Comparison of habitat suitability classes of 2009 and 2019 for sambar in Pench Tiger Reserve, Madhya Pradesh

Class	**2009 (Km^2)**	**2019 (Km^2)**
Unsuitable	403	451
Low suitable	229	202
Moderately suitable	171	126
Highly suitable	285	309

6.3.7.3 Predicted suitability area comparison between 2009 and 2019 for wild pig

For wild pig, there were decreases in high suitable, moderately suitable and low suitable areas, observed between 2009 and 2019 in PTR. However the unsuitable area for wild pig in the study area increased (Table 6.24).

Table 6.22 Area Comparison of habitat suitability classes between 2009 and 2019 for wild pig in Pench Tiger Reserve, Madhya Pradesh

Class	2009 (Km^2)	2019 (Km^2)
Unsuitable	524	563
Low suitable	147	138
Moderately suitable	140	122
Highly suitable	277	265

6.3.7.4 Predicted suitability area comparison between 2009 and 2019 for tiger

For tigers also highly, moderate and low suitable areas decreased in 2019 with an increase in unsuitable area (Table 6.25).

Table 6.23 Area Comparison of habitat suitability classes between 2009 and 2019 for Tiger in Pench Tiger Reserve, Madhya Pradesh

Class	2009 (Km^2)	2019 (Km^2)
Unsuitable	518	556
Low suitable	156	147
Moderately suitable	133	121
Highly suitable	281	264

6.3.7.5 Predicted suitability area comparison between 2009 and 2019 for leopard

For Leopard, the predicted model actually showed increase in the suitable areas both highly and low, but decrease in moderately suitable and unsuitable areas for leopard in PTR (Table 6.26).

Table 6.24 Area Comparison of habitat suitability classes of 2009 and 2019 for leopard in Pench Tiger Reserve, Madhya Pradesh

Class	2009 (Km^2)	2019 (Km^2)
Unsuitable	596	577
Low suitable	89	121
Moderately suitable	142	121
Highly suitable	261	269

6.3.7.6 Predicted suitability area comparison between 2009 and 2019 for wild dog

For wild dog, the predicted model showed decrease in all the suitability classes and increase in unsuitable area in PTR between 2009 and 2019 (Table 6.27).

Table 6.25 Area Comparison of habitat suitability classes of 2009 and 2019 for wild dog in Pench Tiger Reserve, Madhya Pradesh

Class	2009 (Km^2)	2019 (Km^2)
Unsuitable	524	563
Low suitable	147	138
Moderately suitable	140	122
Highly suitable	277	265

6.4 DISCUSSION

Each one of the three HS maps can provide ecological information on major mammalian species according to its favorite area in the sense of favorable resources, sufficiency of undisturbed areas and less competition between species. The species distribution is accordingly influenced by each feature. This is in agreement with the relationship between species distribution and niche as proposed by Pulliam (2000). The distributions of different species and of human activities/visitation and of human-induced events in each habitat type can delineate the places of competition, predation, immigration and re-colonization (Guisan and Thuiller, 2005) by other species as well as the place(s) of pressure by humans. Since species can be found in unsuitable sites, one can say that the realized niche is sometimes larger than the fundamental niche (Pulliam, 1988).

6.4.1 Species preference

Past studies (Sankar et al. 2001, Biswas and Sankar 2002, Karanth et al. 2004, Majumder 2012) had reported high wild ungulate densities in PTR which comprised of chital, sambar and wild pig. Biswas and Sankar (2002) reported chital sambar and wild pig are main prey species of tiger in this area. In the present study, this fact is supported by high positive marginality of chital, sambar and wild pig with tiger. Similarly these wild ungulates had high positive marginality with leopard and wild dog. Karanth et al. (2004) found that in PTR, tiger density falls outside the 95% prediction intervals of prey density which can be interpreted that PTR could support more numbers of tigers in comparison to its prey density. Densities of tiger, leopard and wild dog in PTR as reported by Majumder (2011) were 3.6 (SE 1.5), 4.9 (SE 1.2) and 3.3 (SE 1.2) respectively per 100 Km^2. In spite of similar densities, carnivores like tiger, leopard and wild dog may co-exist since the ecological factors, such as adequate availability of appropriate-sized prey, dense cover and high tree densities may be the primary factors in structuring the predator communities of tropical forests (Karanth 2000). In the present study, the observed low marginalities among the carnivores showed less competition/affinity.

The presence of all the study species (prey/predator) were negatively correlated with major human disturbance indicators such as lopping, cattle dung, wood cutting. This suggested that all these species avoided disturbed areas and preferred areas far from roads and villages. The extent of human presence could be attributed by the presence of 99 villages within 5 Km buffer of PTR. These villages exert immense pressure on forests as people here are mostly dependent on forest for fuel wood and grazing of livestock. Due to adequate protection and support from field staffs, the overall specialisation of the human disturbance models of the carnivore species turned out to be the highest, which can be attributed as the conditions of human disturbances in PTR for carnivores are better than species interaction and resource-geographical conditions. Despite a long history of concern for wild tigers, both their range and total number have collapsed: fewer than 3,500 animals now live in the wild, occupying less than 7% of their historical range (Sanderson et al. 2006) and PTR could turn out to be a major source population of tigers in the Central Indian landscape. It is presumed that if tiger as a flagship species is conserved, it will in turn have positive impact on other major mammalian species conservation as well.

In this study, forest canopy played an important role for the presence of tiger, leopard and wild dog. Similar findings were reported by Karanth (2000) in nagerhole Tiger Reserve. As predator distributions are guided by prey distributions (Karanth 2000), similarly presence of chital, sambar and wild pig distribution are influenced by forest canopies as observed in the present study. Miscellaneous and teak associated forests dominate in PTR. These forest types had shown greater association with all the study species. Water being one of the essential life support factor, contributed equally in all the HS models of the study species.

Though future predictions of HS are modeled only with few habitat classes, still they are powerful enough to enlighten future scenarios. In the given circumstance these predictions are over estimated as same species presence data sets of present day was used for the future scenarios. These results left enough space for validation or contradiction through many similar studies in future.

6.4.2 Management Implication

The HS models provided a tool for the conservation and management planning of major carnivore and wild ungulate species in and around PTR. These models predicted the distribution and the extent of favorable species-specific habitats in the study area. This study provided not only factors governing species presence in PTR but also gave a clear idea of areas which needed urgent management interventions. Utmost care should be taken before any management intervention is planned in highly or moderately suitable areas as few of them may alter habitat quality for the study species. This study also provided good insight for future landscape changes which will help the managers to set priority areas for habitat improvement or restrict areas to deteriorate any further.

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