



**EVALUATING
TIGER HABITAT
AT THE TEHSIL LEVEL**

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EVALUATING TIGER HABITAT AT THE TEHSIL LEVEL

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2006



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Message

Civilizations have held the tiger in awe and fear, yet were inspired by its strength and beauty. The tiger is deeply engraved in our culture, mythology, and psyche. Yet, our present day ways of life threaten its very existence. We have inherited the wealth of nature from our forefathers, and must act as custodians to pass on this wealth undiminished, to future generations. The survival of the tiger is our test case; if we succeed in safeguarding its survival, our generation would have passed the test. For this we need to promote eco-friendly land use in tiger conservation areas. This study assists in identifying these areas. However, it is we, the people of India, who need to act in safeguarding them for the tiger, keeping in mind the well being of the communities who inhabit them. Herein lies the challenge which we need to address with full resolve.


(A. RAJA)



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Foreword

Tigers are currently distributed in just seventeen States of the country. The distribution of tigers in these States depends upon a range of ecological and socio-economic factors. Inadequate information on tiger habitats and associated cofactors has been a limiting factor in developing strategies for its long-term survival.

“Evaluating Tiger habitats in India”, for the first time, presents a country level appraisal to describe the present geographical extent of tiger populations vis-à-vis their habitat quality. The latter, in turn, is dependent on the status of the forest and the biotic disturbance. The tools used for analysis include rapid assessment of tiger occurrences based on the records of past five years in States, remote sensing, and GIS. It provides information on the geography of tiger habitats, the size of such habitat units, and the extent to which such units are connected.

Our Tiger Reserves and Protected Areas are interdispersed amidst landscapes of varying land uses. Tigers move out and sometimes thrive, outside Tiger Reserves and the Protected Area system. Prioritization of such areas is required to foster restorative conservation activities with the active involvement of the local people.

This study highlights the State level habitat situation, critical links, as well as areas, which require immediate attention for recover, through ecologically sustainable landscape level strategies for tiger conservation.



(Prodipto Ghosh)

Dated : 14th June, 2006
Place : New Delhi


जहाँ है हरियाली ।
वहाँ है खुशहाली ॥

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EXECUTIVE SUMMARY

- 1- Evaluating tiger habitat in India is the first ever study of its kind undertaken in the country for determining the current and historical distribution of free ranging tigers, identify the potential forest areas for tiger survival and prioritise these for conservation planning and management. The study shifts the focus from tiger number, protected area oriented conservation strategies to landscape level conservation.
- 2- Increasing pressure on the land for agriculture, grazing and industry by a growing human population has resulted in deterioration of forest quality and extent. This, combined with subsistence level poaching has severely reduced prey populations. Loss of habitat, prey, a high demand and international value for tiger body parts has jeopardised the survival of the tiger. Today most protected areas and tiger reserves are increasingly becoming insular in a sea of human dominated landscapes. Due to the small size of these protected areas, they are unlikely to support, demographically and genetically viable tiger populations. It is imperative to look beyond protected areas for achieving effective long term conservation goals. For ensuring persistence of tiger populations it is essential that they are managed in a meta-population framework where several breeding tiger populations (source populations) share genetic material through dispersing individuals. The need of the hour is to have a holistic approach by considering landscapes as units for conservation management.
- 3- We conducted a questionnaire survey addressed to the Chief Wildlife Wardens for determining spatial occupancy of tigers and their prey at the resolution of a tehsil. Though data were obtained as tiger numbers for the past 5-6 years, these were reduced to mere presence/absence. These data were mapped using a Geographic Information System alongwith remotely sensed information, attribute data, and landscape characteristics depicting habitat extent, quality, and anthropogenic pressures. Tiger occupancy in forested habitats was modeled in a 10 x 10 km grid using stepwise logistic regression.
- 4- A literature survey was conducted to estimate tiger occupancy during the last 150 years at the resolution of districts. This distribution was compared

with the current distribution to evaluate where tigers had become locally extinct.

- 5- Information on detected crimes against tigers was obtained from official records, and from records in the public domain. These were mapped at the tehsil level to understand spatial distribution and intensity of detected poaching of tigers.
- 6- Tiger occupied forests in India have been classified into 6 landscape complexes; namely (a) Shivalik-Gangatic Plains, (b) North-Eastern Hills and Bhramaputra Plains, (c) Central Indian Landscape Complex, (d) Sunderbans, (e) Western Ghats and (f) the Eastern Ghats. Tiger populations within these landscape complexes are likely to share a common gene pool, since tiger habitats within these landscape complexes were contiguous during the recent past. Each landscape complex consists of landscape units that still have contiguous tiger habitat and contain one to many breeding populations of tigers (source populations). Within each landscape unit and sometime between landscape units, there exists a potential to manage tiger populations as a meta-population. This enhances the conservation potential of each of the single populations and probability of their long-term persistence.
- 7- Tigers have been locally extirpated from 97 districts within the recent past constituting 26% of their range in India. Tiger poaching and related offences have been primarily detected in Uttaranchal and Madhya Pradesh, near Tiger Reserves. The Western Ghat landscape complex had fewer registered tiger crimes.
- 8- The Shivalik-Gangetic plain landscape complex is composed of two landscape units; (a) Kalesar to Kishenpur and (b) Dudhwa to Valmiki. The landscape complex had about 20,800 km² of potential tiger habitat on the Indian side. The Dudhwa-Valmiki landscape is now connected only via Nepal forests, and needs to be managed through International cooperation with Nepal.
- 9- North-Eastern hills and Bhramaputra plains is also composed of two landscape units; (a) The largest single landscape unit of about 136,000 km² extending from Pakke Tiger Reserve to Namdapha Tiger Reserve in the East, and towards Dampa Tiger Reserve in the South. Kaziranga

constituting a major source population of tigers, is connected through the Karbi Anglong hills. The landscape continues West upto Balphakram National Park, (b) The second landscape complex consists of Manas Tiger Reserve, in Assam, along with Buxa Tiger Reserve, Gorumara and Singhalila forests of West Bengal. The landscape is fragmented on the Indian side but has forest contiguity through Bhutan, and currently has about 7,200 km² of good tiger habitat.

- 10- The Central Indian landscape complex consists of eleven separate landscapes out of which four have potential to sustain meta-populations of tigers. These are (a) Kanha-Pench landscape of about 16,000 km², (b) Satpura-Melghat (12,700 km²) (c) Sanjay-Palamau (13,700km²) and (d) Navegaon-Indravati (34,000 km²) landscapes. Six other landscapes with single source populations which could potentially persist due to their reasonable large size are (a) Bandhavgarh (b) Panna (c) Ranthamora-Kuno-Palpur (d) Tadoba (e) Simlipal and (f) Saranda landscapes. Currently about 156,000 km² of potentially good tiger habitat exists in this landscape complex.
- 11- The Eastern Ghat landscape complex has the potential to support only one meta-population within the landscape of Nagarjunasagar Tiger Reserve and Gundlar Brahmeshwara forest, covering an area of about 6,000 km². At present about 15,000 km² of potential tiger habitat exists within this landscape complex.
- 12- The Western Ghat landscape complex consist of three landscape units; (a) Forested area from the district of Pune to Palghat in Kerala, and eastwards upto Dharmapuri in Tamil Nadu. This landscape has good potential for long term tiger survival due to its large extent of over 34,000 km² of contiguous forest, with several source populations of tigers that likely exist as a meta-population (b) Forest areas South of Palghat upto Kodaikanal having some connectivity with the Periyar landscape (c) the Periyar-Kalakad landscape unit of about 10,000 km² area. The current potential tiger habitat in the landscape complex is about 51,000 km².
- 13- The Sunderbans landscape complex is the smallest isolated landscape that likely has a single population of tigers. The Sunderbans need to be managed

through International cooperation with the Government of Bangladesh. Sunderban tiger habitat within India is over a 1000 km².

- 14- Size of Priority-I tiger conservation areas were maximum in Central India (29,000 km²), followed by the North Eastern-Hill and Bhramputra plains (19,000 km²), and Western Ghat complex (17,000 km²). These areas are critically important for tigers as they harbour the source populations. Priority-II and III areas are good tiger habitats which serve as links between source populations and can potentially sustain low density breeding populations. The country has about 300,000 km² of potentially good tiger habitat.
- 15- Though the tiger has lost substantial portion of its range during the past 100 years, considerable extent of its habitat still remains in India. The tiger seems to be limited on account of anthropogenic disturbances to its habitat, availability of its prey which is severely depleted, and by direct poaching. To ensure the long term survival of tigers in India it is imperative to offer strict protection to Priority-I areas, and to manage Priority-II and III areas with restorative and ameliorative management inputs by involving local communities and providing them with a direct stake in conservation. Tigers are a conservation dependent species requiring large contiguous forests with fair interspersion of undisturbed breeding areas. This leaves little choice other than to evolve strategies by mainstreaming conservation priorities in regional development policy and planning for managing Priority areas identified in the landscape complexes. Such an approach would ensure that breeding tiger populations have a possibility to share genetic material and exist in a meta-population framework, thereby enhancing the possibility of their survival.

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- The Authors

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Introduction

Tiger is not only a flag bearer of conservation but also an umbrella species for majority of eco-regions in the Indian subcontinent. Its role as a top predator is vital in regulating and perpetuating ecological processes and systems (Terborgh J. 1991, Sunquist et al. 1999). The tiger needs large undisturbed landscapes with ample prey to raise young and to maintain long term genetic and demographic viability (Seidensticker and McDougal 1993, Karanth and Sunquist 1995, Carbone et al. 1999).

Unlike Africa, Latin America or South-East Asia, the forest boundaries in India appear to have stabilized while forest quality continues to deteriorate due to resource extraction (Ghimere 1979, Gunatilake & Chakravarty 2000, Lele et al. 2000). In the past 50 years, humans have changed these ecosystems largely to meet growing demands for food, fresh water, timber, fiber, and fuel (Millennium Ecosystem Assessment, 2005) more rapidly and extensively than in any comparable period of time in human history. Meeting the challenges of increasing demand for land by an ever growing population in the absence of holistic landscape conservation planning has severely compromised the tiger and its ecosystem. If we intend to conserve tigers in their natural habitats, we need innovative approaches to land use planning that maintain connectivity between source tiger populations in a meta-population frame work.

Currently tigers occur in the forest areas of 17 States in India. The distribution of tigers and their density in these forests vary on account of several ecological and anthropogenic factors like forest cover, terrain, natural prey availability, presence of undisturbed habitat and the quality of managerial efforts taken towards protection.

Broadly, the country can be divided into six tiger occupied landscape complexes:

1. Shivaliks and the Gangetic Plain
2. North-East Hills and Brahmaputra Plains
3. Central Indian Landscape Complex
4. Eastern Ghats
5. Western Ghats and
6. Sunderbans

Within the landscapes, the characteristics vary with respect to percentage of forest area and size of undisturbed forest patches (cores). The tiger density and poaching pressures in such landscapes also differ along with the biotic disturbance.

The Protected Areas in India are analogous to small islands in a vast sea of ecologically unsustainable land uses of varying degrees. Tiger reserves and some protected areas serve as source populations of tigers while intervening forested areas act as corridors. Thus the “tiger bearing forests” need to be fostered with protection as well as restorative inputs to ensure their source and corridor value for demographic and genetic viability of tiger populations. This becomes extremely crucial at the national level for evolving a road map to prevent the extinction of the tiger.

This report attempts to take stock of what we have and where. These are essential steps towards assigning priorities and identifying crucial links. The tools used include rapid assessment of tiger occurrence based on the records of past five to six years in Indian States, remotely sensed data and attribute data, analysed using GIS and multivariate statistical models. The report describes the current and recent past geographical range of the tiger. It provides spatial data on tiger distribution at the tehsil level and its associated landscape characterization; which is a precursor for land use planning incorporating conservation concerns and priorities.

History of tigers

The tiger is thought to have an East Asian origin (Hemmer 1987; Herrington 1987; Mazak 1981, 1996), abundant tiger fossils were reported during the Pleistocene period. Glacial and interglacial fluctuations during the Pleistocene and other geological events probably caused repeated restrictions and expansions in the geographical range of the tigers. (Hemmer 1987; Kitchener 1999; Kitchener and Dugmore 2000). Tigers were historically distributed from the tropical forest of South-East Asia (Java, Sumatra, Malaysia) to the Mediterranean forests of Turkey in the West, Soviet Far East in the north east to India in the south west. Eight

subspecies of tigers (*Panthera tigris*) were traditionally recognized, of which three recently became extinct (**Figure 1**). Luo et al. (2004) estimated the most recent common ancestor for tiger subspecies (based on Mitochondrial-DNA haplotypes) to be 72,000–108,000 years old. Extant Tigers are classified as Amur tigers (*P. t. altaica*); northern Indochinese tigers (*P. t. corbetti*); Malayan tiger (*P. t. malayensis*), which are confined to the Malayan Peninsula; Sumatran tigers (*P. t. sumatrae*); Bengal tigers (*P. t. tigris*) and South China tiger (*P. t. amoyensis*). The subspecies status of the South China tiger still needs further confirmation (Luo et al. 2004, O'Brien et al. 2005) (**Figure 1**).

Since the early 1900s, tiger range has decreased drastically due to habitat loss, fragmentation, and human persecution. The population of free ranging tigers has decreased probably from over 100,000 in 1900 to fewer than 7,000 individuals (Nowell and Jackson 1996; Dinerstein et al. 1997; Kitchener and Dugmore 2000). Most populations consist of less than 120 animals, which increase the risk of local extirpation due to demographic and genetic stochasticity (Smith and McDougal 1991; Dinerstein et al. 1997).

Tiger fossils first appeared in India in the late Pleistocene (Brandt 1871; Lydekker 1886; Tscherski 1892; Dubois 1908; Zdansky 1928; Brongersma 1935; Loukashkin 1937; Hooijer 1947; Hemmer 1976, 1987). The pattern of genetic variation in the Bengal tiger corresponds to the premise that tigers arrived in India approximately 12,000 years ago (Kitchener and Dugmore 2000). This recent history of tigers in the Indian subcontinent is consistent with the lack of tiger fossils from India prior to the late Pleistocene and the absence of tigers from Sri Lanka (Kitchener and Dugmore 2000).

The Indian subcontinent was occupied by hunter gatherer communities by the late Pleistocene (Gadgil and Guha 1992). Climate change around 10,000 years before period (YBP) led to extinctions of many species as well as a shift in the society to agro-pastoralism (Gadgil and Guha 1992, Hutchingson et al. 1977). The drier habitat of North-Western India, Indus Plains and the Deccan Peninsula were cultivated much before the moister parts of the Gangetic plains and the West coast (Gadgil and Guha 1992, Posschl 1982, Allchin 1963). Agro-pastoralism along with shifting cultivation during this time would have created a mosaic of habitats that supported high ungulate densities. This was probably a period when tiger densities peaked in the Indian subcontinent.

The tiger had always occupied an important place in Indian mythology. Seals depicting tigers were found from Mohanjodaro and Harappan civilizations (3000 to 1700 B. C. E.) (Thapar R. 2006). The tiger was believed to maintain natural order among animals in the forest and was attributed to have admirable anthropogenic qualities and was therefore worthy of worship (Thapar R. 2006). Rigveda makes no mention of tiger, however later Vedas do so (1500 to 500 B.C.E.). The tiger in Indian culture was revered, admired and

feared. Heros were eulogized as tigers (Thapar R. 2006) and this association of the tiger with culture and social values persist even today (Sankhala 1978). Coins from the era of Samudra Gupta (AD 335-80) depicted tiger hunts with bows and arrows (Rangarajan 2001b, Thapar R. 2006). During medieval times hunting of tigers was a favorite sport of Rajput kings of Rajputana (Todd 1832 and Sankhala 1969). There are records of tiger hunts and tigers being kept in captivity by several Mughal emperors (Rangarajan 2001b). In the more recent past Babur reported tiger hunts near Peshawar on the banks of the river Indus, Jahangir and Shahjahan hunted tigers near Agra (Sankhala 1978 and Rangarajan 2001b) where they are now extinct. It has been stated that Jahangir hunted 17,000 animals during the first twelve years of his reign, which included 86 tigers and lions. This number is insignificant (7 big cats/year) compared to the massacre during the 19th and 20th Centuries (Rangarajan 2001b) by those who held power. At the time of Akbar's death wildlife was abundant and human population low (150-170 million) (Rangarajan 2001b).

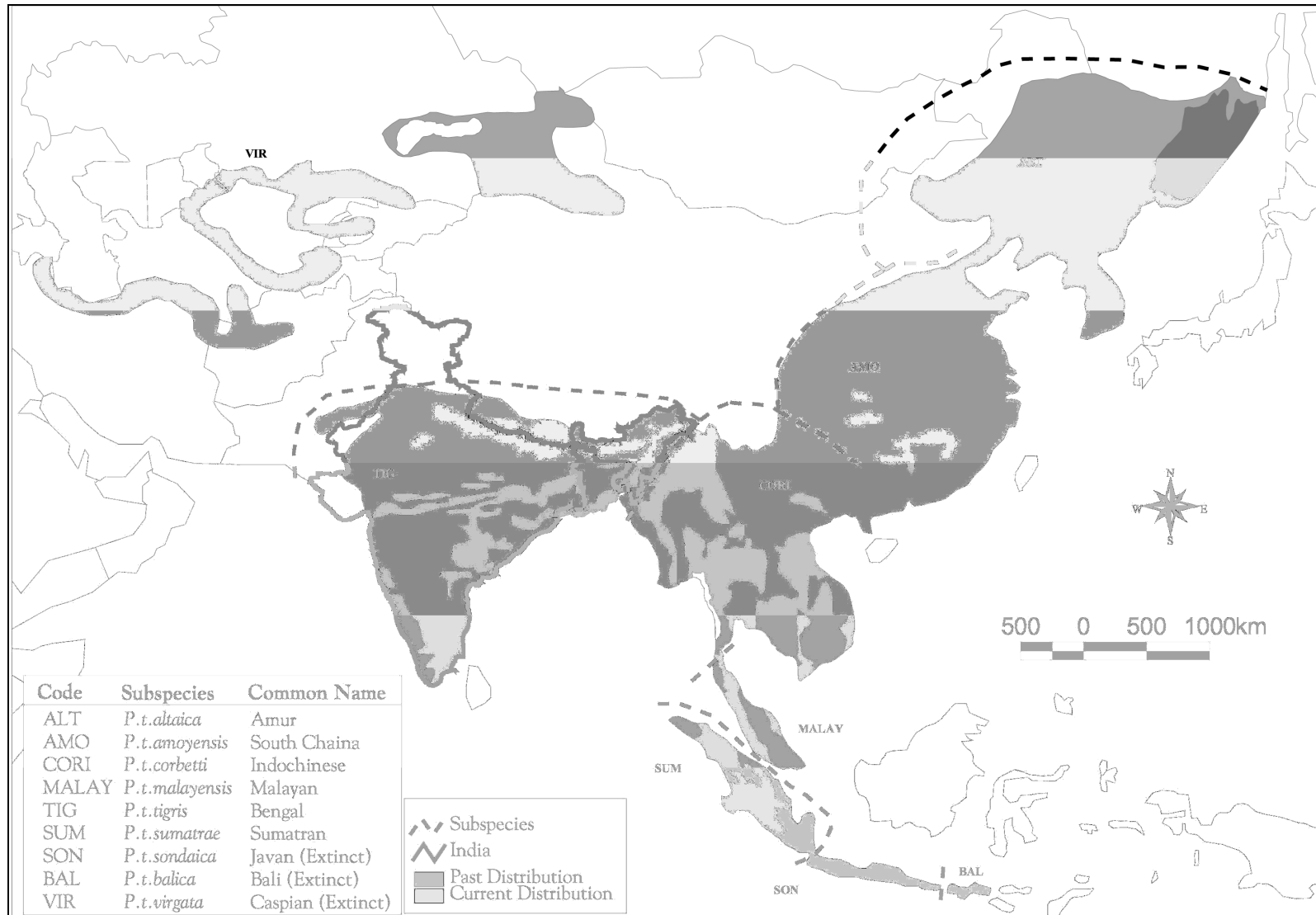
The low human population, socio-cultural environment, abundant natural resources and absence of a bounty system for killing large predators till the advent of the Europeans were the factors resulting in abundant wildlife. There was always conflict between humans and tigers (including other wild animals). The Vedic hymns describe tiger predation on cattle (3000 to 1700 B.C. E.), the Arthshastra (2 B. C. E.) mentions various poisons and traps used to eradicate tigers once they became a threat (Thapar R. 2006). The wildlife and forests changed forever following the great rebellion of 1857. During the British rule, western dominion and utilitarian values dominated wildlife resource management in place of co-existence and custodianship. In British ruled territories methods were devised to exterminate wild animals (Rangarajan 1998, 2001b), and bounties were given to exterminate predators all over the country which continued even after Independence (Sankhala 1978, Rangarajan 1998 & 2001b, Thapar 2006). Major Tweedie wanted to employ 'tiger killers' like mole catchers and rabbit killers in England (Rangarajan 1998). Poisoning of cattle carcass was permitted by British in Southern India (Rangarajan 1998). Poison alone has been responsible for the extermination of large carnivores in Europe and North America and continuous to be a major threat to existing tiger populations. The bounty system funded the killing of 16,573 tigers between 1879-88 alone (Rangrajan 2001b). Computation of total tigers killed between 1875 to 1925 was over 56,000, which excludes records of thirteen years of missing data. However, extrapolation suggests this number to be around 65,000 tigers (Rangarajan 1998). The extension of agriculture and working of forests increased the conflict between large predators and humans (Rangarajan 1995). The Indian Princes and British officers competed amongst themselves for tiger trophies. Availability of rifles and motorized vehicles to the middle class further increased the hunting pressure on wildlife (Rangarajan 1998, 2001a). The Maharaja of Sarguja shot 1100 tigers, Nawab of Tonk 600 tigers, Rulers of Udaipur and Gauripur 500 each, George Yule 400 tigers and many more

who competed to kill as many as they could (Rangarajan 2001b). The 19th Century was not only known for the mindless destruction of wildlife but also for the beginning of conservation movement. There were avid defenders of wildlife both amongst the British officers and native Indian princes (Rangarajan 1998, 2001b, Divyabhanusinh 2005).

Tiger populations were estimated to have declined by 93 percent over a 50 year period in Bundi and Gwalior primarily due to hunting by 1972 (Sankhala 1978). Both Sankhala (1978) and Gee (1964) arrived at similar tiger population estimates of 30,000 and 40,000 respectively for the early 1930's based on their educated guesses. The beginning of tiger habitat evaluation in the country can be traced back to 1966, when the late S.R.Choudhary applied the pugmark technique developed by Dharmakumarsinh for counting lions in Gir (Dharmakumarsinh 1959) in the form of the cooperation census technique for tigers in the State of Orissa. The first systematic estimation of tiger numbers was done in 1972 by 5000 forest department personnel using the pugmark method, and 1827 tigers were estimated. In 1977 tiger numbers in the entire sub-continent were estimated around 2741 (200 in Nepal, 40 in Bhutan, 350 in Bangladesh, and the rest in India) (Sankhala 1978). A four fold increase in the human population, removal and degradation of forests for expansion of agriculture, resource extraction, and hunting (legal and illegal) were primarily responsible for the decline of tiger population by 1974-76.

Smt. Indira Gandhi the then Prime Minister of India played a key role in conserving India's wildlife and the tiger in particular. The enactment of the Wildlife Protection Act in 1972, followed by the launch of Project Tiger in 1973, paved the way for the protection of tigers and their habitat. The 1972 task force report under the chairmanship of Dr. Karan Singh prepared a blue print for management, protection and legal frame work which secured large tracts of existing forests for tigers (Narain et al. 2005). In 1983 another task force under chairmanship of Shri Madhavrao Sindhia addressed the issue of human-wildlife interface, and emphasized the need to integrate people for long term success of conservation efforts. The next two decades (1983-2003) witnessed large scale changes in economic and political scenario in India. The 2005 Tiger Task Force under chairmanship of Ms. Sunita Narain, highlighted the need for integrating people in conservation, settlements of rights in protected areas within a stipulated time frame management based on sound science, good monitoring system, and protection, creation of the National Tiger Conservation Authority and setting up of the National Wildlife Crime Control Bureau.

Figure 1 Historical and current global distribution range of the various sub-species of the tiger



Where can tigers survive?

The habitats which have a probability of long term survival of tigers need to be identified and conserved on the basis of sound principles of conservation biology and landscape ecology (Wickramanayake et al. 1999). Choice or priority setting is a difficult process especially when it comes to resource allocation for conservation. Prioritization spans from expert assessment to hard data based models. In the case of the Indian sub-continent, information available is sketchy or inadequately distributed in space. Hence, surrogates are used instead of precise information about species distribution, and factors affecting their survival. The tiger habitat occupancy at country level was first done by Sankhala in 1978 during the formative phase of project tiger followed by several broad descriptions of distribution by various authors. Land tenures of tiger in Kanha National Park were studied by Panwar (1987). Mapping of habitat occupancy was described by Rishi (1997) to monitor tiger populations. Rishi (1997) who emphasized the concept of eco-administrative unit for planning ecosystem based management of areas situated in and around forests and wildlife habitats. Rajesh Gopal (2001) carried out multicriteria based analysis of undivided Madhya Pradesh in collaboration the National Remote Sensing Agency, using coarse resolution satellite data and GIS, for determining tiger habitat suitability in the State.

The population of tigers in Nepal-terai was mapped by Smith et al. (1998) and the Indian Terai by Johnsingh et. al (2004). These authors derived spatial occupancy models to assess distribution of tigers at large scales and assessed connectivity between tiger populations. The most recent attempts were by Wikramanayake et al. (1999) and Bryja et al. (2005) to map conservation priority areas for tigers in the Indo-Pacific region

Today demographically and genetically viable tiger populations are few and there is an urgent need to keep the connectivity intact to maintain exchange of individuals and genes. There is an urgent need to adopt a dynamic and multifaceted approach for landscape planning, incorporating a holistic integrated inter-agency land use plan for protected areas and multiple use areas. This report summarises current tiger distribution at the coarse scale of tehsils (administrative subdivision of a district) along with information on landscape characteristics and land use patterns; the elements essential for integrated landscape planning incorporating socio-economic and conservation concerns alike (Thapar 2006, Narain et al. 2005, Wikramanayake et al. 1999).

Tiger Distribution

The historical tiger distribution map was constructed for the past 150 years (before the commencement of Project Tiger) through a literature survey. A total of 140 records where mention of the tiger could be attributed to a geographical location (**Appendix 1**) were used

for developing this map (**Figure 2**). Geographical locations mentioned in the literature were mapped to current districts in a GIS with a link to the referenced report.

Data was compiled on tiger presence reported at the tehsil level for the past 5-6 years (1999-2004) through a questionnaire addressed to the Chief Wildlife Wardens of all tiger-states by the Project Tiger Directorate. Though several states had data on tiger numbers in some tehsils (especially in protected areas), only the reported presence of tiger(s) in the past six years were used to score a tehsil as “occupied by tigers” or not. Since tigers were unlikely to live outside of forests, forest cover map was superimposed on the tehsils occupied by tigers, and non forested areas were eliminated from further analysis. The tiger occupied tehsils were further divided into three groups, tehsils that had reported tigers (a) only for 1 year, (b) for 2-3 years and (c) for more than 3 years between 1999-2004.

To compare the historical tiger distribution with the current tiger distribution, the information on current tiger distribution at the tehsil resolution was converted to the coarser scale of districts. The districts in which tigers have become locally extinct were marked (**Figure 2**). Tigers seem to have been preferentially exterminated from the Western and Northern population limits. The Western districts have dry thorn / deciduous forests with low productivity, while the Gangetic Plains have been heavily exploited for intensive agriculture.

Tigers are tenaciously holding their ground in moister forests. Tigers have become locally extinct from 97 districts of India. The area of these districts constitutes 26% of the total area of districts that were occupied by tigers during the recent past.

Detected crimes against tigers seems to follow a pattern corresponding with tiger densities in Central India and Uttaranchal. However the Western Ghat population seems to be comparatively less impacted by poaching (**Figure 3**).

Figure 2 Districts with tiger occupied forests and districts where tigers have become locally extinct within the past 100 years.

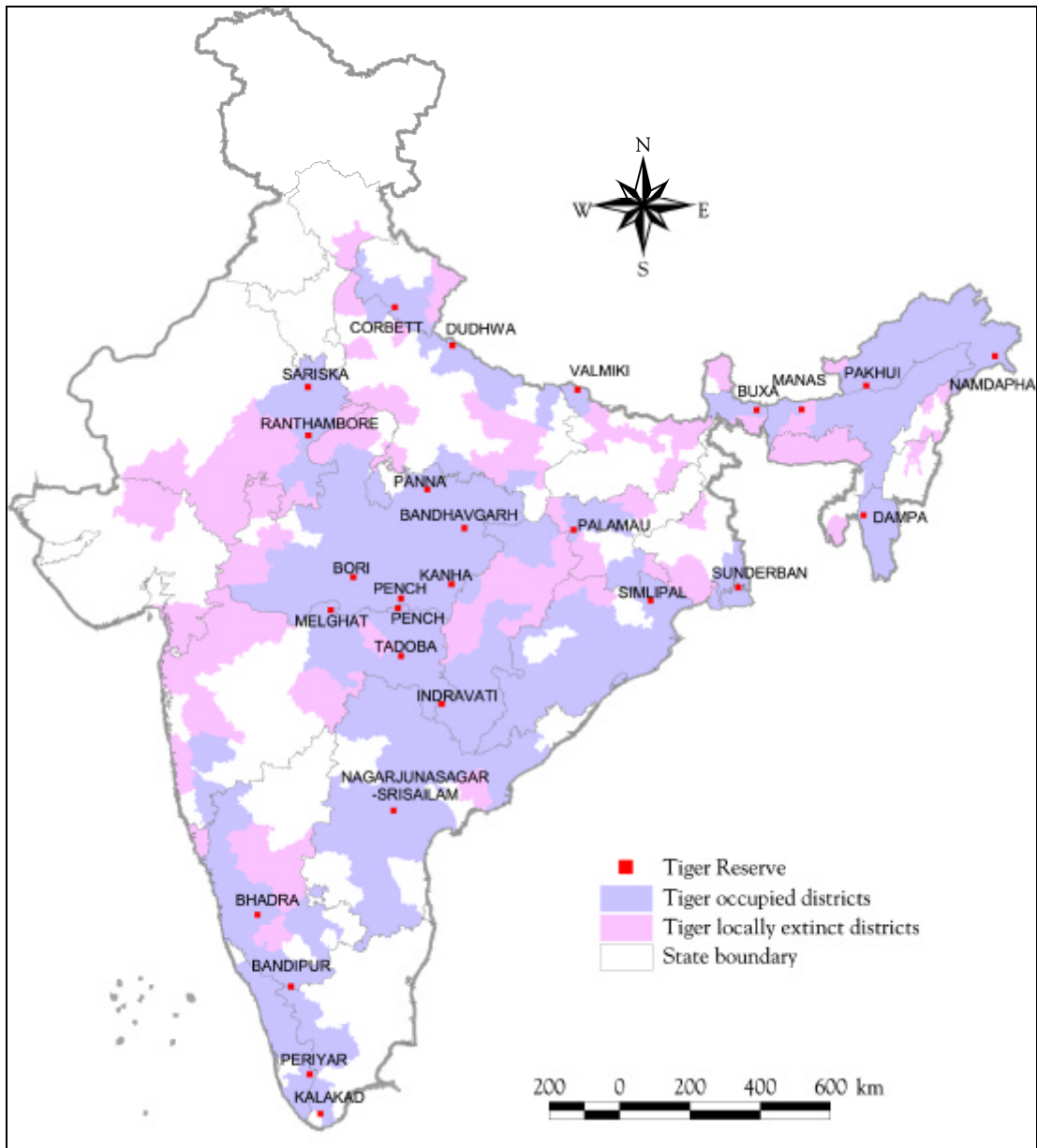
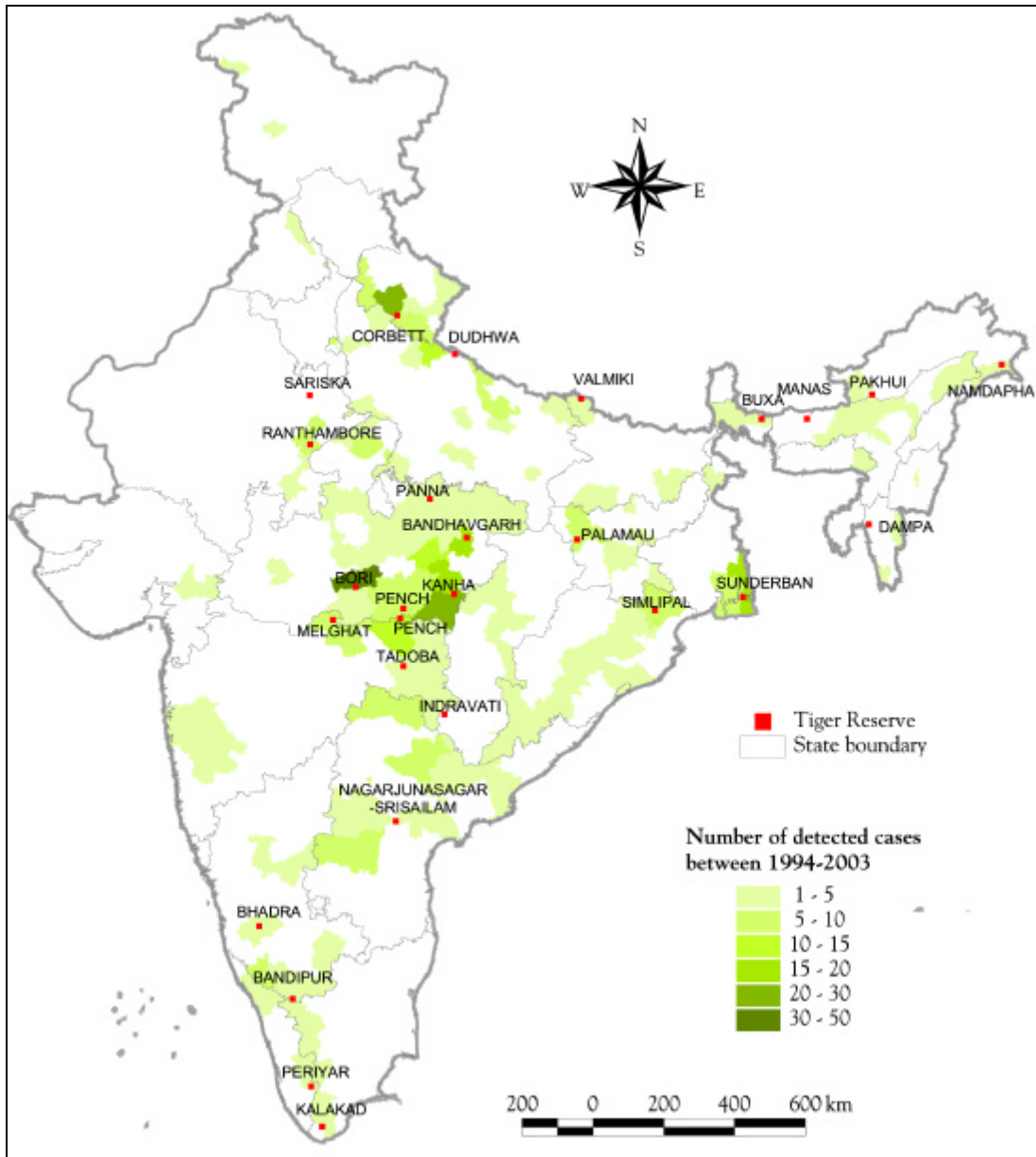


Figure 3 Distribution of detected tiger crimes between (1994-2003)



Source: Project Tiger Directorate
www.wpsi-india.org/statistics/index.php

Tiger occupied landscapes and habitat potential

Entire India was divided into six landscape complexes (**Figure 4**) based on current tiger occupancy and potential for connectivity. A landscape complex is largely a unit comprised of several ecological landscapes, which are interconnected and have a potential for exchanging genetic material between tiger populations inhabiting the complex. The six landscape complexes were (1) Shivaliks and the Gangetic Plain, (2) Central Indian Highlands, (3) Brahmaputra Flood Plains and North Eastern Hills, (4) Eastern Ghats, (5) Western Ghats and (6) the Sundarbans.

The overall spatial occupancy of tigers in a forest patch is based on the premise that small tiger population can persist for long periods given sufficient prey and adequate protection (Karanth & Stith 1999, Mishra et al. 1987, Panwar 1987, Wikramanayake et al. 1999). The priority areas were selected on the basis of population viability (Lande & Barrowclough 1987, Opdam et al. 2003) and population connectivity in the landscape. The habitat quality, prey availability and level of poaching were considered determinants of tiger population persistence and growth (Carbone and Gittleman 2002, Karanth and Stith 1999, Karanth et al. 2004).

A 10km x 10km grid was then superimposed on the forested habitats reported to be occupied by tigers and those in which tigers were not reported within each landscape complex. Data from each grid on 22 different variables (**Appendix 2**) were extracted of which 14 were found to be significantly contributing to the tiger occupancy model. Occupancy of 10 km x 10 km forest patches by tigers was modeled, using variables defining landscape characteristics (patch size, core size, shape and connectivity of forests), climatological data and variables depicting human influences within each landscape complex (**Appendix 2, Figures 5 and 6**). The binary logistic model was used to model the potential of tiger habitat within each landscape complex. The model fit was tested using Receiver Operator Characteristic (ROC) Curves. The area under ROC curves ranged between 98 to 99 percent for all landscape models indicating a good fit (**Appendix 3**).

The concept of the conservation potential of a landscape was adopted from Opdam et al. 2003, Wikramanayake et al. 1999, Chundawat et al. 1999, Dinerstein et al. 1999, Johnsingh et al. 2004, Narain et al. 2005, and Smith et al. 1998. Demographic viability and population persistence information from Kenney et al. 1995, Karanth and Stith 1999, Sunquist et al. 1999, Seidensticker et al. 1999, Smith et al. 1999, Wikramanayake et al. 1999, Smirnov 1999, Miquelle et al 1999 a & b, Rabinowitz 1999, Kumar & Wright 1999, and Carbone & Gittleman 2002, were used.

The probability of tiger occupancy in forested areas of each landscape complex (based on the logistic model) was used to map habitat suitability for tigers. The variables that explained probability of tiger occupancy (**Appendix 3**) were level of forest fragmentation, size of forested patch, prey presence, and anthropogenic pressures (**Figure 7**). Considering Tiger Reserves and tiger occupied National Parks as source populations of tigers, the dispersal from these sources into neighboring forested habitats was modeled by an exponential decay of tiger density with distance from source (**Appendix 3**). Priority for tiger conservation of an area is dependent on its potential to support tigers and its proximity to source populations of tigers. We combined the potential tiger occupancy map (logistic model) with the dispersal map (exponential decay from source populations) considering tigers to disperse and survive only in areas that were contiguous and had potential to sustain them. Tiger habitats were then prioritized into Priority-I, II and III. Priority-I areas have the highest conservation rating as they contain source populations. Priority-II and III areas are dispersal and connecting habitats, crucial to maintain meta-population structure. In cases where contiguous forest did not join source populations, the size, pattern and density of forested patches were evaluated as “stepping stones” for potential tiger dispersal (**Figure 8**). The maps at the level of landscape complexes highlight priority areas for allocation of resources and management inputs to bring about effective long term tiger conservation (**Appendix 2 to 7**).

Figure 4 Distribution of Protected Areas within the six tiger occupied landscape complexes with forest cover of India.

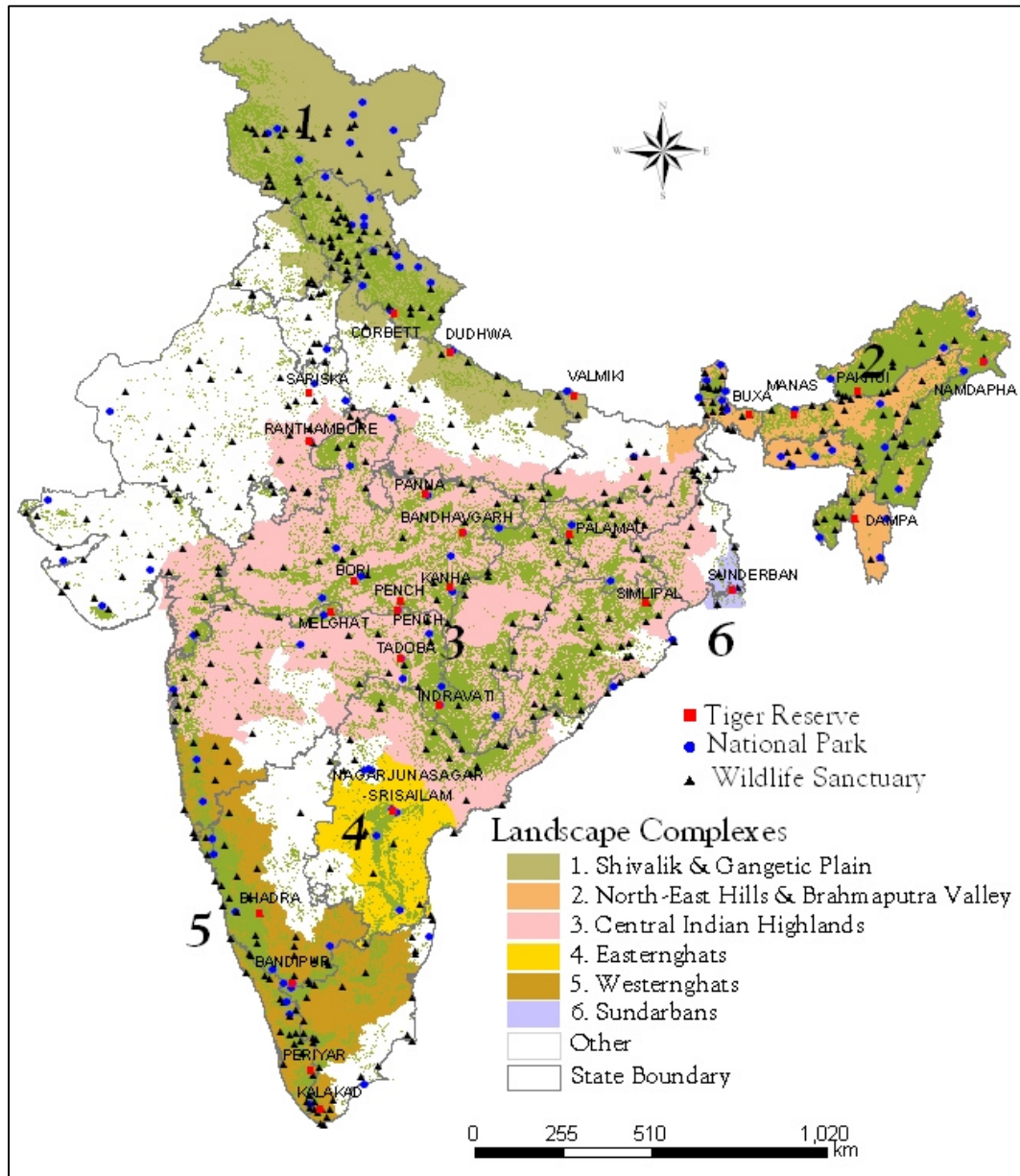
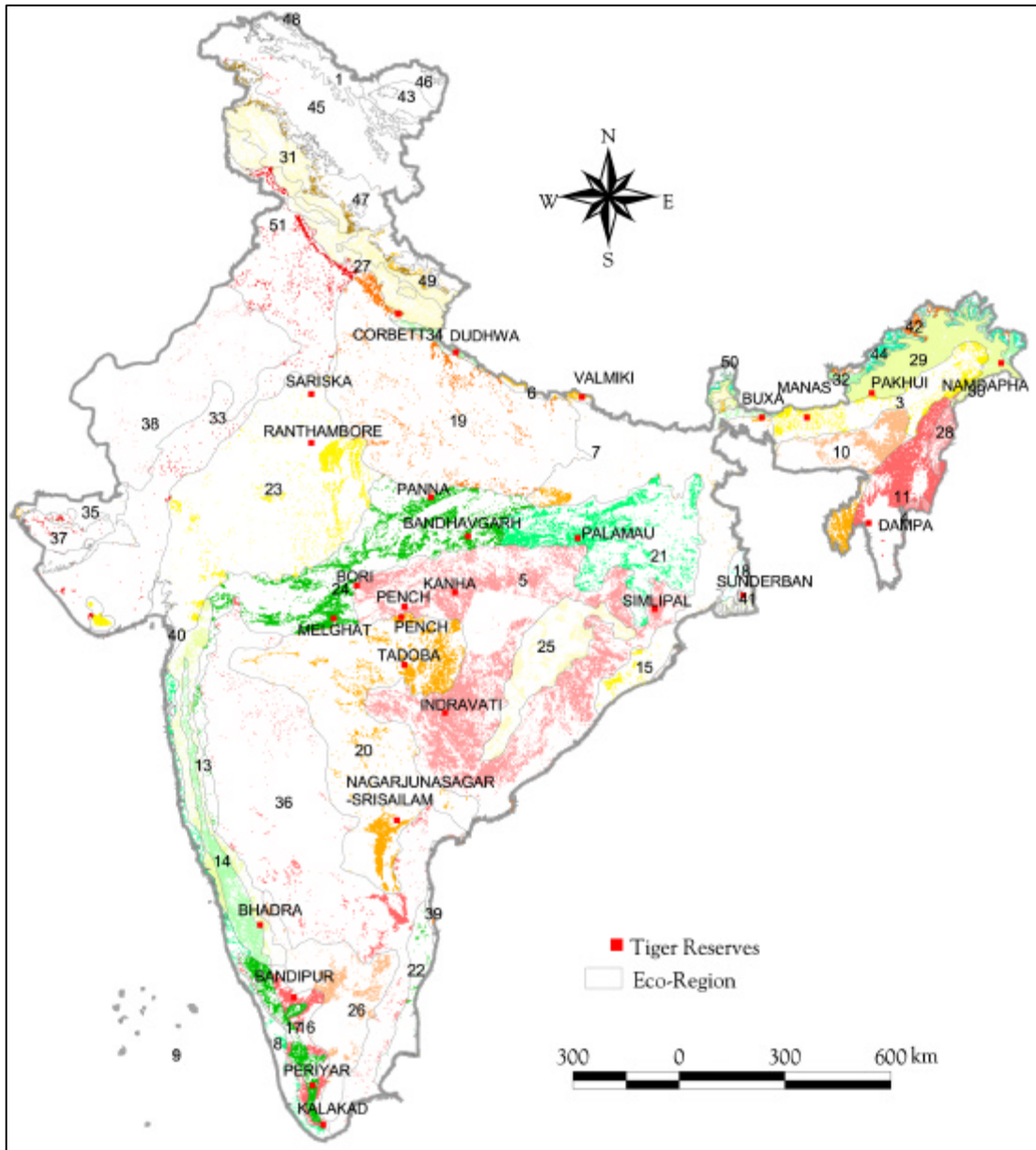


Figure 5 Forest cover map of India showing different eco-regions and tiger reserves



See appendix 2 & 5 for details of eco-regions

Figure 6 Relative human population density map of India (2003) and location of tiger reserves.

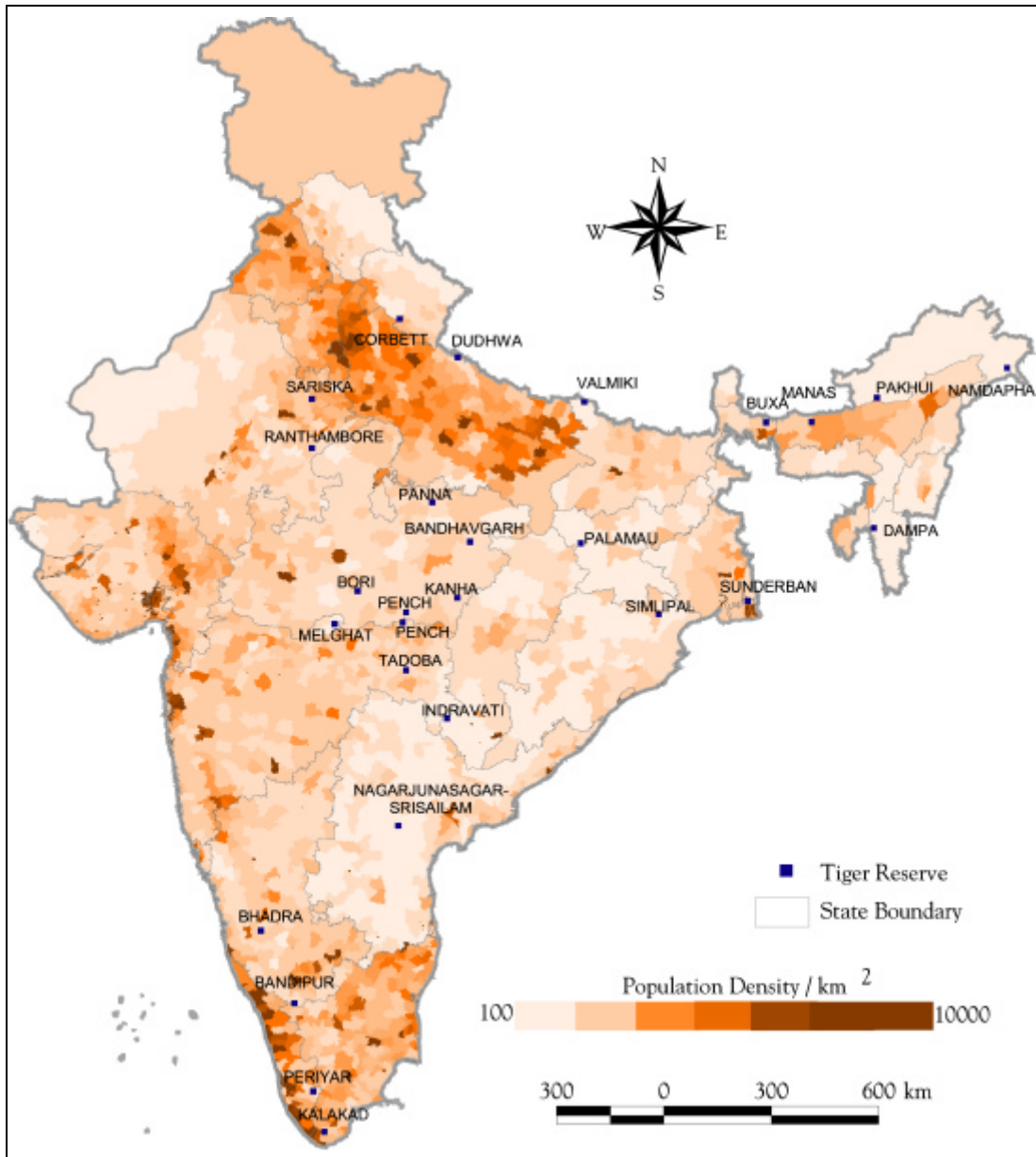


Figure 7 Modeled tiger habitat showing potential of forest patches for tiger occupancy with distribution of tiger reserves and forest cover of India.

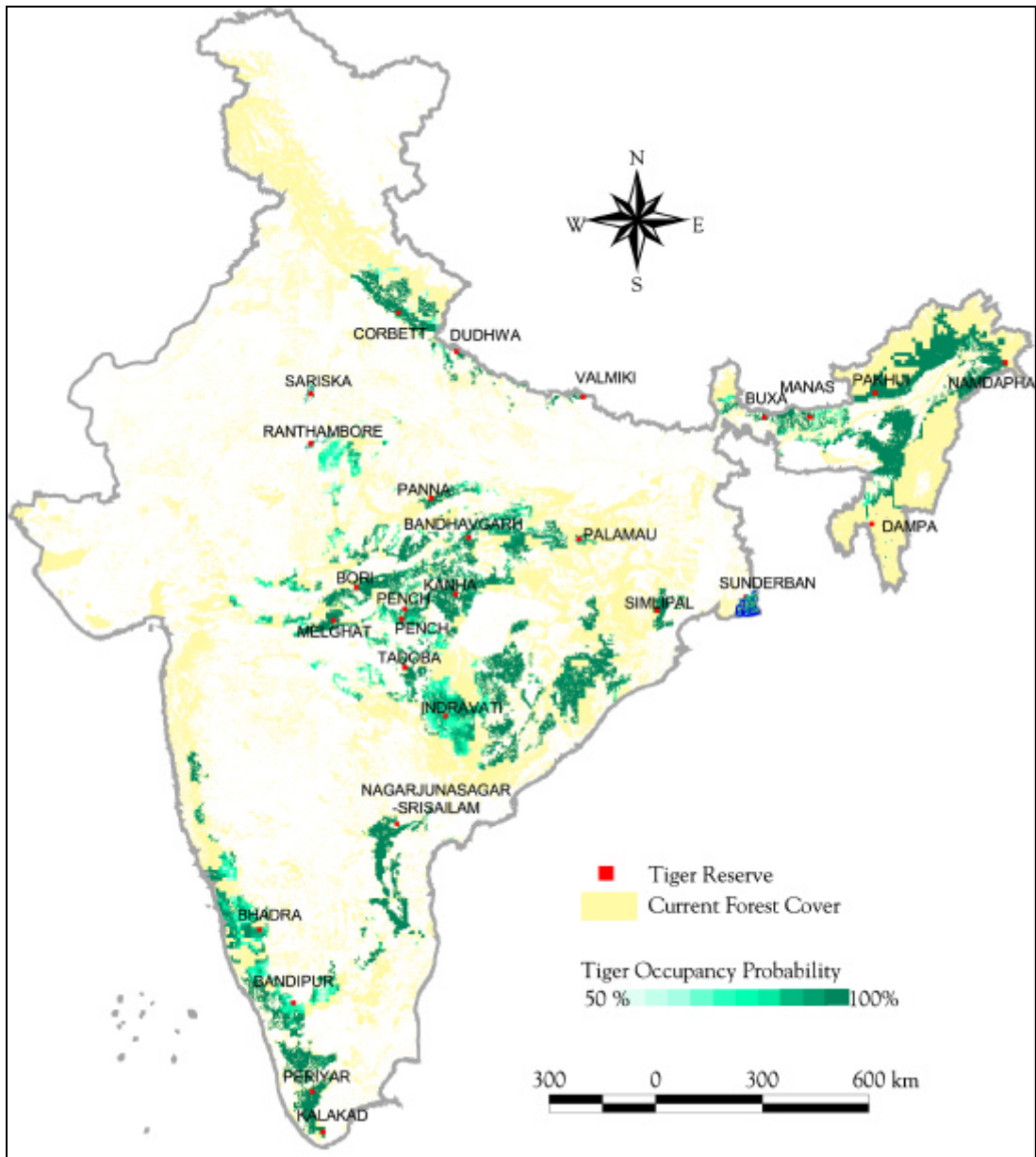
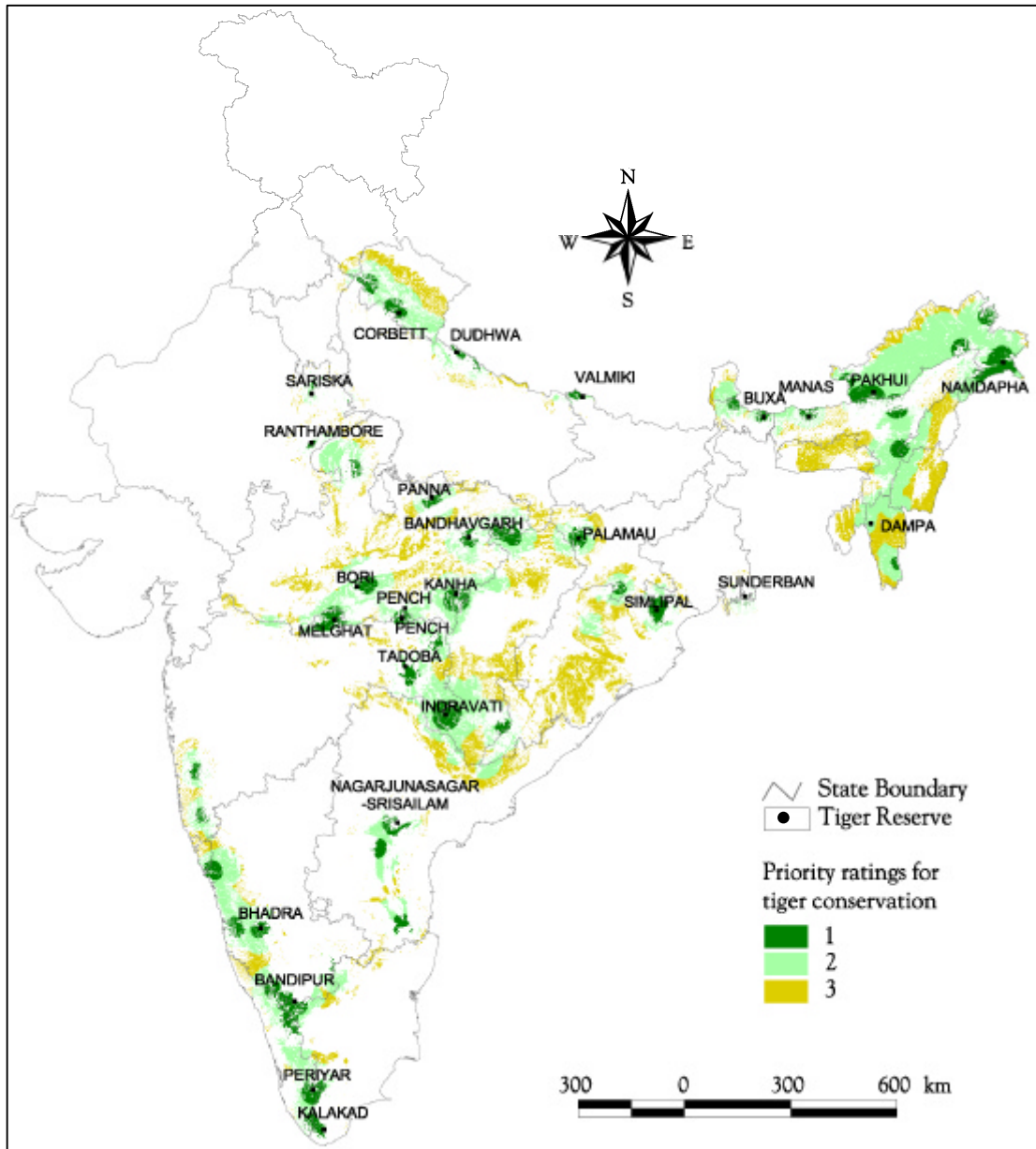


Figure 8 Priority areas for conservation of tiger source populations and maintaining connectivity



LANDSCAPE COMPLEXES

(1) Shivaliks – Gangetic Plain Landscape Complex

Also referred to as the Terai Arc Landscape, this landscape complex stretches from a little west of the Yamuna River through southern Nepal to forests of Bhutan in the east. It stretches across five Indian states with Valmiki Tiger Reserve in Bihar marking its eastern boundary within India. Since key parts of this landscape are in Nepal and Bhutan, an effective conservation strategy will be possible only with trans-boundary co-operation.

The Shivalik hills, the adjoining *bhabar* areas and *terai* plains are in the form of narrow strips running parallel to the main Himalayas, and there is a continuum of forests and wildlife populations across these zones. The Shivaliks, which run along the base of the Himalaya, are an uplifted ridge system formed from the debris brought down from the main Himalaya. The coarse material brought down by the Himalayan rivers is deposited immediately along the foothills to form a pebbly-bouldery layer referred to as the *bhabar*, while the finer sediments or clay is carried further to form the *terai*. The *bhabar* is characterized by low water table, as the deposits are bouldery and porous, and all but the major rivers and streams disappear into the ground on emerging from the hills. The streams reappear along the *terai*, which has fine alluvial soil resulting in high water table. Altitude within the Shivaliks ranges from 750 to 1400 m. The *bhabar* zone exhibits an undulating topography with an altitude ranging between 300 and 400 m. *Terai* is relatively flat with a surface gradient, which is slightly higher near Shivaliks (Johnsingh et. al 2004).

According to the recent classification proposed by Wikramanayake et al. (2002) that takes into consideration both biogeography and conservation values, the landscape corresponds to three ecoregions – (i) Upper Gangetic Plains moist deciduous forest, (ii) *Terai-Duar* savanna and grasslands and (iii) Himalayan sub-tropical broadleaf forest. Of these, the *Terai-Duar* savanna is listed among the 200 globally important areas, due to its intact large mammal assemblage, even though it scores low on plant species richness and endemism. This Landscape also contains a large proportion of the Level I and Level II Tiger Conservation Units, which underscore global and regional priorities for the preservation of wild tiger (Wikramanayake et al. 1999).

The vegetation in the area comprises of a mosaic of dry and moist deciduous forests, scrub savannah and productive alluvial grasslands, which harbour a rich fauna including several endemic and globally endangered species. Prominent among such species are tiger, Asian elephant, one-horned rhinoceros and swamp deer. Other endemic and obligate species found in this Landscape are hog deer (*Axis porcinus*), hispid hare (*Caprolagus hispidus*), Bengal florican (*Houbaropsis bengalensis*) and swamp francolin (*Francolinus gularis*). Many of these species, surviving in small populations, have their last home in this Landscape (Johnsingh et al. 2004).

For tigers, the landscape holds some promise as the tiger inhabited forests in the region are still somewhat connected. If key corridors can be maintained and a few more restored, the landscape has the potential to become one of the strongholds for tigers.

Total geographic area : 422675 km².

Political units : Parts of Jammu & Kashmir, Punjab, Haryana, Himachal Pradesh, Uttranchal, Uttar Pradesh and Bihar.

Average population density : 239 km⁻² (Figure 9)

Total protected area : 4492 km² (7.1% of the total land area)

Total forested area : 93094 km².

Major biogeographic zones: 1. Himalaya (West Himalaya (2B)), 2. Semi Arid Punjab Plains (4A) and 3. Gangetic Plains (Upper Gangetic Plains (7A) & Lower Gangetic Plains(7B))

Major ecoregions :

Ecoregions	Geographical Areas (sq km)	Forest Areas (sq km)
Himalayan subtropical broadleaf forests	4949	790
Himalayan subtropical pine forests	41019	18706
Lower Gangetic Plains moist deciduous forests	3297	198
Terai-Duar savanna and grasslands	5537	1244
Upper Gangetic Plains moist deciduous forests	69209	8210
Western Himalayan broadleaf forests	47683	18588
Western Himalayan subalpine conifer forests	11124	3960

Temperature range : Minimum average 7.4° C , Maximum average 40.8° C

Precipitation: Mean 104 cm, Range 56 to 173 cm

Landscape characteristics of the Shivaliks and the Gangetic Plain (Figure 10)

Parameters	Value
Number of forest patches	5660
Forest patch density per 1000 km ²	3.5
Mean forest patch area (km ²)	11.48
Mean forest perimeter to area ratio	33.8
Total forest core area (km ²)	3337
Number of disjunct forest core areas	233
Mean forest core area (km ²)	0.59
Median forest core area (km ²)	9
Total forest core area in forest patches >1000 km ²	2796

Figure 9 Distribution of human settlements, tiger reserves, and human population density of the Shivalik – Gangetic Plain landscape complex.

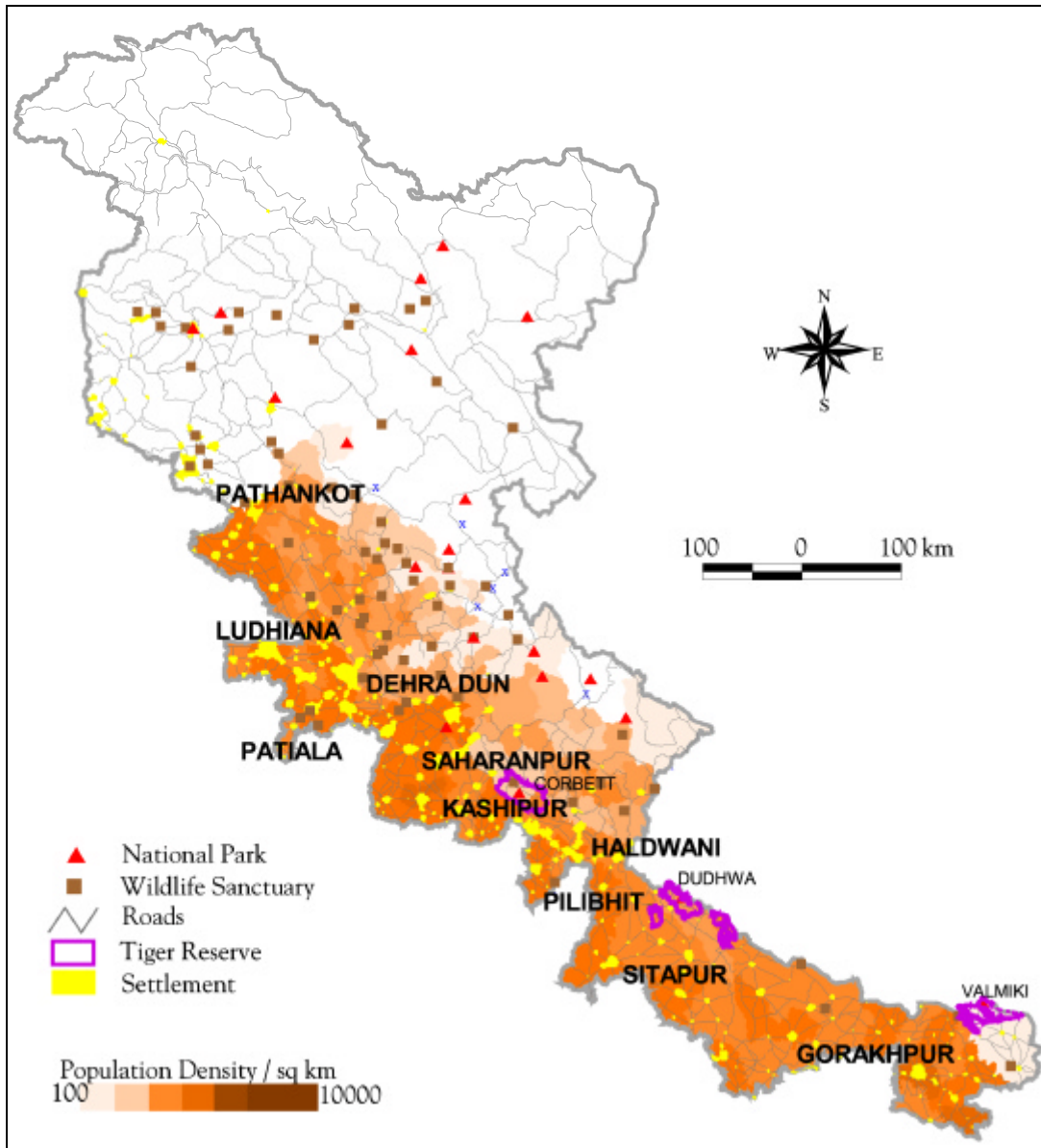


Figure 10 Distribution of Protected Areas and various size of forest patches in the Shivalik – Gangetic Plain landscape complex.

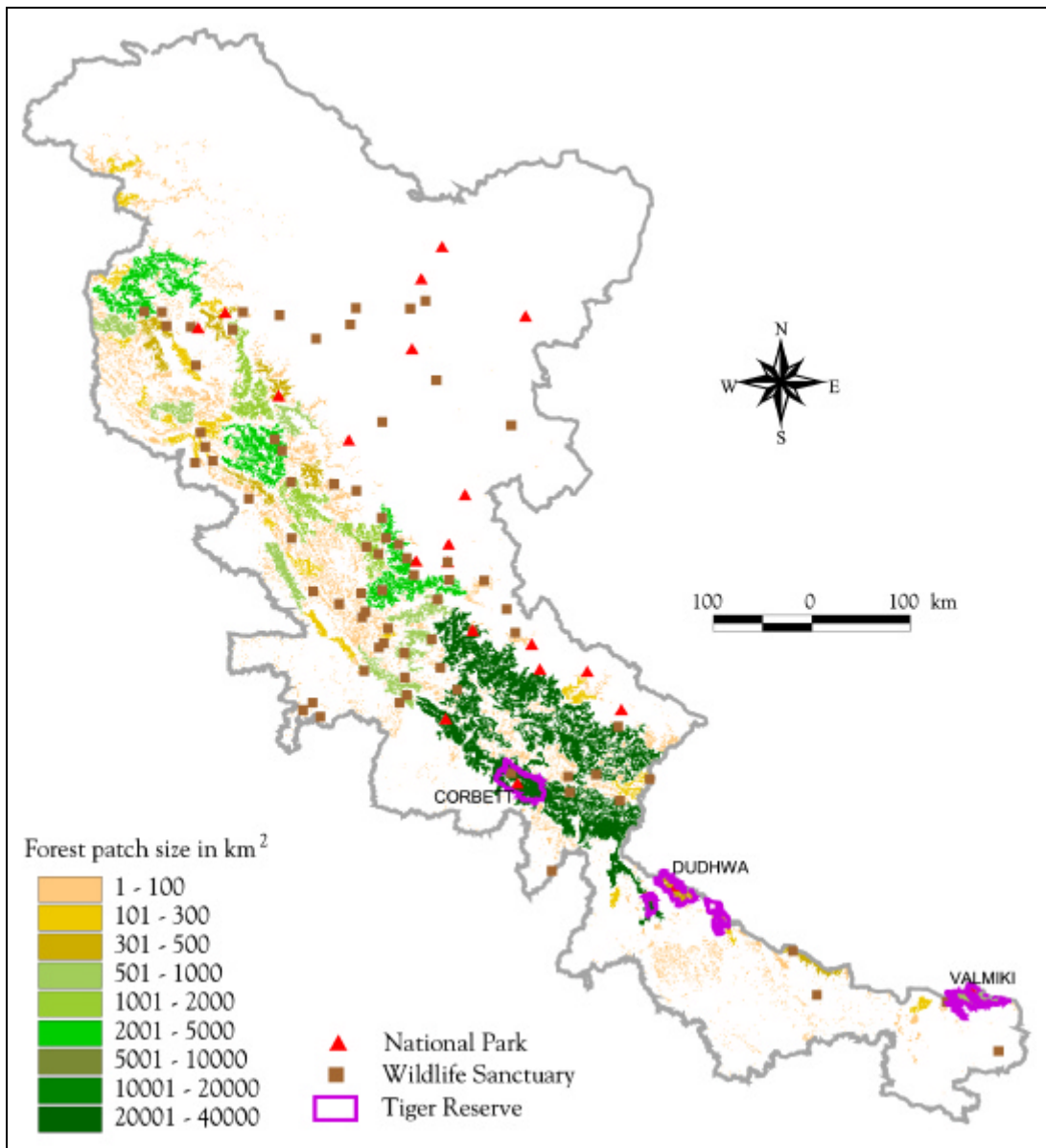


Figure 11 Potential tiger habitat in Shivalik – Gangetic Plain landscape complex along with forest cover and protected areas

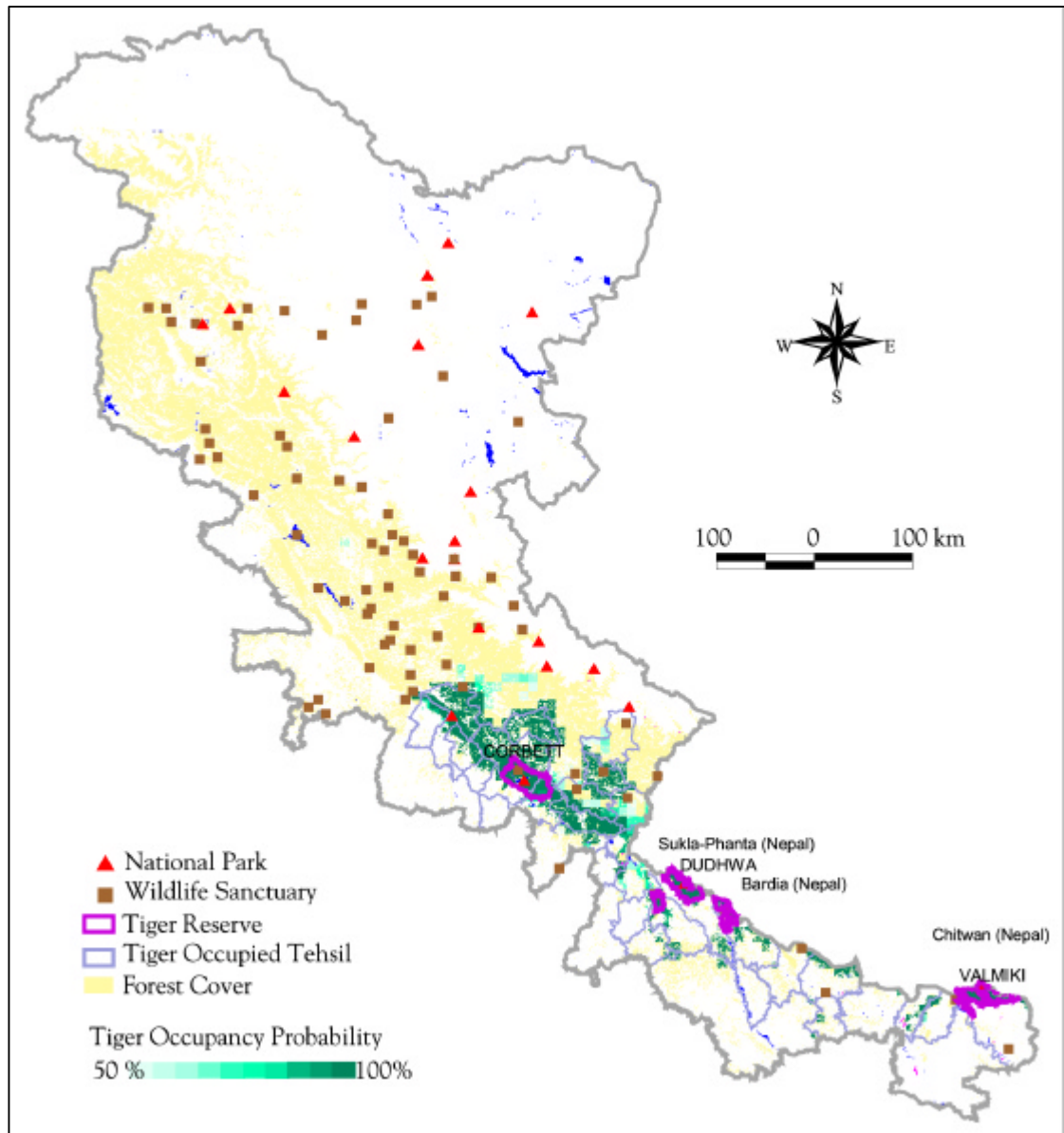
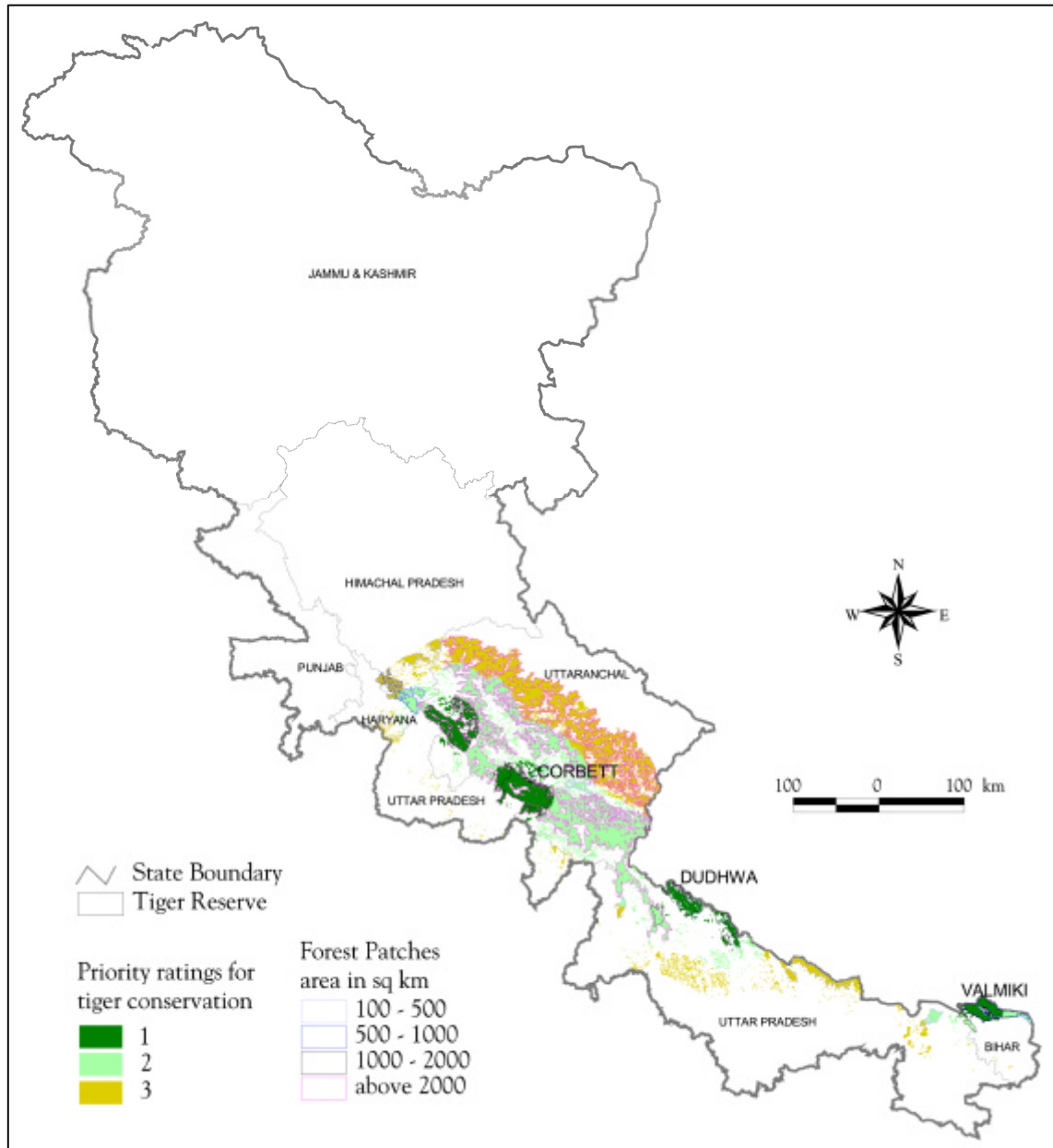


Figure 12 Priority areas within the Shivalik – Gangetic Plain landscape complex for conservation of tiger source populations and maintaining connectivity



Tiger Habitat Status:

Percentage area of the landscape complex in terms of districts from which tiger has become locally extinct : 29%

Forested area of tehsils where tiger is currently reported: 22326 km² (21.82% of forest)

Potential habitat for tiger occupancy in the landscape complex: 20807 km² (20.34% of forest) (Figure 11).

Tiger habitat in this landscape exists in two contiguous 'relatively' large patches (**Figure 12**), which consist of :

(a) Kalesar in Haryana to Kishanpur in Uttar Pradesh covering areas of Rajaji National Park and Corbett Tiger Reserve (21,500 km²). This landscape unit is the most promising one for long term tiger conservation in this landscape complex.

(b) Dudhwa Tiger Reserve and Sohagi Barwa in Uttar Pradesh and Valmiki Tiger Reserve in Bihar (2600 km²) are connected through the Shivalik forests (Churia hills) of Nepal. These forests in Nepal have protected areas like Sukla Phanta, Bardia, and Chitwan National Parks. This landscape unit has high tiger conservation potential through transboundary conservation efforts and International cooperation and commitment. The tiger habitats within India by themselves have limited long term value, unless managed as a holistic landscape including connectivities and source populations in Nepal.

(2) North East Hills and Brahmaputra Flood Plains

The north east is one of the most important areas in the Indian subcontinent from a conservation perspective. Of all zones in India, it is perhaps the richest in communities, species and endemics. There are more species in this zone which have been included in Schedule I of the Wildlife (Protection) Act, 1972 than anywhere else in the country.

This area represents the transition zone between the Indian, Indo-Malayan and Indo-Chinese biogeographical regions, as well as a meeting place of the Himalayan Mountains and peninsular India. It was in the north east that the northward migrating “Deccan Peninsula” first touched the Asian landmass after the break-up of Gondwanaland in the early tertiary period. The north east is thus the biogeographical gateway for much of India’s fauna and flora and as a consequence is one of the richest in biological values (Rodgers & Panwar 1988).

The lowland-highland transition zone has the highest diversity of biomes or ecological communities. Species diversities within these communities are also extremely high. The Khasi-Jaintia hills of Meghalaya were described as a one of the richest botanical habitats of Asia as early as 1854. It is not only the plant communities that are diverse, but also the animal communities exhibit species richness not found elsewhere in the region (Rodgers & Panwar 1988). North east India contains large populations of many important mammalian fauna like the elephant (*Elephas maximus*), rhino (*Rhinoceros unicornis*) and water buffaloes (*Bubalis bubalis*).

The north east landscape complex is still biologically inadequately explored. Many species remain to be discovered and described. Even where initial exploration is done, knowledge about community or species biology remains incomplete. There is thus potential for even greater biological values to be documented. The tiger, though widely distributed throughout this landscape complex, inherently occurs at low densities due to low prey availability in the hilly tracts. The Brahmaputra flood plains, in contrast, have high prey biomass and in turn support one of the highest tiger densities reported in the world (Karanth & Nichols 2000).

Total geographic area : 271129 km².

Political Units : It consists of Sikkim, Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura & West Bengal partially or fully.

Average population density : 114 km⁻² (**Figure 13**)

Total protected area : 12527 km² (6.8% of the total Land Area)

Total forested area : 156896 km²

Major biogeographic zones : 1. Trans Himalaya- Tibetan Plateau (1B), 2. Himalaya (Central Himalaya (2C) & East Himalaya (2D)), 3. Gangetic Plains-Lower Gangetic Plains (7B) and 4. North East (Brahmaputra Valley (9A) & North east Hills (9B))

Major ecoregions :

Ecoregions	Geographical Areas (sq km)	Forest Areas (sq km)
Brahmaputra Valley semi-evergreen forests	54205	12013
Eastern Himalayan broadleaf forests	49552	6580
Eastern Himalayan subalpine conifer forests	12217	3310
Himalayan subtropical broadleaf forests	547	146
Himalayan subtropical pine forests	1944	768
Lower Gangetic Plains moist deciduous forests	22820	5649
Meghalaya subtropical forests	39950	8463
Mizoram-Manipur-Kachin rain forests	55738	18822
Northeastern Himalayan subalpine conifer forests	5054	1432
Terai-Duar savanna and grasslands	4567	602

Temperature range : Minimum average 8° C , Maximum average 34.4° C

Precipitation: Mean 215 cm, Range 149 to 310 cm

Landscape Characteristics of North East Hills And Brahmaputra Flood Plains (Figure 14)

Parameters	Value
Number of forest patches	3824.0
Forest patch density per 1000 km ²	4.5
Mean forest patch area (km ²)	18.5
Mean forest perimeter to area ratio	34.2
Total forest core area (km ²)	15588.0
Number of disjunct forest core areas	241.0
Mean forest core area (km ²)	3.03
Median forest core area (km ²)	9
Total forest core area in forest patches >1000 km ²	14867

Tiger Habitat status:

Percentage area of the landscape complex in terms of districts from which tiger has become locally extinct : 22.5%

Forested area of tehsils where tiger is currently reported: 104053 km² (66.3% of forest)

Potential habitat for tiger occupancy in the landscape complex: 64295 km² (41% of forest) **(Figure 15)**

The North Eastern Hills and Bhramaputra Plains constitute the most well connected landscape complex **(Figure 16)**.

(1) The largest contiguous forested landscape is over 136,000 sq km. This landscape unit commences in the North West from Pakke Tiger Reserve through the forests of Palia, Tale valley, Mouling and Dr. D. Ering Sanctuaries into Dibung National Park and upto Namdapha Tiger Reserve in the East. The landscape continues south through some degraded areas into Intanki National Park, and further South to Dampa Tiger Reserve and Blue Mountain National Park. Kaziranga National Park in the Bhramaputra flood plains is connected through the Karbi Anglong Hills to Intanki in the South. This connectivity through Karbi Anglong is crucial for dispersal of tigers from their source population in Kaziranga. Kaziranga has lost its connectivity to the North (to Pakke) due to intensive agriculture on Northern banks of Bhramaputra flood plains. Intanki National Park is also connected westwards through priority III forests upto Balphakram National Park. This landscape has contiguous forest across the International border with Myanmar. The weak links in this landscape are the forests in the districts of Mon, Mokok Chung, Tuensang, Zuheboto, Wokha, and Pekh in the East. The landscape between Balphakram National Park and Intaki National Park through the districts of Karbi Anglong, West Khasi Hills, East Khasi Hills and East and West Garo Hills is fragmented. The major source populations of tigers in this landscape are Kaziranga and Pakke in India and dispersing tigers from Bhutan and Myanmar.

(2) Manas - Ripa Chirang - Buxa/Jaldapara – Gorumara - Singhalila landscape unit. This landscape is about 7,200 km² with a single block of 5000 km² from North and West Bengal (Gorumara) to the coniferous forests of Sikkim (Singhalila). The connectivities in the Bhramaputra plains are patchy and fragmented, but the landscapes are connected through the forests of Bhutan. On the Indian side, “stepping stone” connectivity exists between Gorumara, Jaldapara, Buxa, and Ripa Chirang through the district of Jalpaiguri. Connectivity between Ripa Chirang and Manas is lost on the Indian side. This landscape needs to be managed through transboundary International cooperation with the Government of Bhutan.

Figure 13 Distribution of human settlements, tiger reserves, and human population density of the North East Hills and Brahmaputra Flood Plains landscape complex

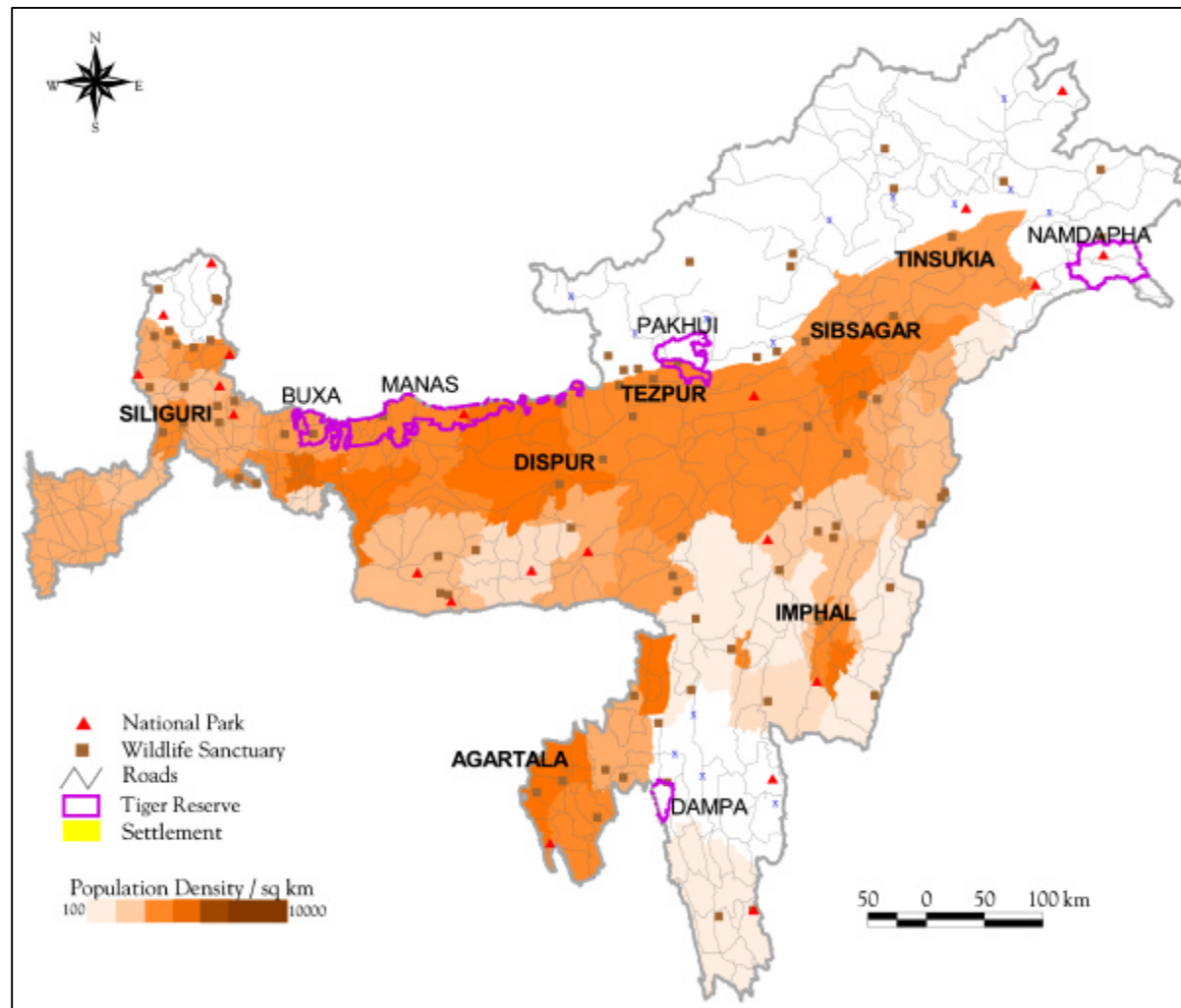


Figure 14 Distribution of Protected Areas and various size of forest patches in the North East Hills and Brahmaputra Flood Plains landscape complex

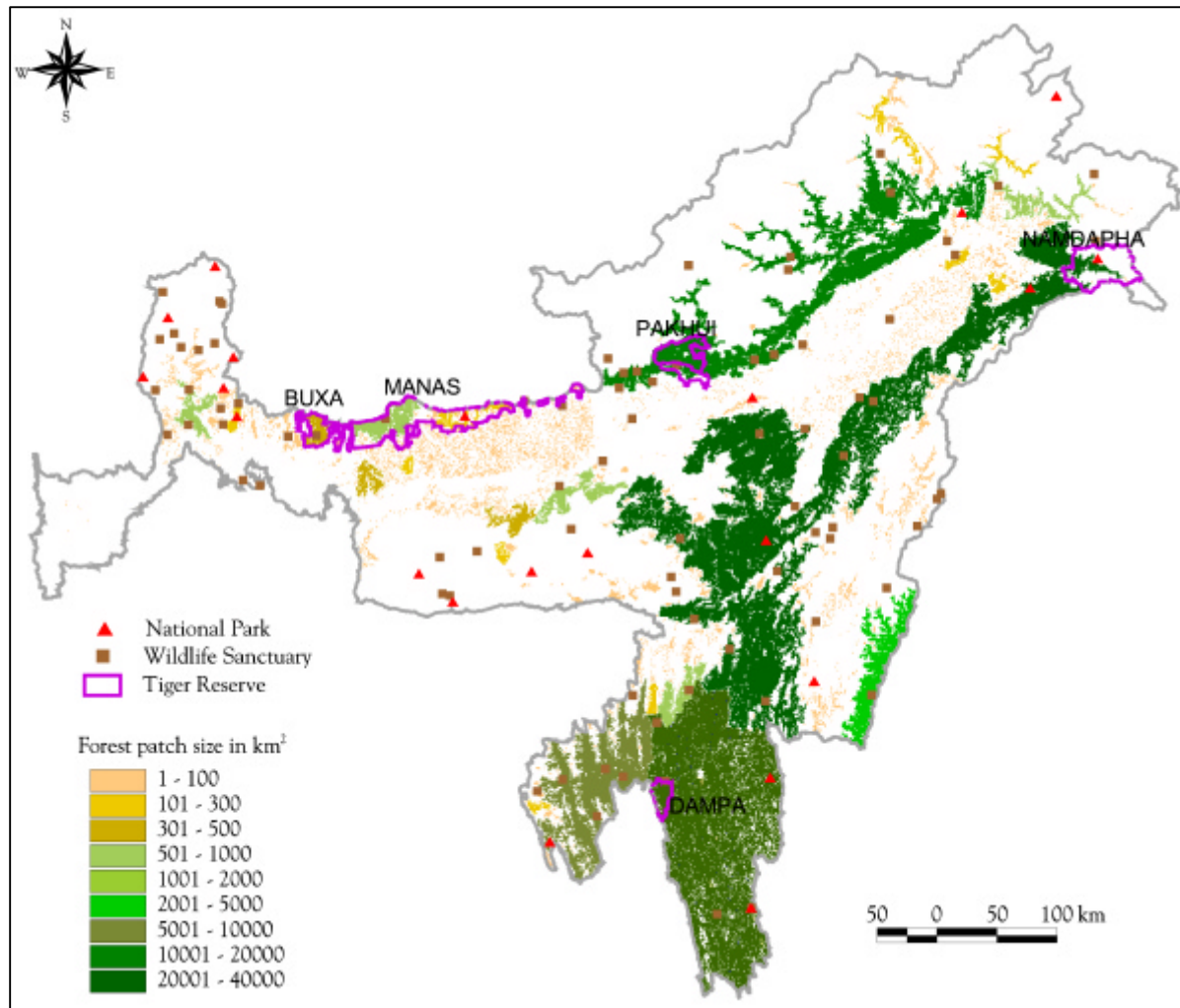


Figure 15 Potential tiger habitat in the North East Hills and Brahmaputra Flood Plains landscape complex along with forest cover and protected areas

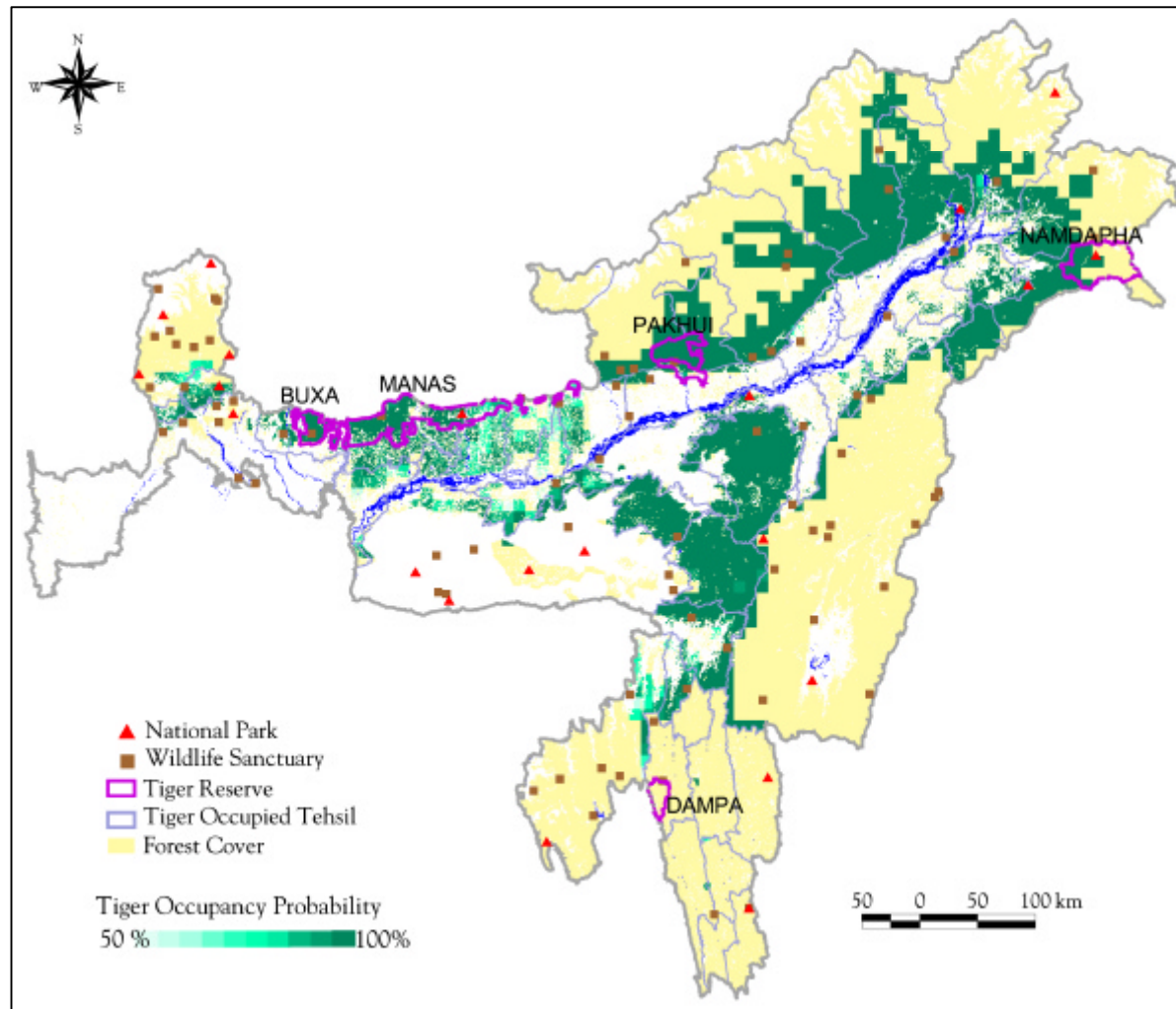
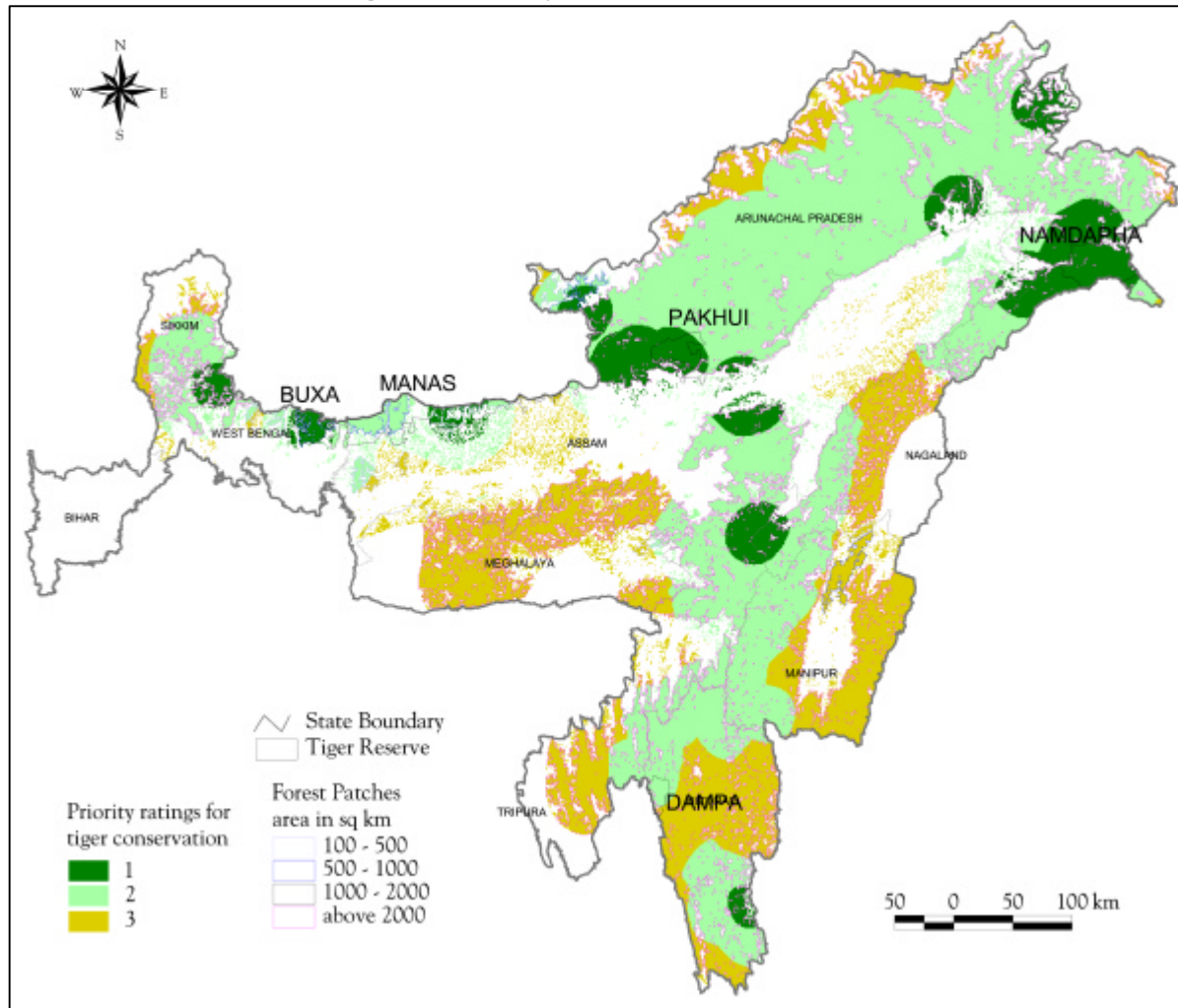


Figure 16 Priority areas within the North East Hills and Brahmaputra Flood Plains landscape complex for conservation of tiger source populations and maintaining connectivity



(3) Central Indian Landscape Complex

Whilst much of the central Indian forests have been greatly disturbed by anthropogenic development, the zone does contain some of India's finest forests, particularly in undivided Madhya Pradesh. The majority of the forests are of a deciduous nature, but there are regions of greater diversity in the hill ranges. Relict populations of buffalo and swamp deer suggest, a much wider distribution of these species in the past. Even though the zone has some of the largest wilderness areas of India, there are growing signs of forest and environmental degradation. The Deccan highlands form the principal catchment for many of Central and Southern India's main river systems (Narmada, Tapti, Mahanadi and Godavari) loss of forest cover is already discernable in increased frequency of drought, floods, erosion and reservoir siltation. Thus there is a need for greater conservation inputs for wildlife, forest resource and water catchment purposes (Rodgers & Panwar 1988).

Central India is principally the zone of deciduous forests. The northern part of the zone has forests dominated by stunted Sal, Anogeisus, Acacia and miscellaneous species. Part of the landscape is moist with good sal forests having an interspersion of miscellaneous species. The southern half of the landscape has a drier forest association. The central part of the landscape consists of teak and miscellaneous species. Few natural grasslands which were confined to river valleys are now lost to agriculture. Some areas are maintained in the successional stage of anthropogenic grasslands (e.g. old village sites or wastelands) by fire, tree cutting and livestock pressure.

Most wildlife species are widespread through the whole zone, e.g. chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai, chowsingha (*Tetraceros quadricornis*). However, some species are more frequent than others, while a few species are restricted to moister areas, e.g. barking deer (*Muntiacus muntjak*) and gaur (*Bos gaurus*). Some species are restricted to drier, open areas, - e.g. blackbuck (*Antelope cervicapra*) and chinkara (*Gazella gazella*), but still have a wide distribution. Species which have small relict population include elephant, the wild buffalo and the hard ground swamp deer. The gharial (*Gavialis gangeticus*) is restricted to a few rivers flowing into the Ganges and Mahanadi Rivers. The carnivore include tiger, leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*) and dhole (*Cuon alpinus*). However their ranges are increasingly fragmented as natural forest areas decrease in size (Rodgers and Panwar 1988). The better protected areas do provide example of the levels of density and diversity that mature wildlife communities can attain, but these are few in number.

This landscape complex probably has the largest number of tigers in the world. Most of the tiger reserves in the landscape still have connectivity, with the potential of sustaining meta-populations. With protection of corridors, restorative ecology, and rejuvenation of prey

outside protected areas the region has one of the best potential for long term tiger conservation.

Total geographic area : 1170220 km²

Political units : Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, Chhatisgarh, Orissa, Andhra Pradesh, Maharashtra, Rajasthan and West Bengal partially or fully.

Average population density : 142.5 km⁻² (Figure 17)

Total protected area : 25739.4 km² (4.1% of the total Land Area)

Total forested area : 406580 km²

Major biogeographic zones : 1. Semi Arid (Punjab Plains (4A) & Gujarat Rajputana (4B)), 2. Western Ghats (Malabar Plains (5A) & Western Ghat Mountains (5B)), 3. Deccan Peninsula (Central Highlands (6A), Chotta-Nagpur (6B), Eastern Highlands (6C), Central Plateau (6D) & Deccan South (6E)), 4. Gangetic Plains (Upper Gangetic Plains (7A) & Lower Gangetic Plains (7B)) & 5. Coasts (East Coast (8A) & West Coast (8B))

Major ecoregions :

Ecoregions	Geographical Areas (sq km)	Forest Areas (sq km)
Central Deccan Plateau dry deciduous forests	142721	21975
Chhota-Nagpur dry deciduous forests	117407	30751
Deccan thorn scrub forests	59365	5650
Eastern highlands moist deciduous forests	320189	93820
Kathiawar-Gir dry deciduous forests	148074	25267
Lower Gangetic Plains moist deciduous forests	51131	3530
Malabar Coast moist forests	4586	1228
Narmada Valley dry deciduous forests	157365	41578
North Western Ghats moist deciduous forests	20423	7618
North Western Ghats montane rain forests	4666	2429
Northern dry deciduous forests	56085	14490
Orissa semi-evergreen forests	14617	3034
Upper Gangetic Plains moist deciduous forests	66297	8450

Temperature range : Minimum average 7.4° C , Maximum average 40.8° C

Precipitation: Mean 94 cm, Range 49 to 161 cm

Landscape Characteristics of the Central Indian Landscape Complex (Figure 18)

Parameters	Value
Number of forest patches	19405.0
Forest patch density per 1000 km ²	9.4
Mean forest patch area (km ²)	13.6
Mean forest perimeter to area ratio	34.2
Total forest core area (km ²)	30272.0
Number of disjunct forest core areas	1013.0
Mean forest core area (km ²)	1.04
Median forest core area (km ²)	9
Total forest core area in forest patches >1000 km ²	28313

Tiger Habitat status:

Percentage area of the landscape complex in terms of districts from which tiger has become locally extinct: 30%

Forested area of tehsils where tiger is currently reported: 178998 km² (44.03% of forest)

Potential habitat for tiger occupancy in the landscape complex: 156548 km² (38.5% of forest) (Figure 19)

Within Central Indian landscape complex potential meta-populations of tigers exist in four landscape units (**Figure 20**).

1) Kanha-Pench Landscape : This is one of the best landscapes (16,000 km²) that exists today with two, source populations of tigers connected as a potential meta-population. The weakest connectivity for this landscape exists at the forested border of Seoni and Wara Seoni tehsils, which needs to be managed with restorative inputs on a priority basis. This would ensure the linkage between the source populations and foster metapopulation existence.

2) Satpura-Melghat landscape : Though tiger densities in this landscape are medium to low (even in source populations), the landscape features (12,700 km²) are conducive for long term persistence of a meta-population. To boost up the conservation value of this landscape it may be pertinent to increase protection and prey populations. The weakest link in this landscape is in Itarsi tehsil which needs protection and restoration.

3) Sanjay-Palamau landscape : The landscape is characterized by low tiger and prey population, with high biotic pressure. Target areas of concern are forests in Pratapur, Pal and Samri tehsils (13,700 km²). These need to be protected and their habitat values enhanced to sustain prey and tiger populations. The Bandhavgarh Tiger Reserve can potentially be an important source for this landscape. Currently no contiguous forest patch exists between Bandhavgarh and Sanjay-Palamau landscape units. However, several small forest patches exist which could serve as “stepping stones” for the spill over population of tigers from Bandhavgarh. These forest patches (Priority II) need to be protected and enhanced in the tehsils of Beohari, Jaisinghnagar and Sohagpur to increase the conservation value of this landscape.

4) Navegaon-Indravati landscape : This is one of the largest intact forested landscape (34,000 km²) in Central India. However, its current conservation value for tigers is poor due to anthropogenic pressures, insurgency and low prey populations. There is a paucity of any major source population of tigers. There is a potential for connectivity with Tadoba Tiger Reserve and Kanha-Pench landscape through “stepping stone” forest patches. Target forests to connect these source populations are in the tehsils of Gond, Pipri, and Sirpur for Tadoba, and Dongargarh, Sulekasa, and Deori in the case of Kanha-Pench landscape. If the

former connectivity is restored through the patch forests of Dongargarh, Sulekasa and Deori two large landscapes of (34,000 and 16,000 km²) area would be connected. This has the potential to exist as a meta population, as one of the best tiger conservation areas in the world.

5) Isolated Tiger Populations : Many small to medium size habitat blocks exist in Central India that support isolated tiger populations. Some of these populations have the potential to be connected to larger tiger bearing landscapes or to each other.

(a) Bandhavgarh Tiger Reserve: The forest block that includes Bandhavgarh is about 2000 km². It has fragmented forest patches towards its North West which has potential for some connectivity with Sanjay-Palamau landscape. To the south, there is potential for connectivity through more degraded patchy forests with the Kanha-Pench landscape.

(b) Panna : The forest patch that includes Panna is 3500 km². Panna has lost all potential for connectivity with other tiger landscapes but due to its size, if properly protected and managed can sustain a sizeable tiger population.

(c) Ranthambore–Kuno–Palpur–Madhav_: Though Ranthambore forest patch (300 km²) is physically disjunct, it has the potential to be a source for Kuno-Palpur landscape (4000 km²). The connectivities through forest patches is poor, but the landscape is sparsely populated with ravinous terrain which is conducive for movement of dispersing tigers. The possibility of tigers dispersing into Madhav-Shivpuri (650 km² forest patch) via stepping stone forest patches also exist.

(d) Tadoba Tiger Reserve : This is included in a forest patch of 2000 km², and has the potential to become an important source population for the Navegaon-Indravati landscape. It has the potential for sharing genetic material with Kanha-Pench landscape through restorative management of intervening areas ranging between 5-20 km² in size.

(e) Simlipal Tiger Reserve : It is a part of a forested patch of 3800 km². The potential for connectivity with another tiger occupied landscape is poor. However, due to its large size Simlipal has the potential to sustain a sizable tiger population.

(f) Saranda National Park : The forest patch that includes the Saranda National Park is about 7400 km². This forest has the potential for connectivities towards the South with forested districts of Sundargarh, Sambalpur, Denkanal, Puri, Phulbani and Ganjam, covering an area of about 15,000 km².

Figure 17 Distribution of human settlements, tiger reserves, and human population density of the Central Indian landscape complex

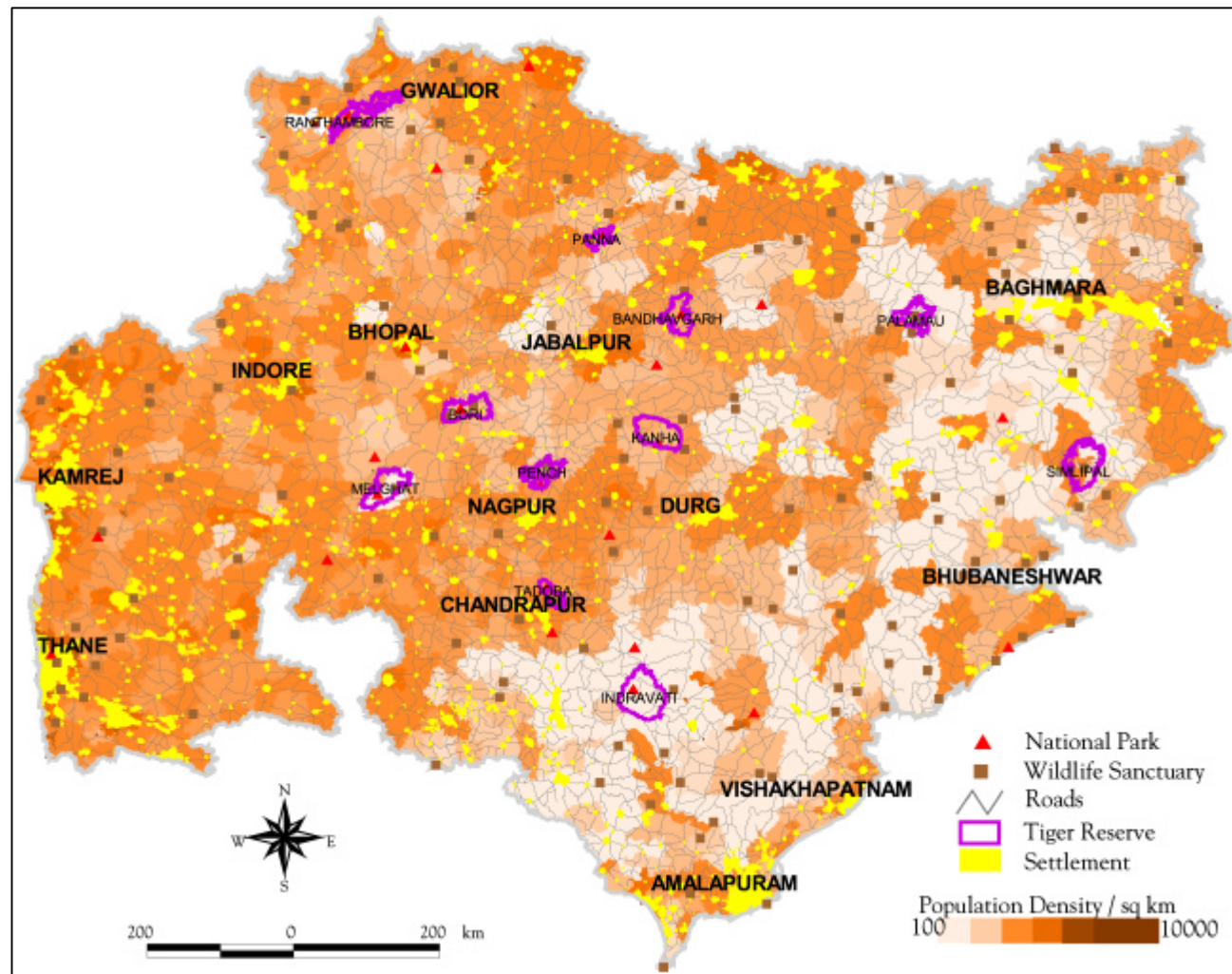


Figure 18 Distribution of Protected Areas and various size of forest patches in the Central Indian landscape complex

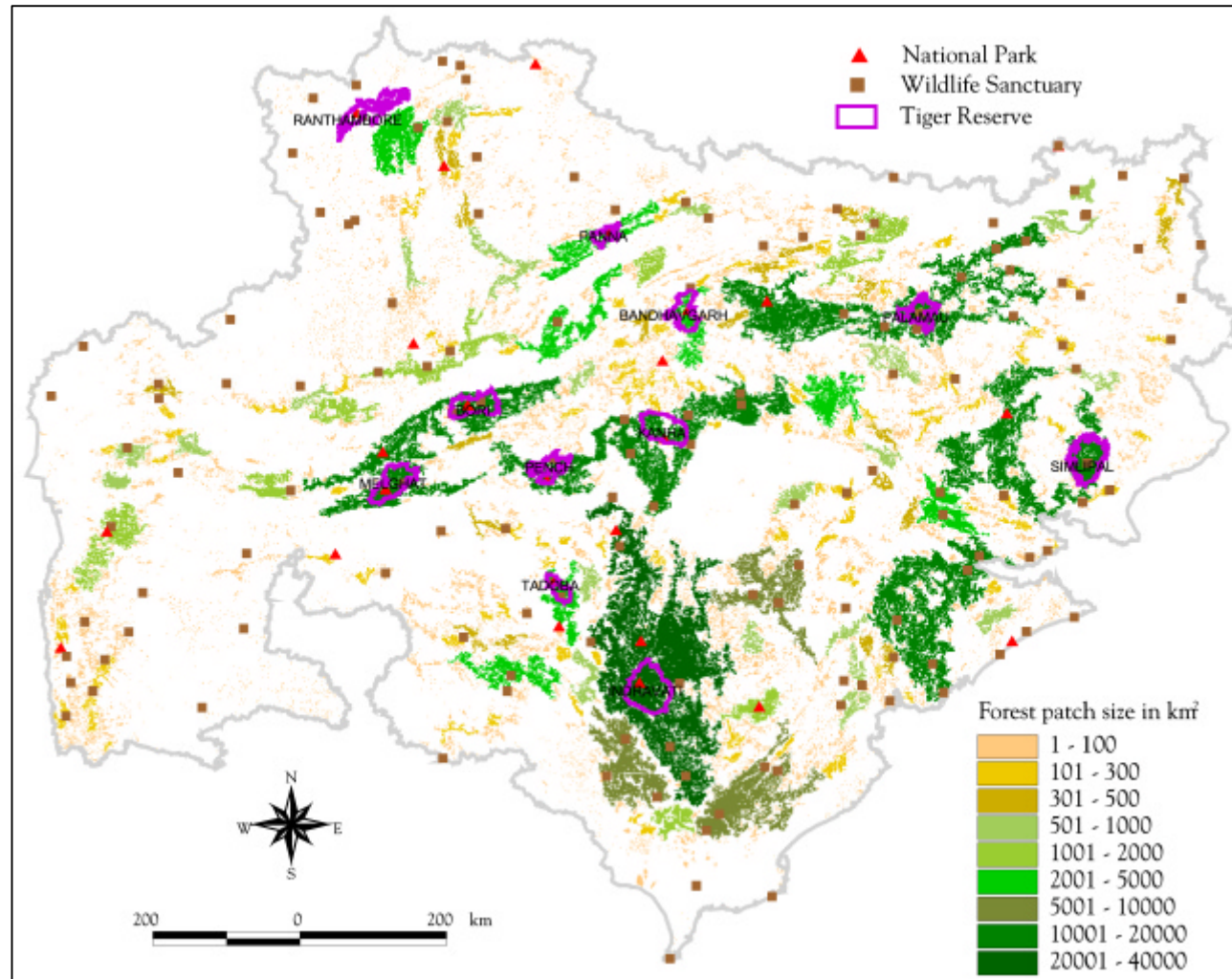


Figure 19 Potential tiger habitat in the Central Indian landscape complex along with forest cover and protected areas

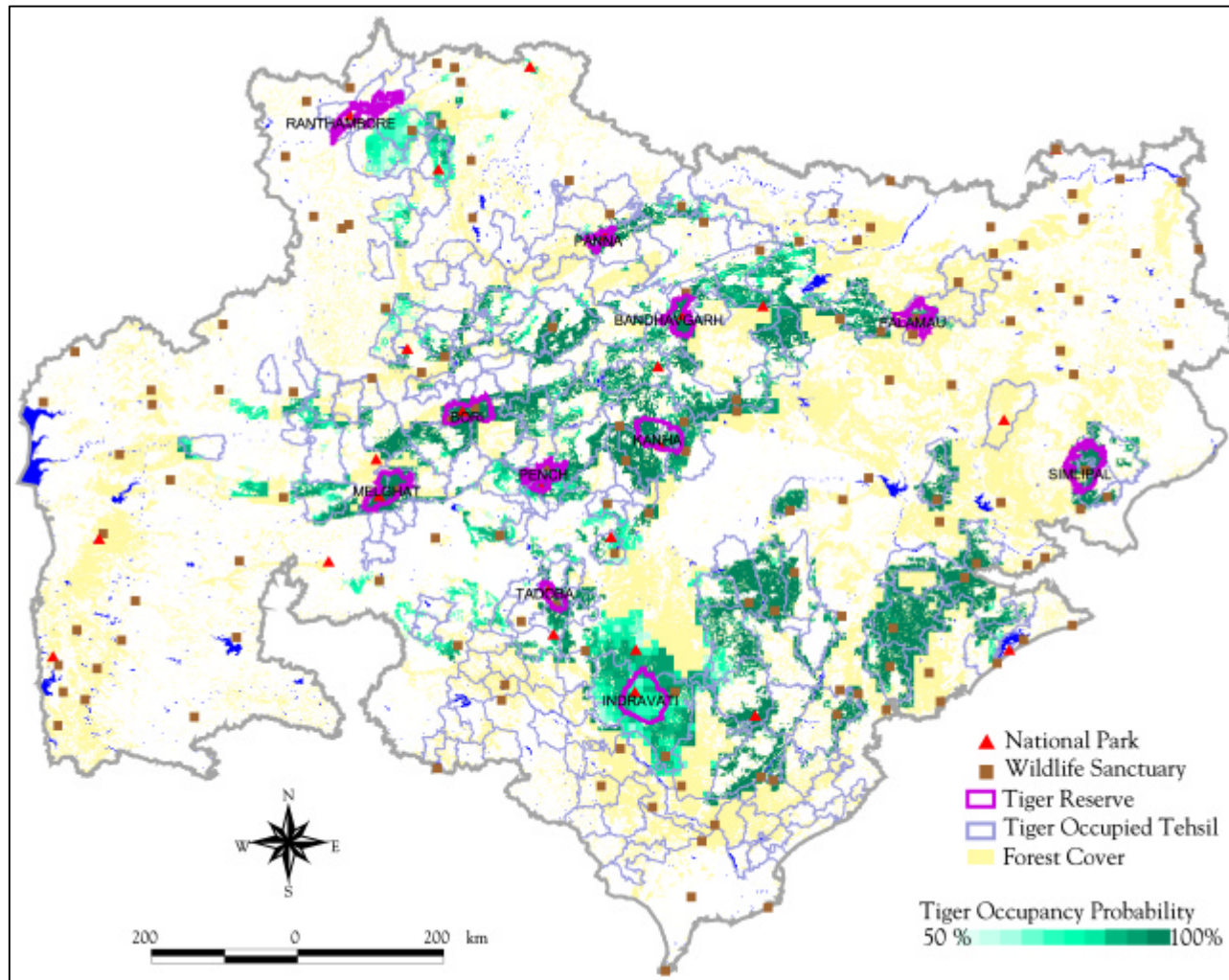
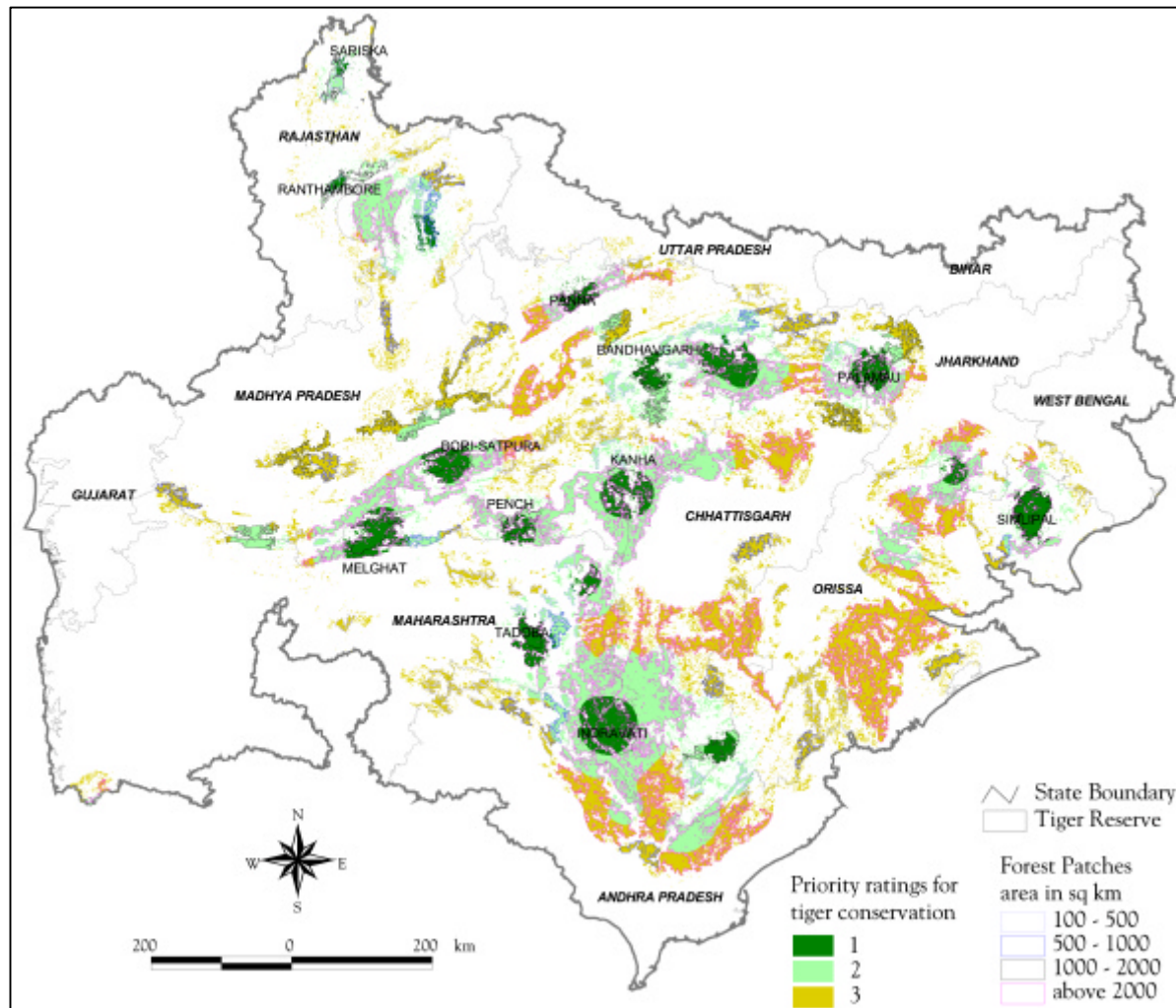


Figure 20 Priority areas within the Central Indian landscape complex for conservation of tiger source populations and maintaining connectivity



(4) Eastern Ghats Landscape Complex

Eastern Ghats are a long chain of broken hills and elevated plateaus, running along the Indian east coast and passing through the states of Orissa, Andhra Pradesh and Tamil Nadu (with more than 50% of it being in Andhra Pradesh). The region has a regime of climate that favours luxurious growth of vegetation and forest. This zone has important biological values including viable elephant, gaur and other mammalian populations, as well as a wide diversity of plant communities, with a mixture of subtropical and tropical evergreen elements.

The Eastern Ghats are endowed with a lot of diversity as it harbours various types of coastal ecosystem such as, estuaries, mangroves, lagoons and coral reefs. They extend over a length of several hundred kilometres between the rivers Mahanadi and Vaigai along the East Coast (after Rodgers and Panwar 1988).

The forests of Eastern Ghats mainly include tropical dry and moist deciduous types with few patches of semi-evergreens existing in association with high lands. Floristic surveys carried out at district and zonal levels reported nearly 2000 species of flowering plants in the region.

Although the historic continuity of Eastern Ghat forests with those in Central India along the Chota Nagpur Plateau is now almost lost, there are still enough large forest areas within this landscape. Nagarjunasagar Srisailem Tiger Reserve, the largest Tiger Reserve in India, adds to its conservation value. However, this habitat is presently plagued by extremist problems, which makes implementation of conservation measures difficult.

Total geographic area : 120764 km²

Political units : Andhra Pradesh only.

Average population density : 65.1 km⁻² (**Figure 21**)

Total protected area : 3385.2 km² (2.8% of the total Land Area)

Total forested area : 2416.4 km²

Major biogeographic zones : 1. Deccan Peninsula (Central Plateau (6D) & Deccan South (6E)) and 2. Coasts—East Coast (8B)

Major ecoregions :

Ecoregions	Geographical Areas (sq km)	Forest Areas (sq km)
Central Deccan Plateau dry deciduous forests	53562	8607
Deccan thorn scrub forests	61018	9442
East Deccan dry-evergreen forests	3557	778
Goadavari-Krishna mangroves	2497	333
South Deccan Plateau dry deciduous forests	105	46

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation: Mean 124 cm Range 71 to 192 cm

Landscape Characteristics of the Eastern Ghats Landscape Complex (Figure 22)

Parameters	Value
Number of forest patches	2062.0
Forest patch density per 1000 km ²	8.6
Mean forest patch area (km ²)	7.6
Mean perimeter to area ratio	36.1
Total forest core area (km ²)	4371.0
Number of disjunct forest core areas	33.0
Mean forest core area (km ²)	1.15
Median forest core area (km ²)	10.5
Total forest core area in forest patches >1000 km ²	3853

Tiger Habitat status:

Percentage area of the landscape complex in terms of districts from which tiger has become locally extinct :

Forested area of tehsils where tiger is currently reported: 21034 km² (77.9% of forest)

Potential habitat for tiger occupancy in the landscape complex: 15837 km² (58.6% of forest) **(Figure 23)**

The Eastern Ghat landscape complex consists primarily of three separate forest **(Figure 24)** blocks. 6000 km² area of Nagarjunasagar Tiger Reserve-Gundla Brahmeshwara proposed National Park, 3000 km² block of forest comprising of Srivenkateshwara National Park and 700 km² forest patch in the tehsils of Kanigiri, Baduel, Udayagiri and Giddalur. The Nagarjunasagar forest block has the best potential for tiger conservation in this landscape followed by the Tirupati forest block. However the 3 forested blocks are isolated with low probability of sharing tiger gene pools through “stepping stone” forest patches. The Tirupati forest patch likely had good connectivity with the Western Ghat landscape during the recent past. Currently, only small forest patches dot the intervening landscape between the Eastern and Western ghats, which are unlikely to act as corridors for tiger movement.

Figure 21 Distribution of human settlements, tiger reserves, and human population density of the Eastern Ghats landscape complex

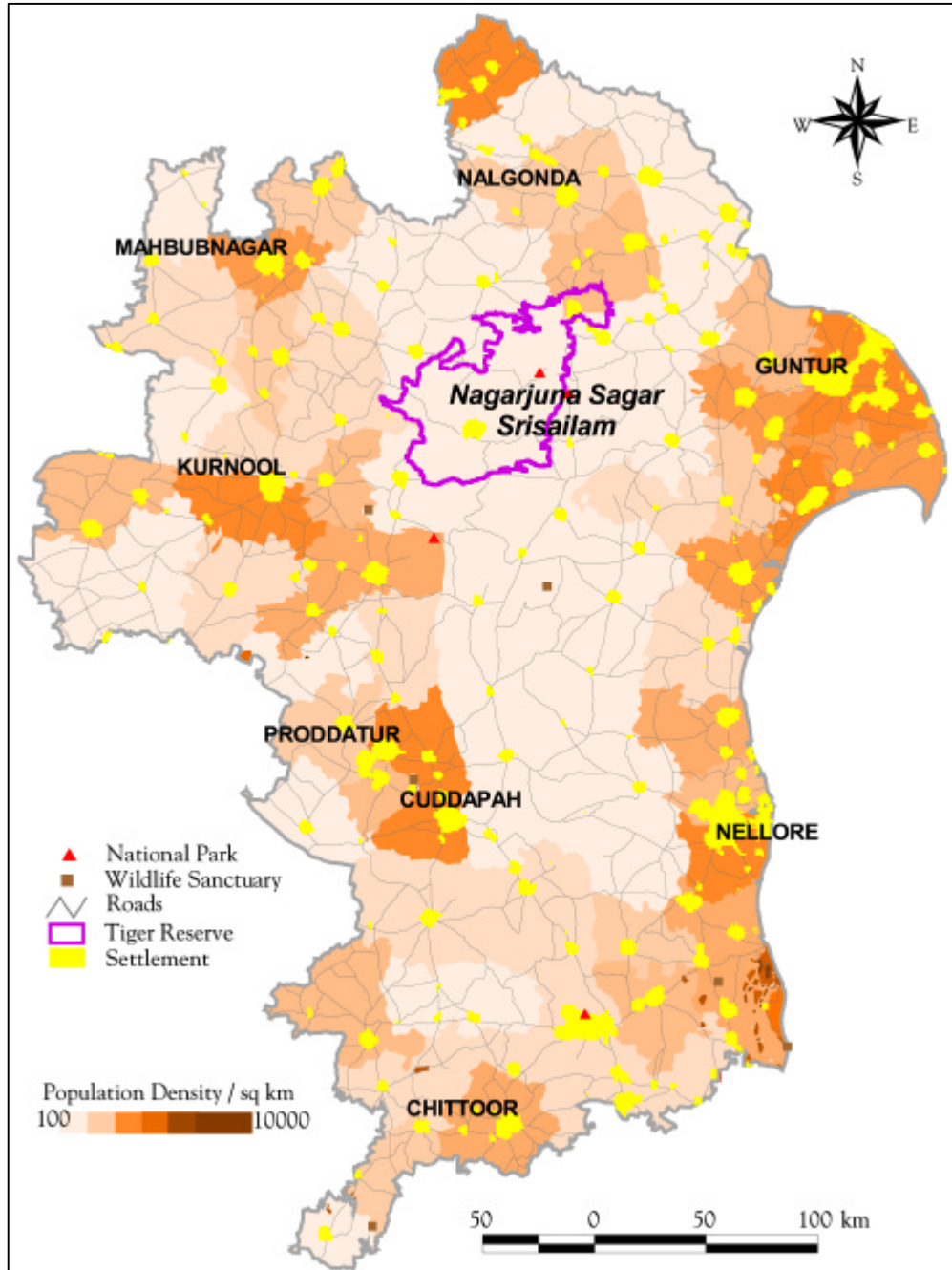


Figure 22 Distribution of Protected Areas and various sizes of forest patches in the Eastern Ghats landscape complex

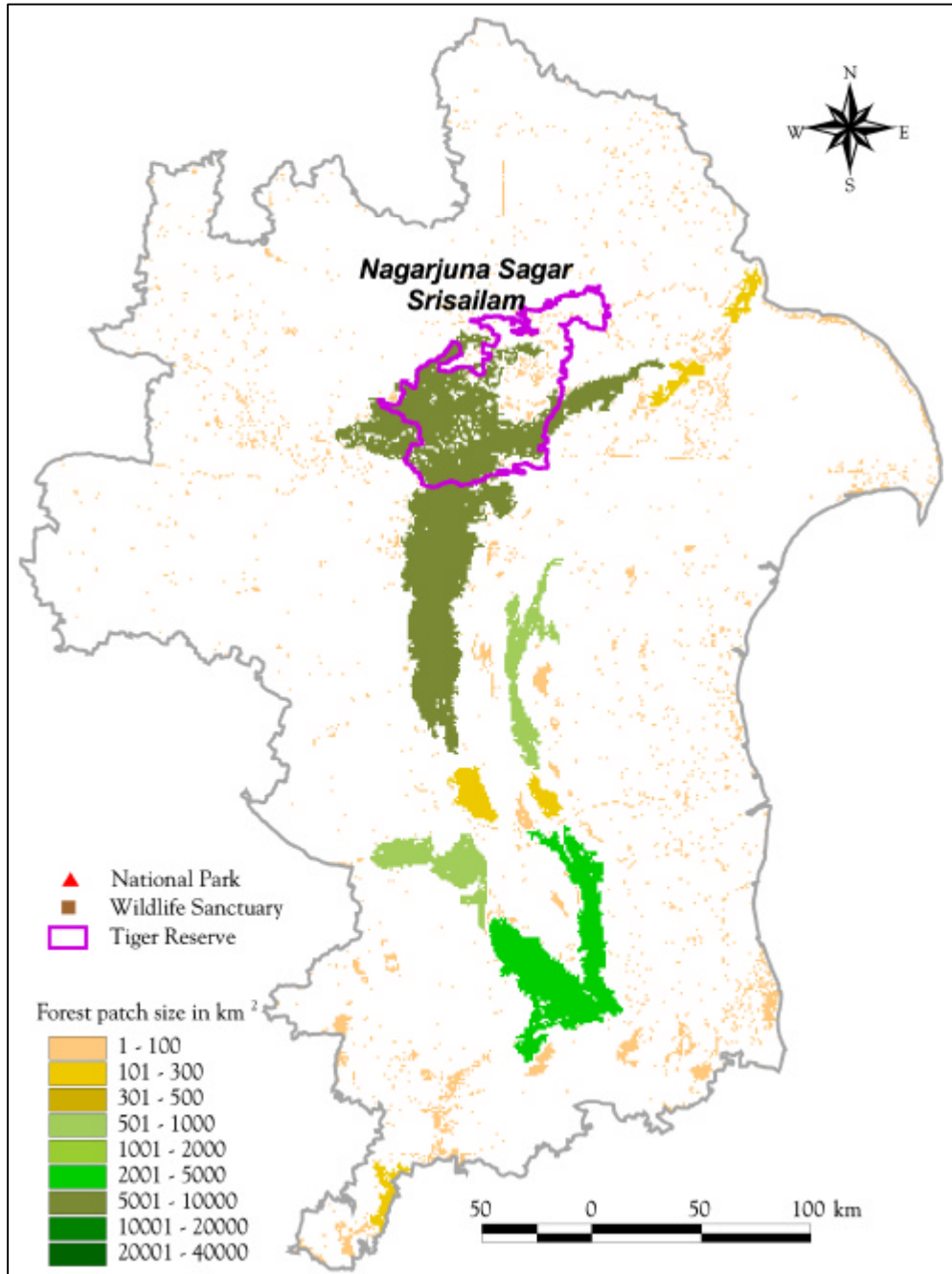


Figure 23 Potential tiger habitat in the Eastern Ghats landscape complex along with forest cover and protected areas

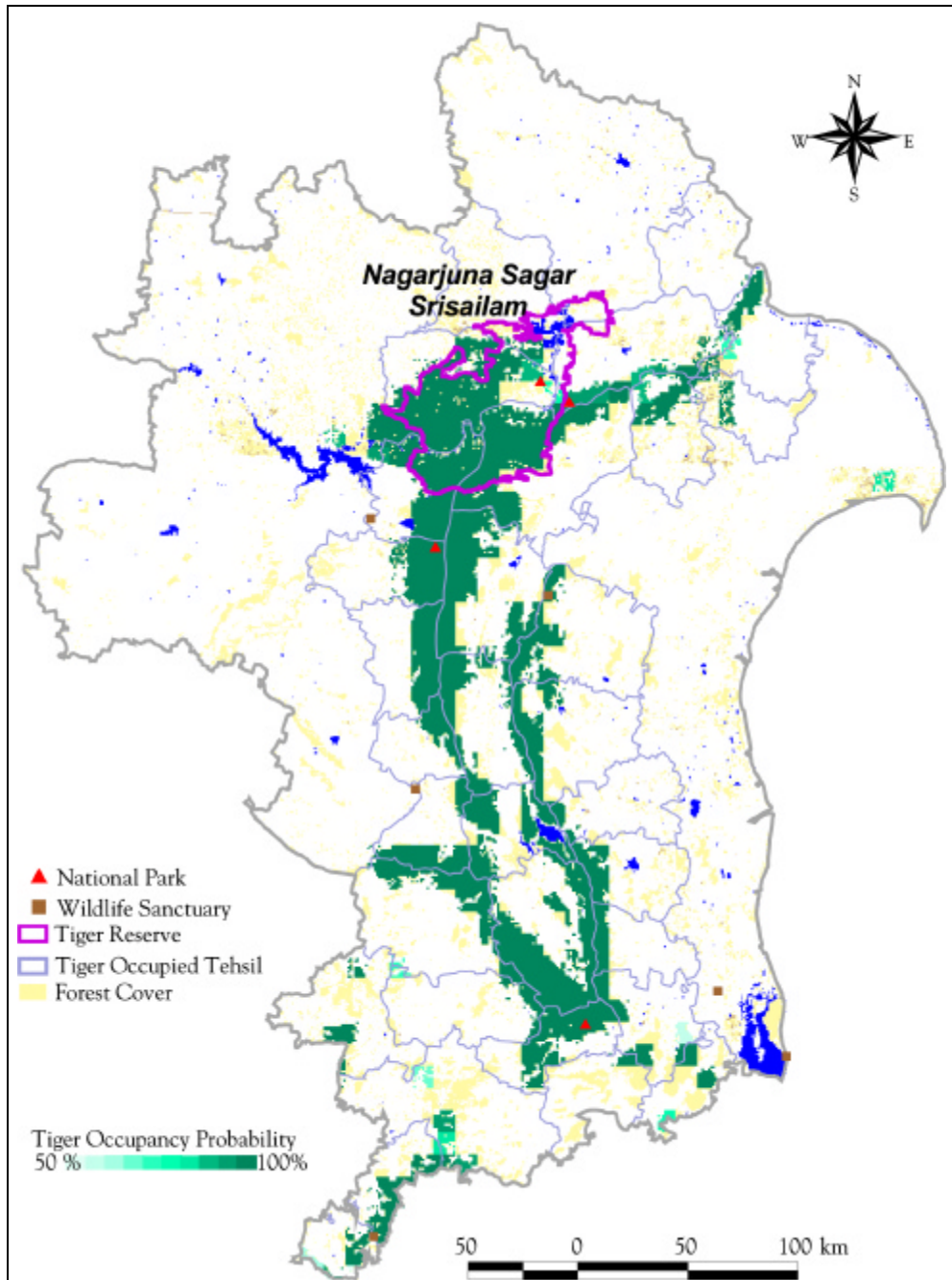
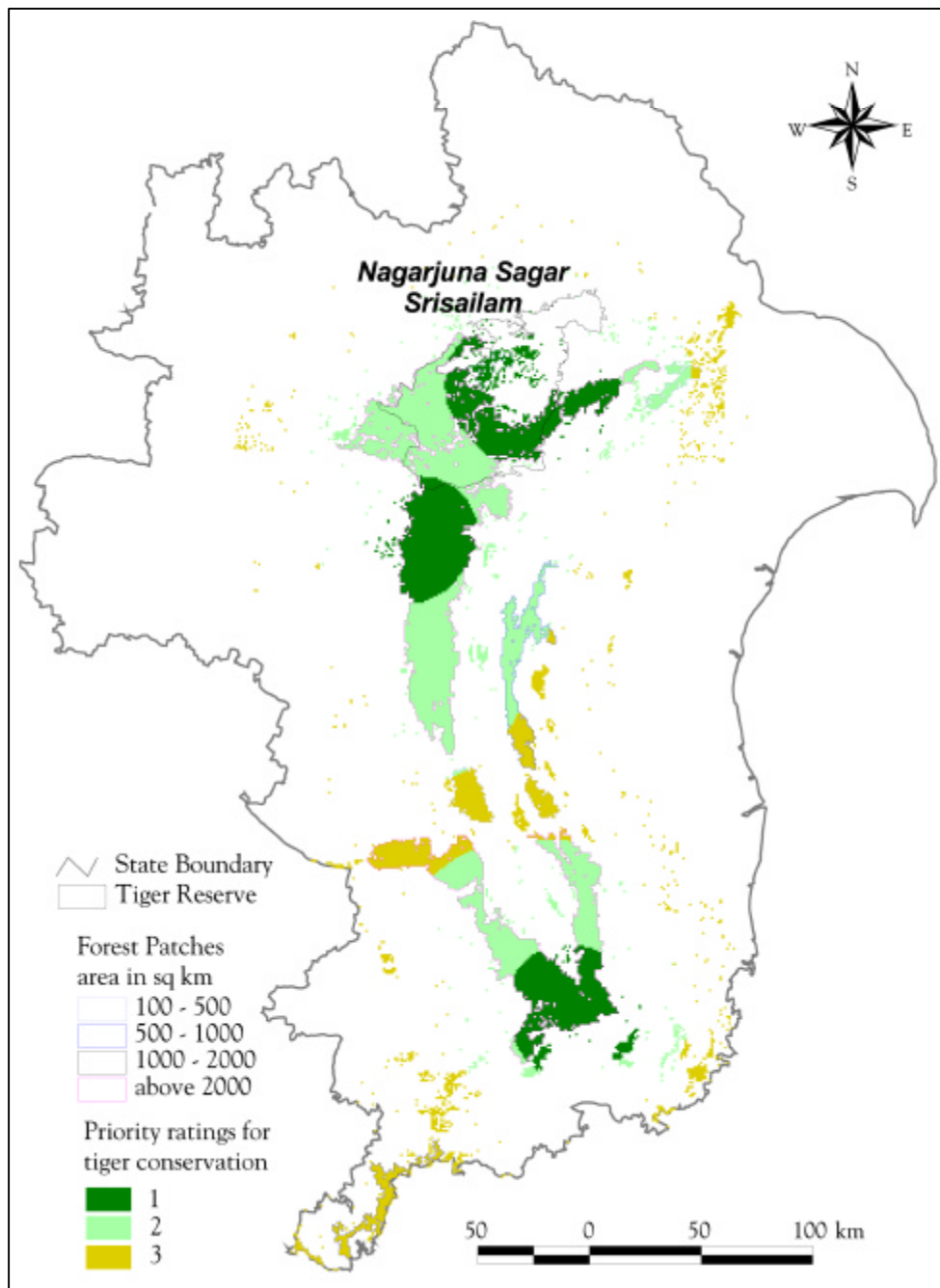


Figure 24 Priority areas within the Eastern Ghats landscape complex for conservation of tiger source populations and maintaining connectivity



(5) Western Ghats Landscape Complex

The Western Ghats is one of the major tropical evergreen forest regions in India. The zone has already lost a large part of its forest cover, and environmental pressures continue to increase. The remaining extent of natural forest coupled with its exceptional biological richness (2/3rd of India's endemic plants are found here) and ever increasing levels of threat (agriculture, reservoir flooding, plantations, logging and over exploitation) are factors which necessitates major conservation inputs (Rodgers and Panwar 1988).

Like all tropical evergreen forests, the resource has values other than the mere presence of diverse biological communities. These forests have an essential role in maintaining water supply to the Krishna, Godavari and Cauvery river systems of peninsular India which have importance for irrigation and hydro-electric power. The scale of forest degradation which is causing loss of dry season flow and siltation of reservoirs is a cause for concern.

The high rainfall, gentle slopes and good soil resources of the Western Ghats are conducive for commercial plantation of tea, coffee, cocoa, rubber, cardamom, quinine, etc. resulting in pressure on the remaining forest lands. These factors also permit rapid growth of plantation trees, both hardwood and commercial softwoods. This has led to logging and clearance of natural forest on a large scale and their replacement by monoculture. The western ghat states have high human densities with a growing demand for land. Thus, there is increasing pressure for the diversion of forest lands for agriculture and development.

The proportion of evergreen forest resource in the country is less per unit area of land, as well as per head of human population than most other nations in the tropical forest region. This calls for special attention to save our remaining evergreen dwindling forest resources.

India has some 15000 species of higher plants, of which around 4000 (27%) are reported from the Western Ghats, which is only 5% of over total land area (Rodgers and Panwar 1988). Botanical values include a great range of major associations, each with a very high proportion of endemics. These endemics are often highly localised by dispersal barriers and many are extremely vulnerable due to increasing habitat disturbance.

The Western Ghats landscape has populations of most of the vertebrate species found in peninsular India, alongwith an endemic faunal element of its own. The large mammal communities which are missing from the landscape are the more arid bovid group e.g. gazelles, blackbuck, and nilgai, and the moist grassland fauna like swamp deer and buffalo.

High levels of endemism is found in vertebrates especially in herpetofauna . The endemic freshwater fish fauna are of interest, as these have affinity to the north east Indian taxa lending support to the Satpura hypothesis (Mani 1974).

The Western Ghats were historically a good habitat for the tiger which was distributed throughout its forests. Currently most of the northern Western Ghats have lost their tigers while the southern portion of this landscape complex is still a major stronghold for the species.

Total geographic area : 281726 km²

Political units : Tamilnadu, Kerala, Karnataka, Maharashtra (partially).

Average population density : 318.7 km⁻² (**Figure 25**)

Total protected area : 10009.9 km² (5.8% of the total Land Area)

Total forested area : 101467 km²

Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B)), 2. Deccan Peninsula (Central Plateau (6D) & Deccan South (6E)) and 3. Coasts (East Coast (8A) & West Coast (8B))

Major ecoregions :

Ecoregions	Geographical Areas (sq km)	Forest Areas (sq km)
Deccan thorn scrub forests	64711	5664
East Deccan dry-evergreen forests	4962	875
Malabar Coast moist forests	30020	7603
Narmada Valley dry deciduous forests	5755	748
North Western Ghats moist deciduous forests	26448	6813
North Western Ghats montane rain forests	25684	12280
South Deccan Plateau dry deciduous forests	77442	14096
South Western Ghats moist deciduous forests	23653	6800
South Western Ghats montane rain forests	22808	8387

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation: Mean 289 cm, Range 206 to 410 cm

Landscape Characteristics of the Western Ghats Landscape Complex (Figure 26)

Parameters	Value
Number of forest patches	4983.0
Forest patch density per 1000 km ²	6.1
Mean forest patch area (km ²)	13.7
Mean forest perimeter to area ratio	34.6
Total forest core area (km ²)	11123.0
Number of disjunct forest core areas	242.0
Mean forest core area (km ²)	2.03
Median forest core area (km ²)	13.5
Total forest core area in forest patches >1000 km ²	10969

Tiger Habitat Status:

Percentage area of the landscape complex in terms of districts from which tiger has become locally extinct : 17%

Forested area of tehsils where tiger is currently reported: 36316 km² (35.8% of forest)

Potential habitat for tiger occupancy in the landscape complex: 51808 km² (51.1% of forest) (Figure 27)

The Western Ghat landscape complex consists of 3 major forested landscape units (**Figure 28**).

1) North-Central Western Ghat Landscape: The largest of these landscapes extends from the district of Pune in the north and stretches south along the Western Ghats to the district of Palghat in Kerala, and to the eastern district of Dharmapuri in Tamil Nadu (39,600 km²). There are several National Parks, Sanctuaries and Tiger Reserves in this landscape eg. Koyna, Radhangir, Bhagwan Mahavir, Ansi, Kudremukh, Bhadra Tiger Reserve, Nagarhole-Bandipur Tiger Reserve, Silent Valley, Dr. Jayalalitha, Eravikulam, Mukurthi and Bannerghatta. This landscape covers contiguous forest area of 39,000 km² and has the highest potential for long term tiger conservation. Though the area coverage is large, the forested landscape towards the North is narrow along the Western Ghat ridge. This area needs protection and prey restoration for fostering tiger conservation.

2) South-Central Western Ghat Landscape: Forested areas to the south of Palghat gap comprising the sanctuaries of Chimmory, Parambikulam, Anamud, Thattekadu, Indira Gandhi, Chinnur, Idukki, Shola forest and Kodai Kanal. This covers a contiguous area of about 4400 km². This area, though not having any National Park or Tiger Reserve, has a potential for tiger conservation. It is also connected to the South through degraded forest patches which may likely permit tiger movement with the landscape comprising of Periyar-complex.

3) Southern Western Ghat Landscape : Periyar-Agastyamalai-Kalakad is the Southern most tiger occupied landscape covering an area of about 6000 km². It has some potential connectivity with the Northern forests, which can be restored by management and protection (in the tehsils of Palaiyam, Udumbanchola, Todupulai and Pirmed). This would enhance the value of this landscape as a metapopulation within a larger landscape of over 10,000km².

Figure 25 Distribution of human settlements, tiger reserves, and human population density of the Western Ghats landscape complex

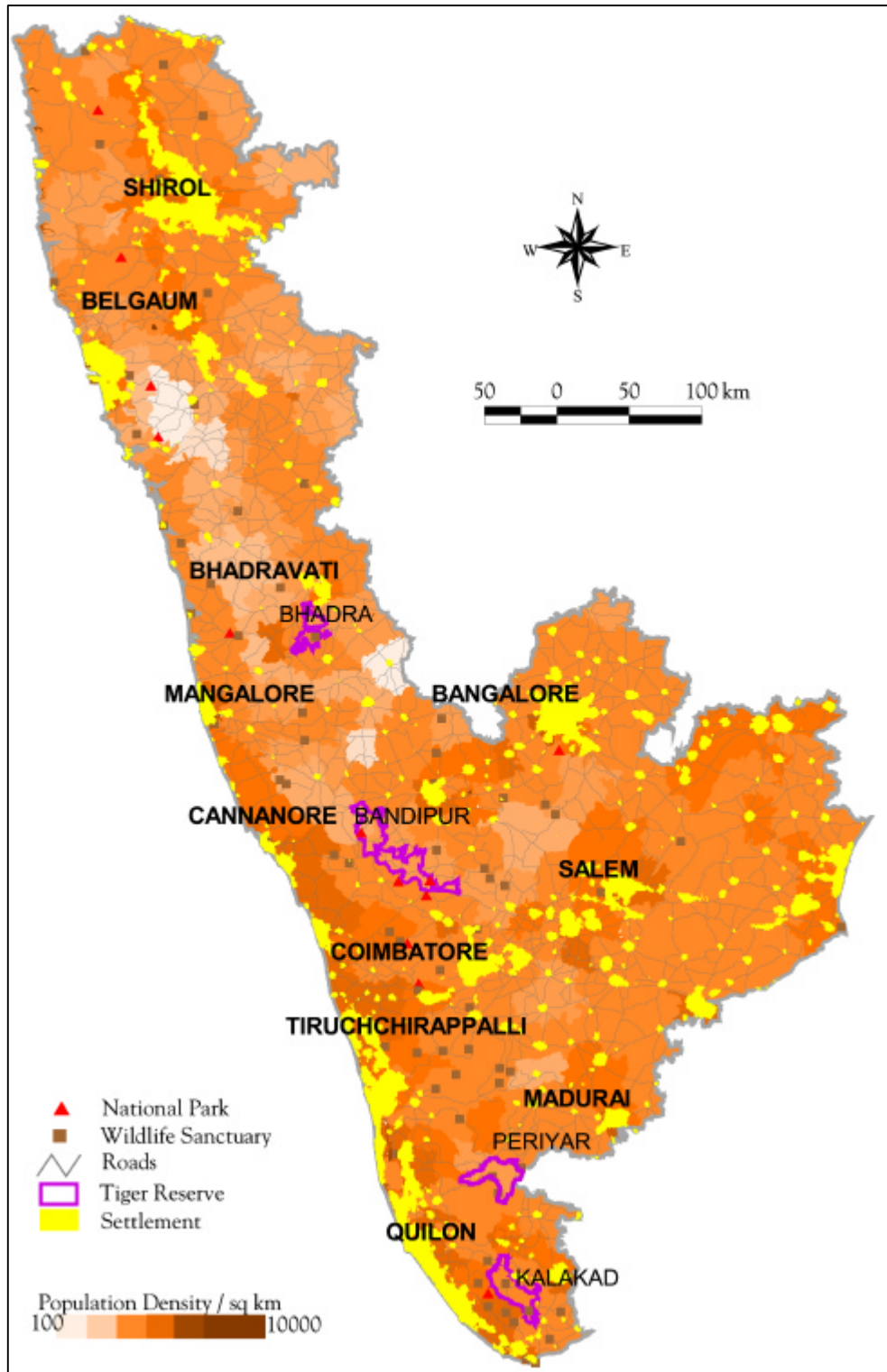


Figure 26 Distribution of Protected Areas and various size of forest patches in the Western Ghats landscape complex

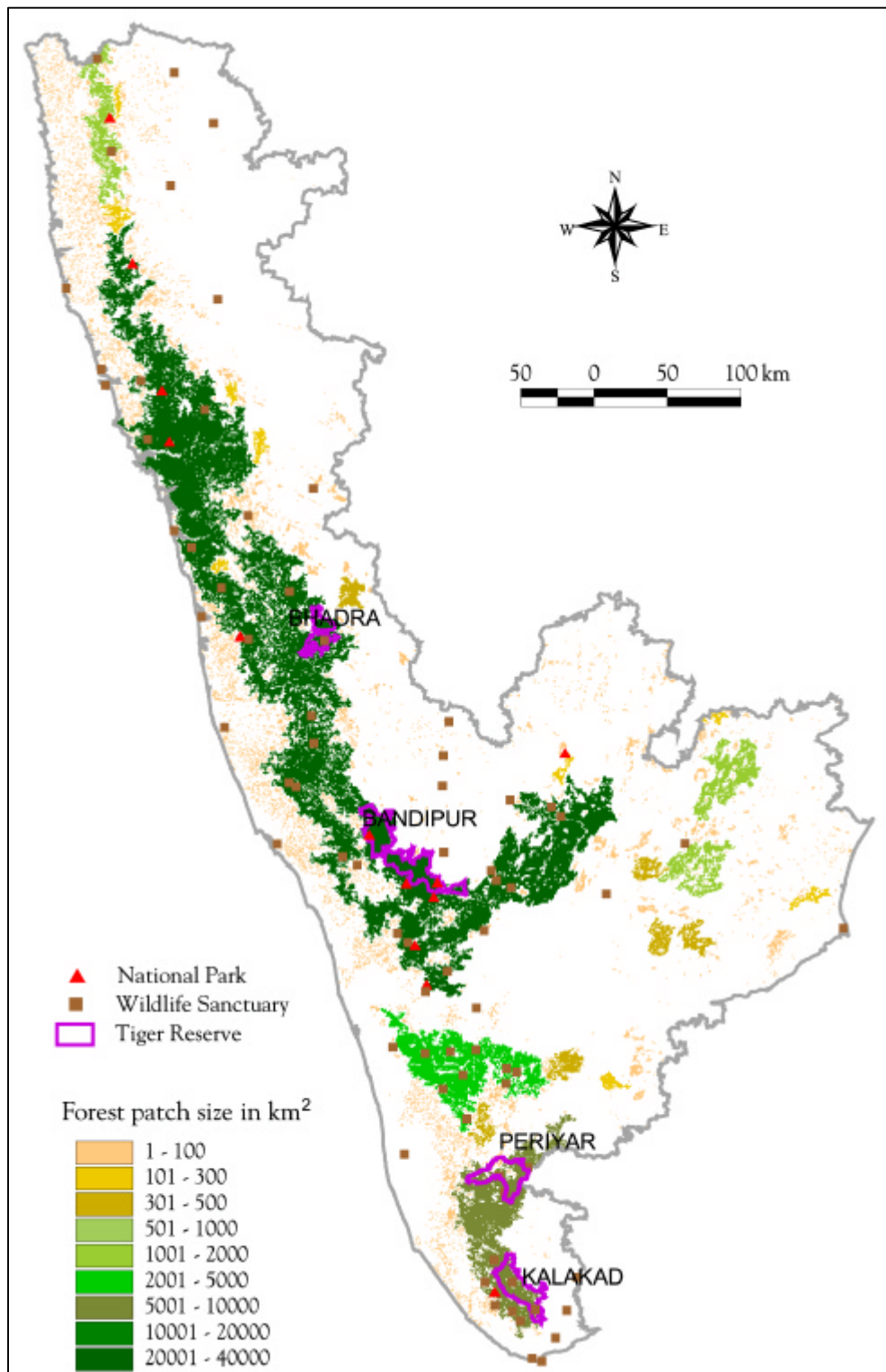


Figure 27 Potential tiger habitat in the Western Ghats landscape complex along with forest cover and protected areas

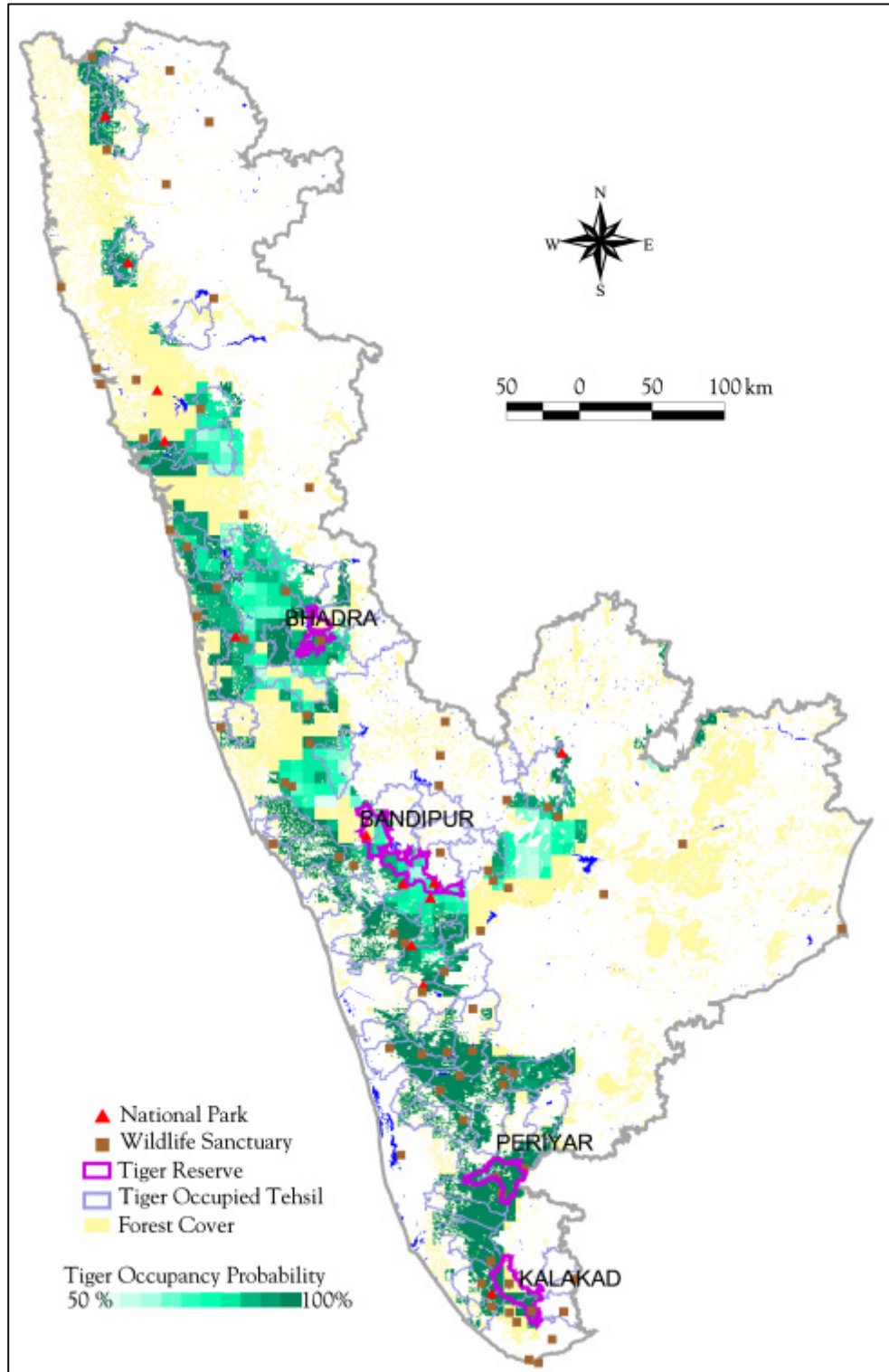
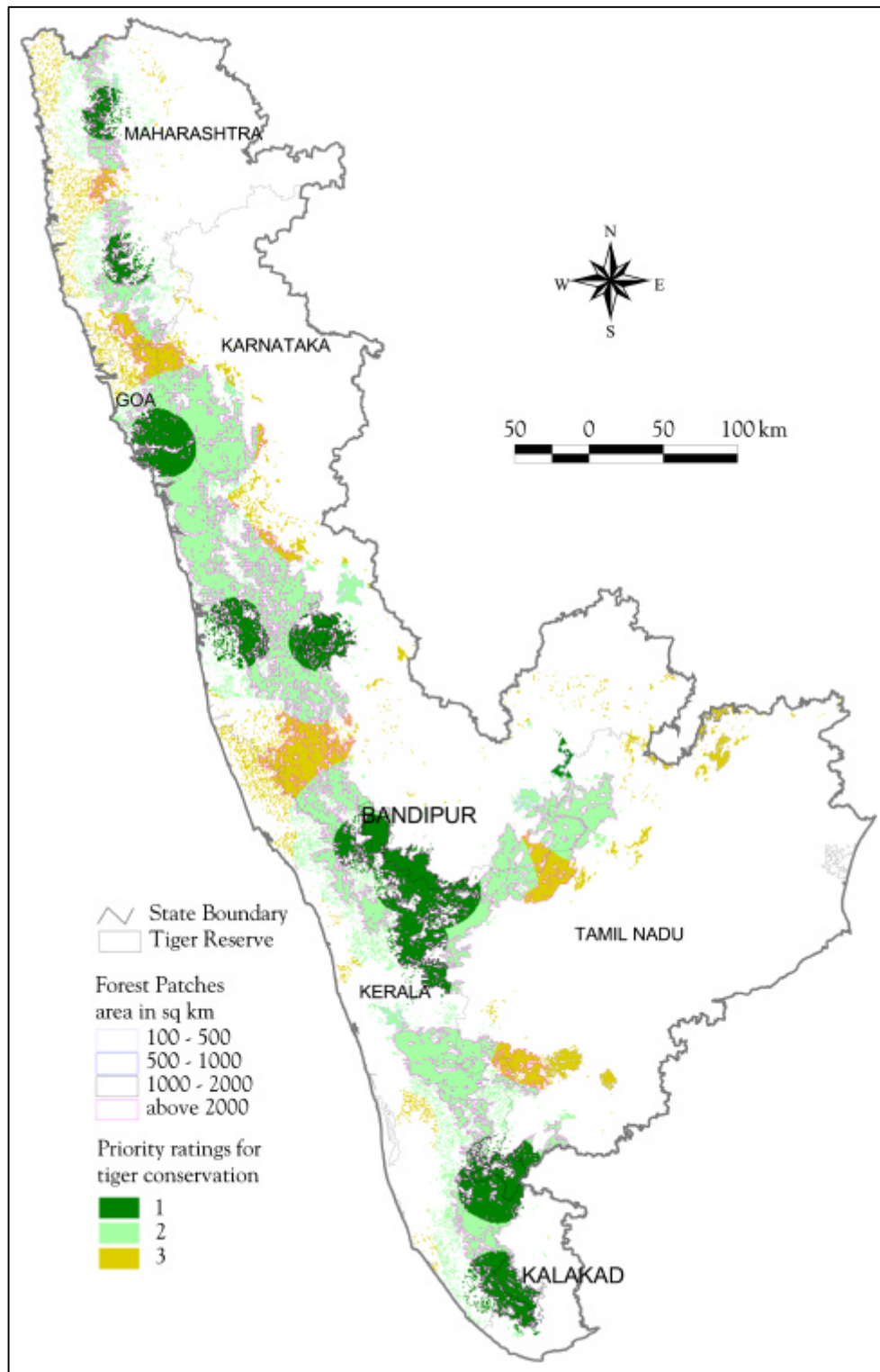


Figure 28 Priority areas within the Western Ghats landscape complex for conservation of tiger source populations and maintaining connectivity



(6) Sunderbans

The Sunderban mangroves are part of the sub continent's largest mangrove system, and perhaps harbour the country's single largest tiger population in a unique ecological setting. These forests have salt water crocodiles (*Crocodylus porosus*), estuarine and marine turtles, three species of fresh water dolphins and avifauna. With its network of tidal rivers, channels, mudflats, creeks and an archipelago of around 54 islands, - Sunderbans provide a dynamic eco-system which is geologically still under formation,

The vegetation is confined only to the forested tracts of the active delta, popularly known as the Mangrove Tidal Forests. Out of the 50 mangrove species of the world, around 35 are found in Sunderbans in addition to 117 other halophytic mangrove associates. The mangroves have characteristic stilt roots with numerous lenticels and pneumatophores to adapt to the high salinity, submergence, fine clayey soil, tidal currents and occasional fresh water flow of the region.

Sunderbans provide shelter to a large number of euryhaline / brackish water algae, a wide variety of fishes, and to crustaceans like shell-fish, prawns, estuarine crabs and ghost shrimps in its rivers and nutrient enriched creeks. They serve as nurseries for several commercially important fish species. Besides the tiger other species of interest are fishing cat (*Felis viverrina*), chital, rhesus monkey (*Macaca mulatta*), wild pig (*Sus scrofa*), otters, Irawady and Gangetic dolphins, monitor lizards (*Varanus spp*), snakes (including python), estuarine crocodiles, sharks, and a large variety of local and migratory birds.

Ecological services of Sunderbans are extremely valuable to local communities. On an average, 500 quintals of honey and 30 quintals of wax are being collected every year by local people under license from the forest department.

Although deltaic mangrove systems are known to be very productive, most of that productivity remains confined to the aquatic system, and the habitat can support only low densities of terrestrial mammalian prey, and in turn, tigers. Although the inherent inaccessibility of these habitats makes scientific documentation and research efforts more challenging, nevertheless it imparts some degree of natural protection to tigers. Perhaps the best protection for Sundarbans tigers is their fearsome reputation of being habitual man-eaters.

Total geographic area : 2585 km²

Political units : South 24 Paragana(s) (West Bengal).

Population density : 1437.4 km⁻²

Total protected area : 2585 km²

Total forested area : 1474 km² (**Figure 29**)

Major biogeographic zone :

It comes under east coast 8B of biogeographic zones, and Sunderbans mangroves of ecoregions.

Temperature range : Minimum average 17.2° C, Maximum average 38.6° C

Precipitation mean : 162 cm, Range : 108 to 223 cm

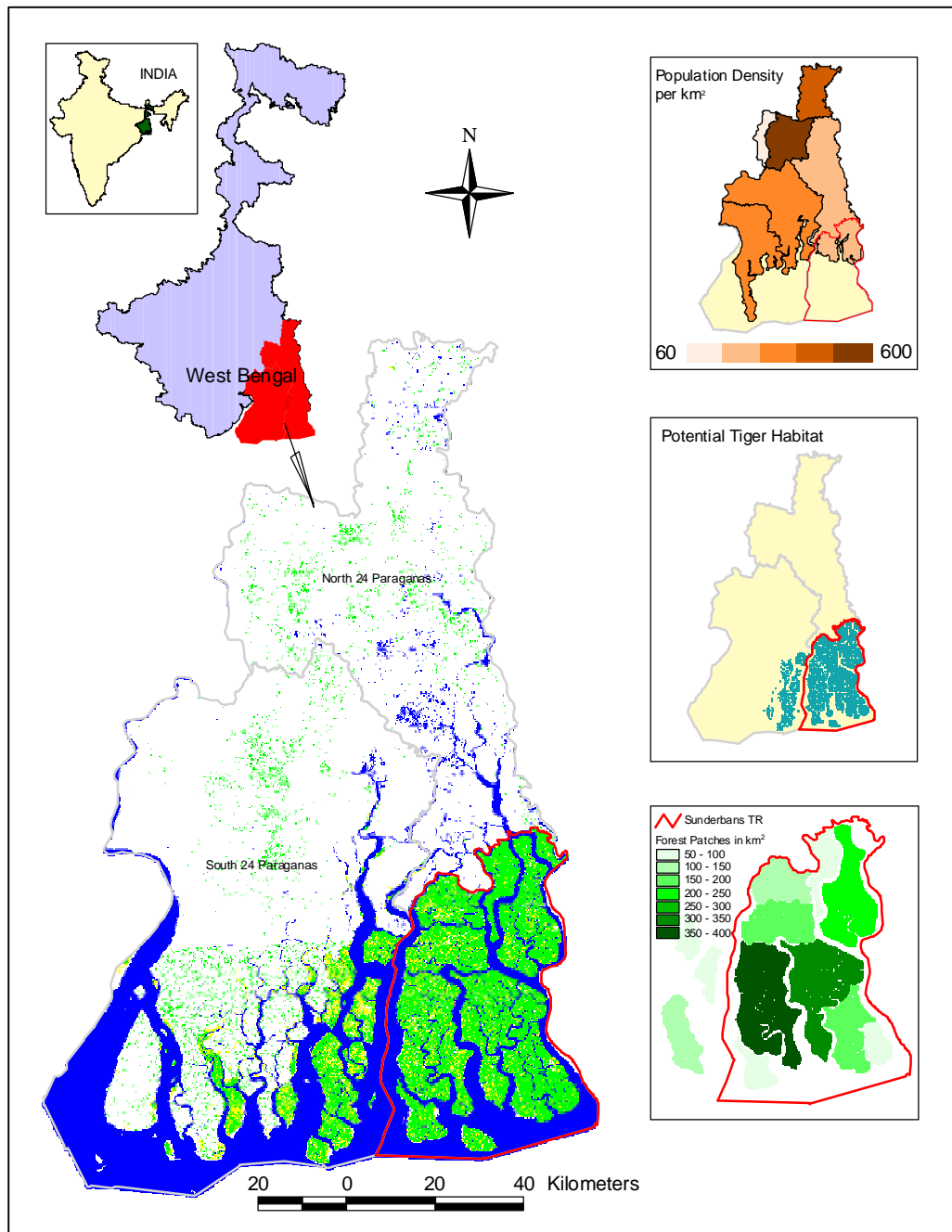
Landscape Characteristics of the Sunderbans (Figure 29)

Parameters	Value
Number of forest patches	737
Forest patch density per 1000 km ²	12.3
Mean forest patch area (km ²)	3.1
Mean forest perimeter to area ratio	16.6
Total forest core area (km ²)	534.4
Number of disjunct forest core areas	128
Mean forest core area (km ²)	0.72
Median forest core area (km ²)	14.29
Total forest core area in forest patches >1000 km ²	534.42

The Sunderbans comprise of a total forested landscape of 1474 km² in West Bengal stretching into Bangladesh. The mangrove forest is traversed by several tidal channels forming small to large forest islands. Animal movement across the smaller channels is common. Tigers have been recorded to cross larger (>5 km width) channels as well. Therefore, the total mangrove forests of India and Bangladesh have a tiger population that can potentially share their gene pool.

The Sunderbans are isolated and do not have any forest connection to other tiger occupied landscapes (North Eastern Hills). Being the only forest in the region, there is heavy biotic pressure for forest resources, fisheries, and non timber forest produce (NTFP) collection. These need to be regulated and the forest protected to ensure the long term survival of the tiger in this unique landscape.

Figure 29 Forest cover, forest patches and human density of the Sunderban landscape



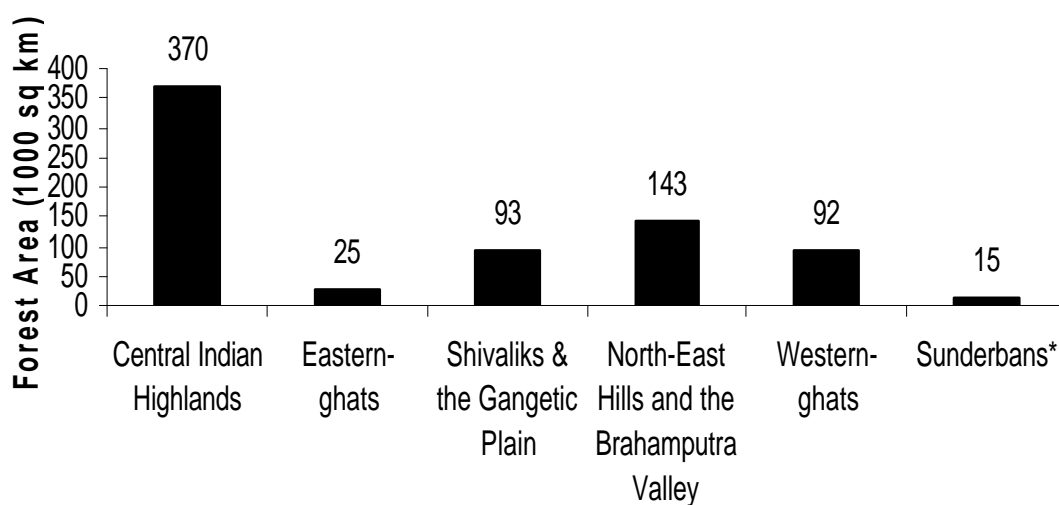
Comparing landscape complexes

Distribution of tiger reserves within the different landscape complexes has ensured that the tiger acts as a true “umbrella species” for the conservation of biodiversity of the various ecoregions of the country. The exception being hot and cold deserts in Western India and the high Himalayas and semi-arid regions of Rajasthan, Gujrat and the Deccan.

The North East hills and Bhramaputra plains landscape and the Central Indian Highland landscape have the largest percentage of forest cover (**Figure 30 and 31**). These two landscapes followed by the Western Ghats have the largest areas of relatively undisturbed forests (core areas) (**Figure 32 and 33**). The Eastern Ghat landscape complex is least fragmented. Thus considering landscape features alone, Central Indian Highlands, North East hills and Bhramaputra plains seem to have the best potential for long term tiger conservation. The Central Indian Highland landscape complex also has the largest area of potential tiger habitat of about 156,000 km² out of a total of around 309,000 km² of tiger habitat in the country (**Figure 34**). However, “undisturbed” forests constitute only about 64,500 km² (20%) of the tiger occupied forests.

The areas under Priority I for tiger conservation were similar between Central Indian landscape (29,000 km²), North East Hills and Bhramaputra Valley (19,000 km²) and Western Ghats (17,000 km²) (**Figure 35**). These areas have source populations of tigers and need strict protection. Priority-II conservation areas serve as links between source populations and as low density sources. Many of the Priority III areas are either contiguous links or serve as “stepping stone” habitat blocks. In Priority II and III areas, protection along with management strategies that are inclusive of livelihood issues of local communities are crucial for effective conservation. In these areas restorative management of habitat is essential for enhancing prey populations. Also providing cheaper protein alternatives to local communities would reduce substance level poaching for wild meat. Priority II and III areas are crucial for connectivity within the landscape that if managed and restored could maintain meta-population structure of tigers thereby enhancing their potential for long term survival.

Figure 30 Total area under forest cover in the different landscape complexes



* area in 100 sq. km

Figure 31 Percent forest cover and forest patch density in the six tiger occupied landscape complexes

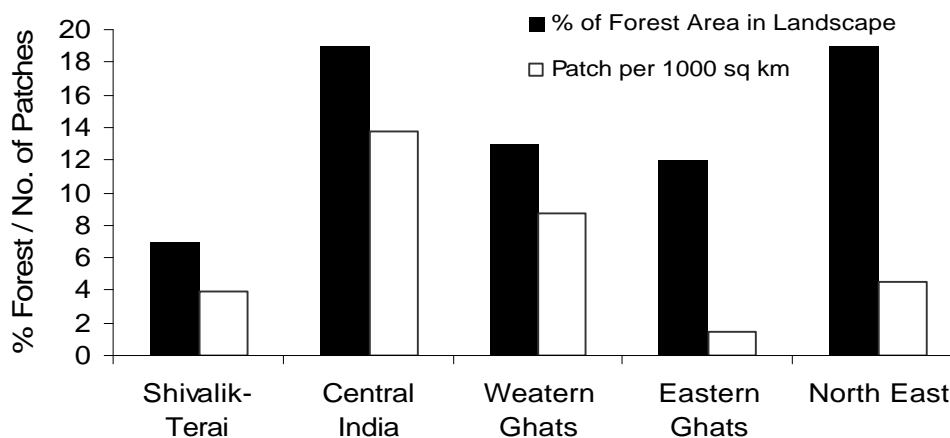


Figure 32 Area of relatively undisturbed forest cores within forest patches greater than 1000 km² in different landscape complexes

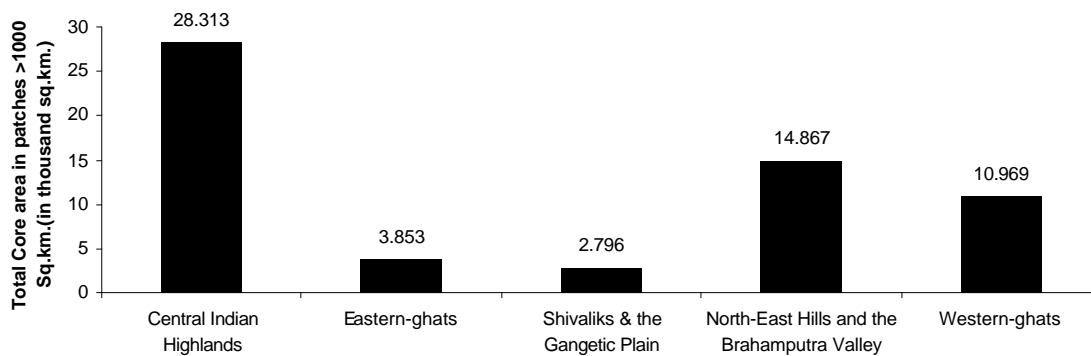


Figure 33 Forest area in patches greater than 2000 km² and the area in forest core within these patches

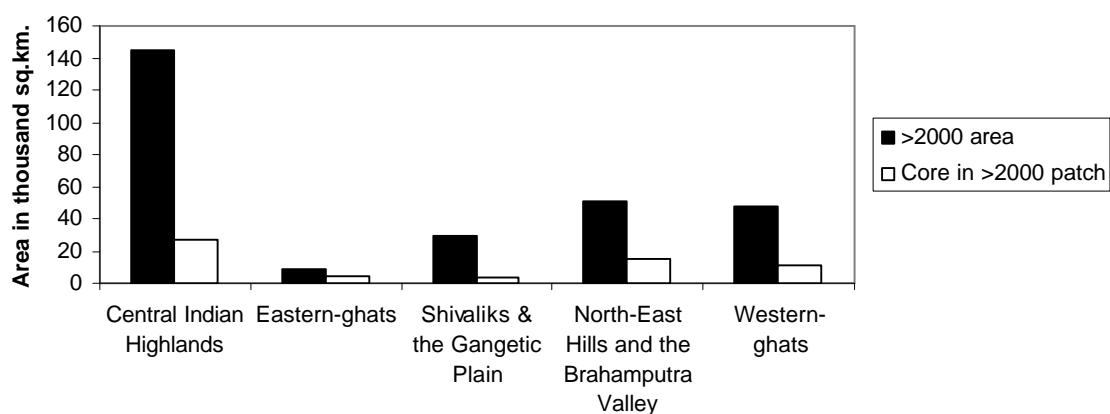


Figure 34 Potential Tiger Habitat in each landscape complexes

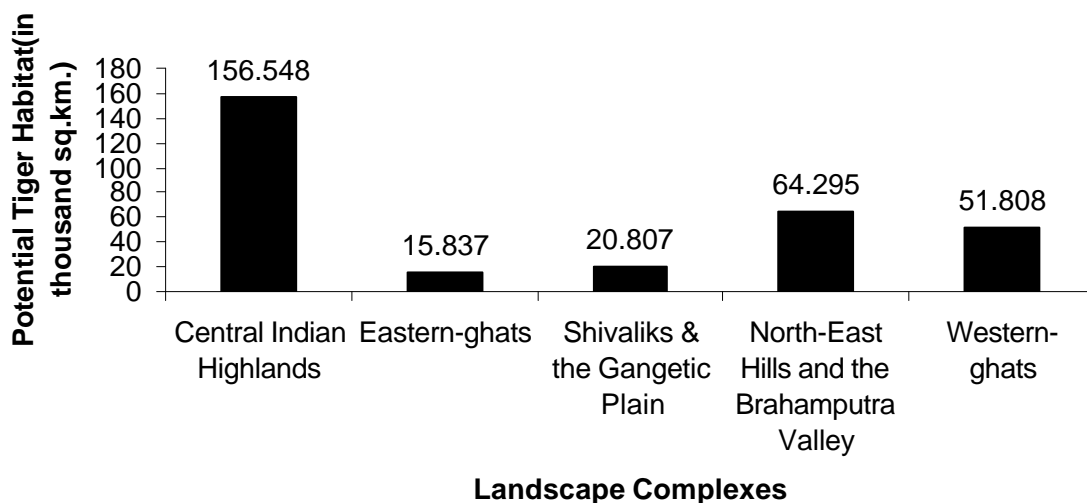
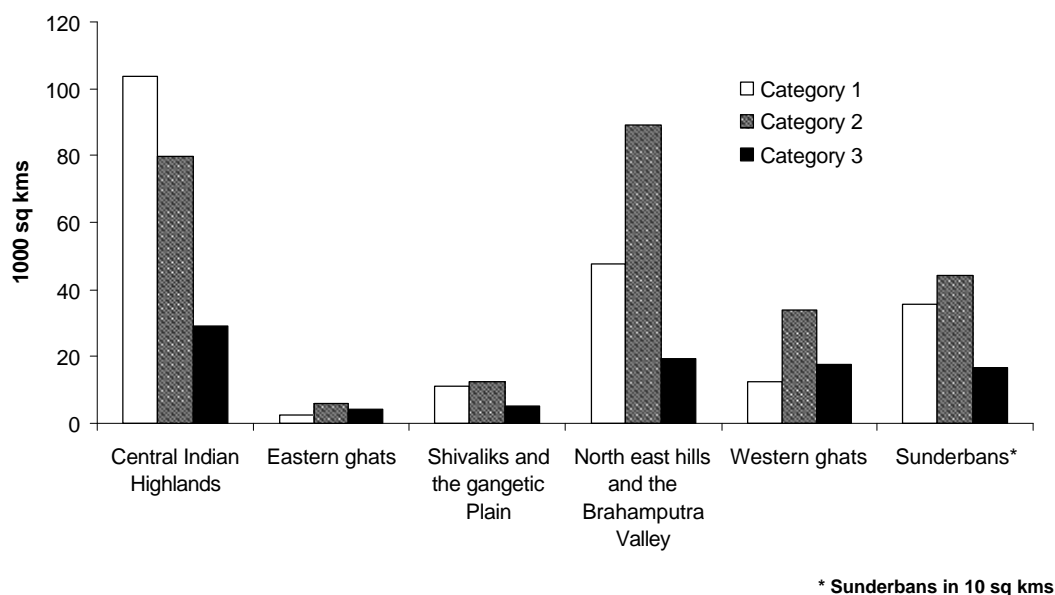


Figure 35 Forest areas under different tiger conservation priority ratings within landscape complexes.



TIGER HABITAT
IN
STATES

ANDHRA PRADESH

The state of Andhra Pradesh in east central peninsular India is typical of the extensive Deccan biogeographic zone. It forms a major part of the Eastern Ghats landscape complex and also harbour a small part of the Central India landscape complex defined in present study. The vegetation of the state is largely arid dry deciduous teak and miscellaneous or thorn forest. The hills add greatly to the biological diversity, and are centres of endemism for plant, birds and other wildlife. There are several endemic floral taxa in the Eastern Ghats. Some examples are *Andrographis beddomei*, *A.nallamalayana*, *Argyria arakuensis*, *Boswellia ovalifoliata*, *Cycas beddomei*, *Euphorbia senugtae*, *Eriolaena lushingtonii*, *Kalanchoe cherukondensis*, *Leucas mukerjina*, *Memecylon madgolense*, *Pimpinella tirupatiensis*, *Phyllanthus naryanaswamii*, *Staurogyne perpusilla*, *Strobilanthes circarensis*, *Strobilanthes jeyporensis*, *Toxocarpus roxburghii* and *Uvaria euchinata*.

Major parts of the Eastern Ghats lying in Orissa and Andhra Pradesh are under explored. Further explorations are justified as many floral elements found in the Eastern Himalayas (Meghalaya and Assam) shows disjunct distribution in the hills of Visakhapatnam district, and some are found in Kalahandi and Bailadila. Of these *Saussurea heteromalla*, *Polygala furcata*, *Sloanea sterculicea* (Small trees), *Sapium eugeniaefolium* (Small trees), *Bulbophyllum densiflorum*, *Eulophia explanata*, *Forrestia mollissima* var. *glabrata*, *Prunus jenkinsii* (medium-sized tree), *Chirita hamosa*, *Raphidophora decursiva*, *Beilschmiedia sikkimensis* (medium-sized trees), *Parabena sagittata*, *Miucuna nigricans*, *Anaphalis adnata*, *Lysimachia alternifolia*, *L.decurrens* and *Callicarpa macrophylla* are worth mentioning. Similarly, *Ensete glaucum*, a relict species found in Meghalaya, Burma, Thailand etc., was recorded from Visakhapatnam hills (NBSAP, 2000).

A few plants formerly believed to be endemic to the Western Ghats were recently recorded in the wild from the Eastern Ghats. The significant ones include *Nothopegia racemosa*, *Syzygium malabarica*, *Glochidion ellipticum* and *Debregaesia malbarica* (trees); *Xenacanthus pulneyensis*, *Pouzolzia bennettiana* (shrubs); *Lobelia zeylanica*, *Dicliptera zeylanica*, *Plectranthus mollis*, *Pilea trinervia* (all herbs); *Microstylis versicolor*, *Polystanchya flavescens* (Orchids) (NBSAP, 2000).

Andhra's northern portion of the Eastern Ghats has a Sal forest community and the higher reaches have a moist-deciduous-semi evergreen transition with many endemic species. To the south, the ghats have a deciduous cover, including the isolated red sanders forest on the Tamil Nadu border.

The southern half of the state, below the Krishna River, is a mixture of thorn forest communities. Faunal elements include tiger, leopard, and typical dryland predators, - wolf (*Canis lupas*), hyaena (*Hyaena hyaena*) and jackal (*Canis aureus*), with sambar, sloth bear, chital, chowsingha and chinkara.

The rivers have mugger and turtle populations, and their coastal deltas have some remaining mangroves. Large brackish and freshwater lakes and swamps are important waterfowl areas. The coasts have some minor turtle beaches and potential saltwater crocodile habitat. The southern coastal fringe has pockets of dry evergreen forest, perhaps the most threatened of all of India's forest types (Rodgers and Panwar 1988).

Population Density : 275 km⁻² (Figure 36)

Total protected area : 4.72 % (12972.43 km²)

Total forested area : 54544 km² (20% of total geographic area)

Major biogeographic zones: 1. Deccan Peninsula (Eastern Highlands (6C), Central Plateau (6D) & Deccan South (6E) and 2. East Coast (8B)

Major Eco regions of Andhra Pradesh :

Eco Regions	Area (sqkm)
South Deccan plateau dry deciduous forests	46
Goadavari-Krishna mangroves	510
East Deccan dry-evergreen forests	778
Deccan thorn scrub forests	11709
Central Deccan plateau dry deciduous forests	15269
Eastern highlands moist deciduous forests	18858

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation : Mean 89 cm Range 49 to 150 cm

Tiger Habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct: 4%

Forested area of tehsils where tiger is currently reported: 53423 km² (97.94% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 37) (Appendix 7):

Priority I : 4409 km²

Priority II : 11933 km²

Priority III : 14798 km²

Figure 36 Map of Andhra Pradesh showing distribution of human settlements, tiger reserves and human population densities

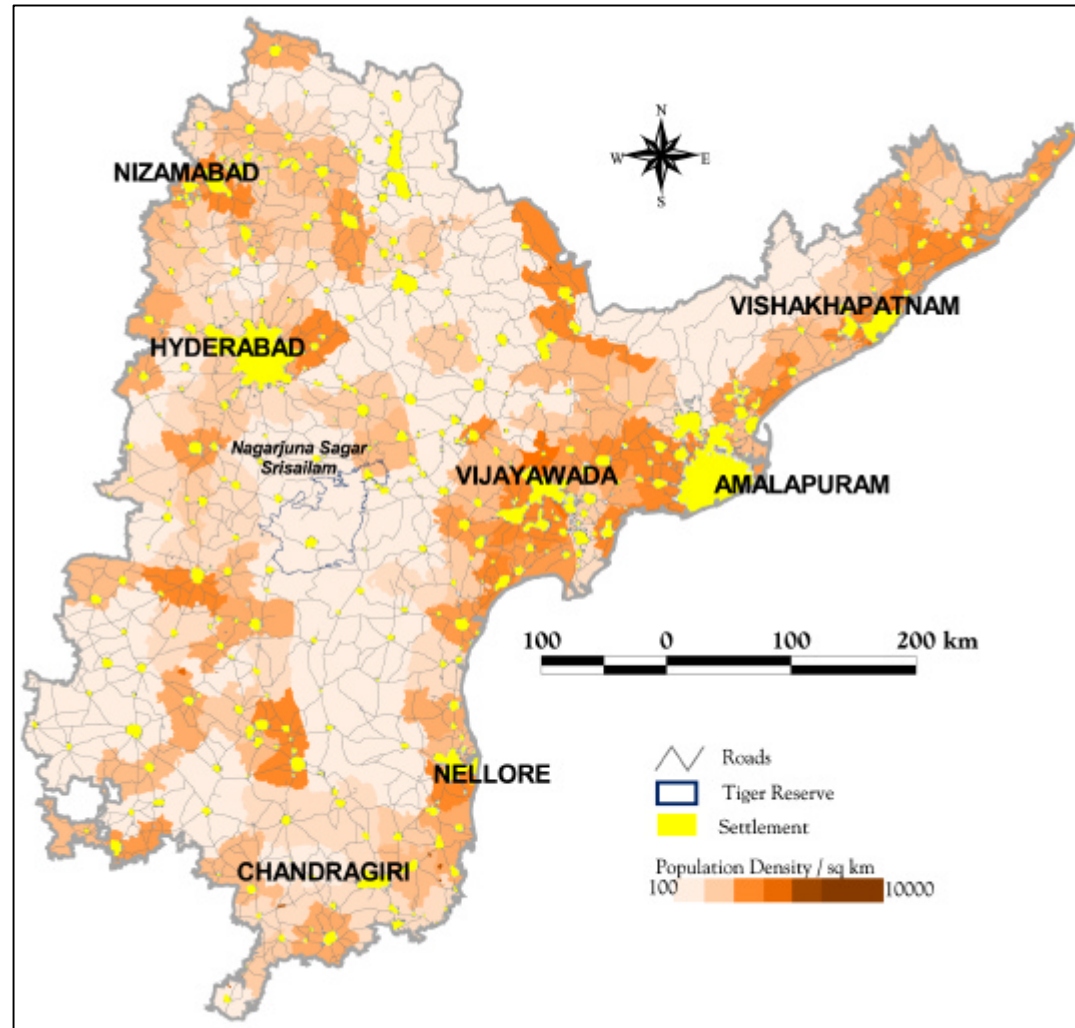
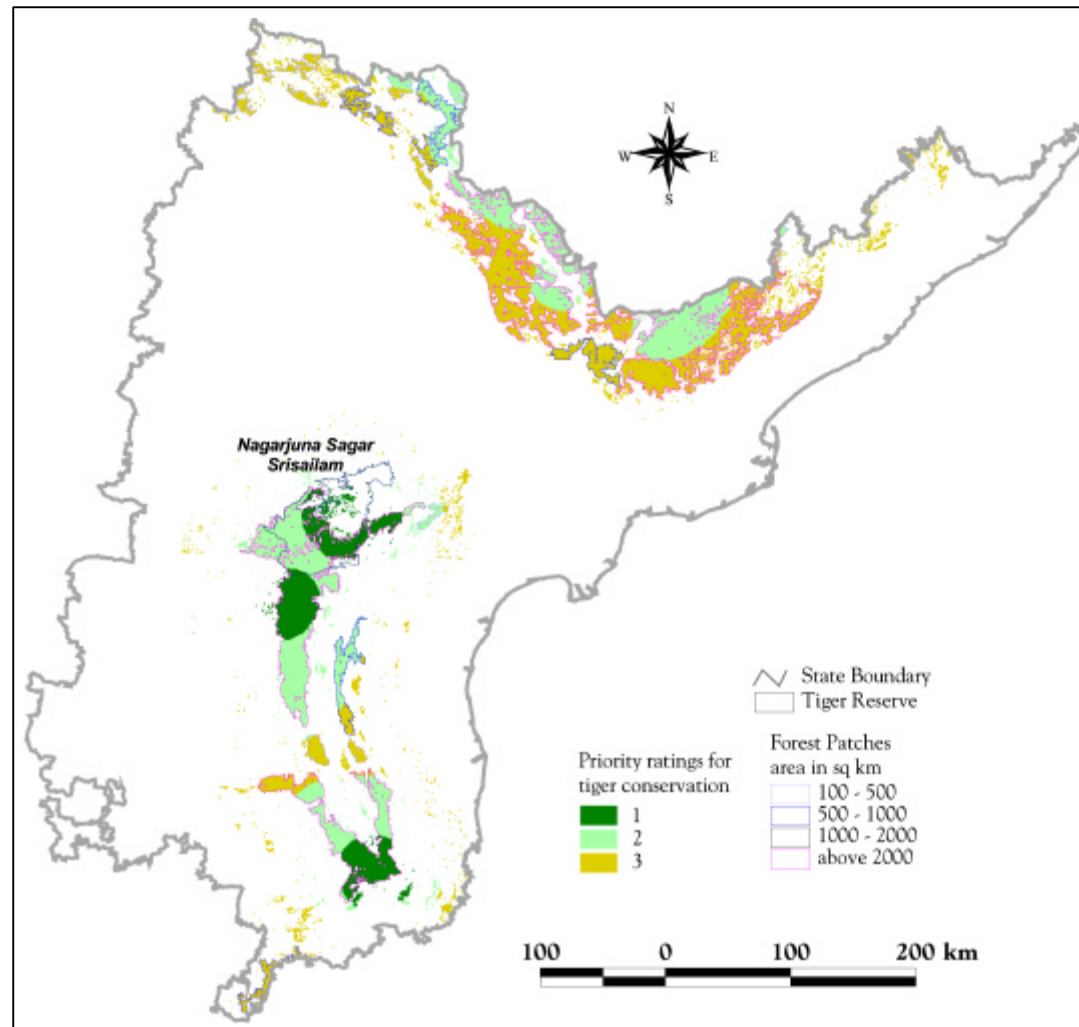


Figure 37 Priority areas within Andhra Pradesh for conservation of tiger source populations and maintaining connectivity



ARUNACHAL PRADESH

Arunachal's position on the boundary of the Palearctic, Chinese, Malayan, and Indian biogeographic regions give this relatively small state a special significance from the conservation perspective. Biogeographic origin, altitudinal diversity and a largely unspoilt forest cover all serve to make Arunachal Pradesh one of the richest areas in India in terms of habitat and community diversity. It falls within the North East hills and Brahmaputra Flood Plains landscape complex of present study.

The state encompasses biomes from tropical grasslands and moist evergreen forest to alpine scrub and permanent snow fields. Floristically there are more than 5000 species of flowering plants, - including 600 species of orchids, 89 species of bamboos, 18 species of canes, 40 species of rhododendrons, 400 ferns, 24 species of gymnosperms and a high number of unexplored algae, fungi, lichens, bryophytes, and micro-organisms. Thus, this eastern Himalayan State harbors more than 33% of the total Indian flora and is the center of origin of number of cultivated plants. Faunistically, the state is rich in having more than 100 mammals, 650 birds, 83 reptiles, 130 fishes and 7 non-human primates along with innumerable species of insects, micro-organisms and other life forms. This rich biodiversity in both flora and fauna have contributed to its recognition as one of the 18 "Biodiversity Hotspots" in the world (NBSAP, 2000).

The state has some of India's finest evergreen forest with fauna that includes tiger, elephant, gibbon, several carnivores, and pheasants. The faunal elements of the state are not homogeneous in their distribution, - the deep river valleys must act as barriers to species dispersal. The high mountain fauna has takin, serow, goral, as well as musk deer and a variety of pheasants. Many species are endemic to Arunachal and some are classified as extremely rare. Recent discoveries of Leaf deer (*Muntiacus putaoensis*, Datta et al. 2003) and Arunachal macaque (*Macacca munzala*) hint at the yet undiscovered biological richness of the state. Arunachal falls in the biotic province East Himalayas, - being the only representative of this province in India.

Such a great diversity of life forms, bio-geographical, ecological and environmental factors has greatly influenced the indigenous people inhabiting the state who are distinguished into 25 tribes and 110 sub-tribes (Rodgers and Panwar 1988).

Population density : 13 km⁻² (**Figure 38**)

Total protected area : 11.82 % (9897.2 km²)

Total forested area : 68186 km² (81% of total geographic area)

Major biogeographic zones : East Himalaya (2B)

Major ecoregions of Arunachal Pradesh:

Eco Regions	Area (sq km.)
Mizoram-Manipur-Kachin rain forests	36.00
Brahmaputra valley semi-evergreen forests	1255.00
Northeastern Himalayan sub alpine conifer forests	1432.00
Eastern Himalayan sub alpine conifer forests	2912.00
Eastern Himalayan alpine shrub and meadows	3040.00
Eastern Himalayan broadleaf forests	5753.00

Temperature range : Minimum average 8° C, Maximum average 34.4° C

Precipitation : Mean 174 cm Range 102 to 438 cm

Tiger Habitat status:

Percentage area of the state in terms of districts from which tigers have become locally extinct : 2%

Forested area of tehsils where tiger is currently reported: 68063 km² (99.82% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 39) (Appendix 7):

Priority I : 12320 km²

Priority II : 47507 km²

Priority III : 4879 km²

Figure 38 Map of Arunachal Pradesh showing distribution of human settlements, tiger reserves and human population densities

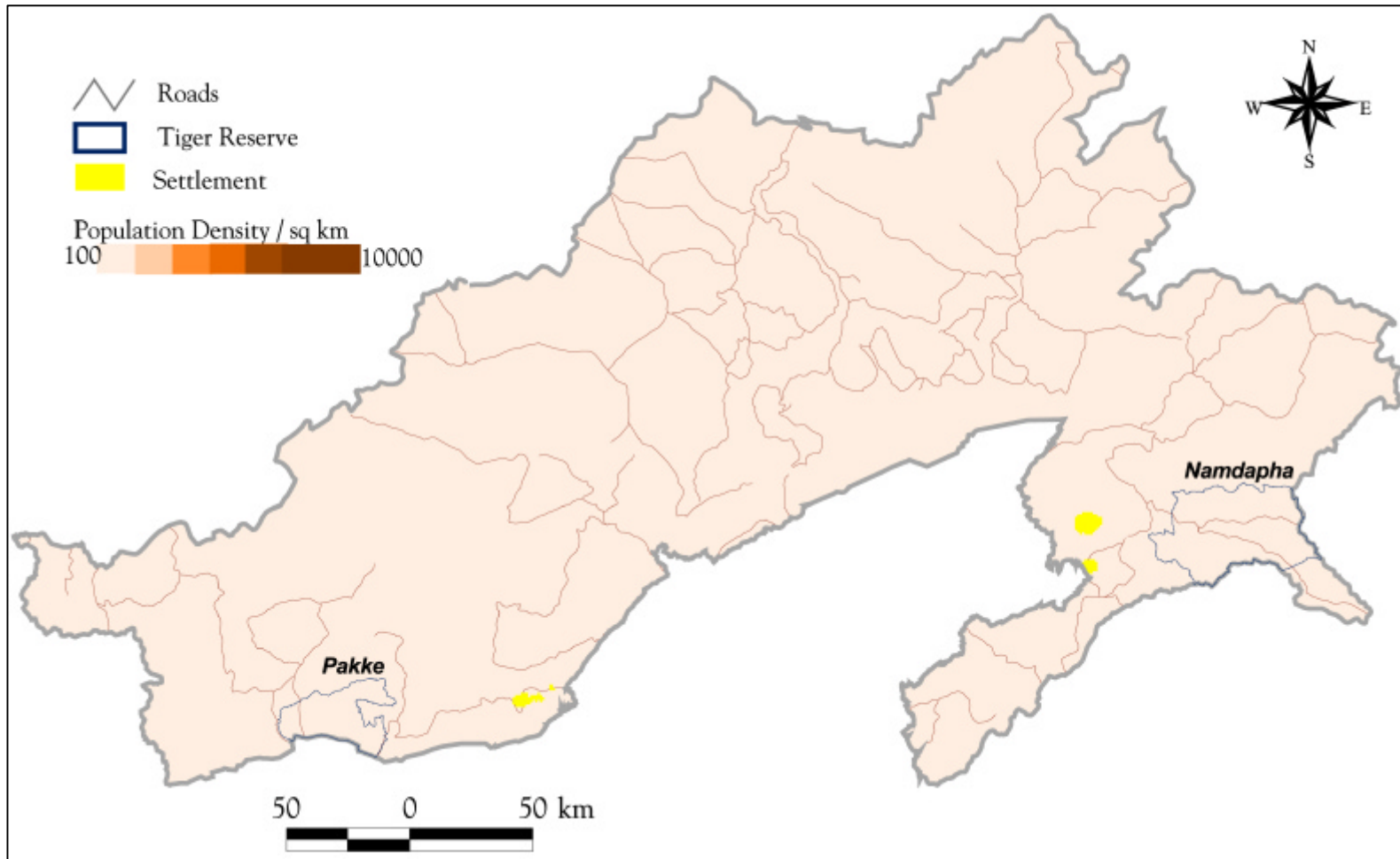
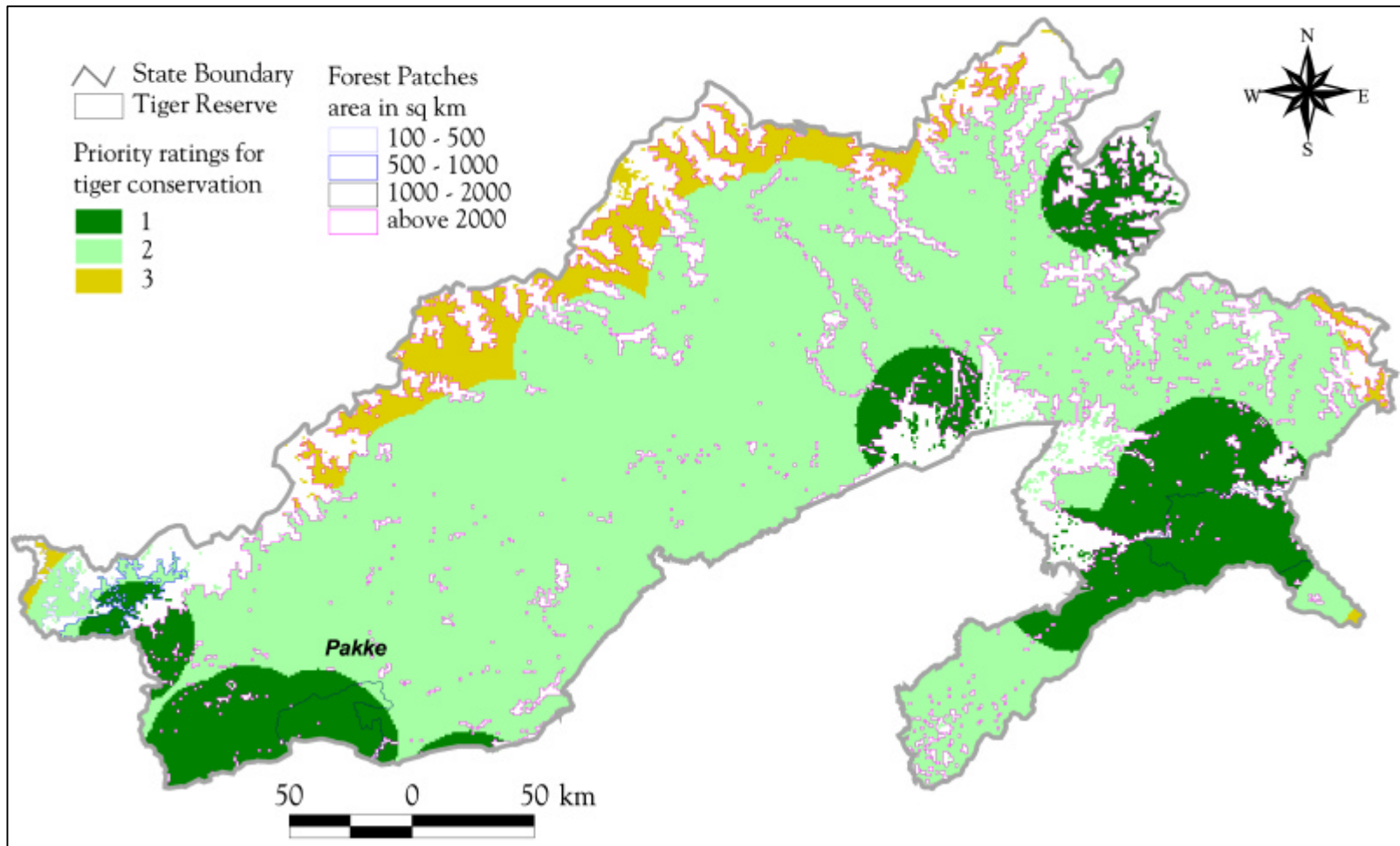


Figure 39 Priority areas within Arunachal Pradesh for conservation of tiger source populations and maintaining connectivity



ASSAM

The state of Assam is the largest part of the biogeographic zone North-East India, which is considered as one of the most biologically diverse areas of all south Asia. The physiographic configuration of Assam is characterized by diverse features such as floodplains, marshes and beels, scattered hillocks, folded hill ranges and old plateaus. The state has two distinct biogeographic components, - the alluvial floodplains of the Brahmaputra River, and the forested hills and valleys of the Cachhar districts; both of which are part of the North East hills and Brahmaputra Flood Plains landscape complex of present study. The state lies in the regime of monsoon climate with a hot and wet summer and a cool and dry winter.

The floral diversity of Assam is astonishing, - although due to incomplete reporting from certain areas like North Cachar hills, parts of Tinsukia district that contains patches of tropical rain forest and parts of Kokrajhar district, the exact number of species in Assam still remains uncertain. However, the available records and enumeration lists suggest that there are 3017 species of flowering plants. Assam houses quite a good number of medicinal plants including several rare, endangered and endemic species. The state is also rich in bamboo diversity, where 10 genera and 42 species can be found. In the case of cane, the total number of species reported stands at 14.

Orchids belonging to the family Orchidaceae are one of the largest groups of flowering plants. North east India claims the largest share in the world with about 72% species that covers around 825 species under 145 genera. Besides, the problem of grazing, some unplanned human activities and interference through collection for ornamental, medicinal and commercial purposes, many terrestrial and saprophytic orchids are now on the verge of extinction. In Assam, about 192 species of orchids are distributed in the plains and hilly areas. A large part of Assam is covered by wetlands rich in both flowering and non flowering plants. The rural communities rely upon the wetlands for various purposes and harvest a variety of products like fish, fodder, food items etc. (NBSAP, 2000).

About 193 species of mammals and more than 958 species and subspecies of birds are so far reported from Assam. The state possesses 16 important wildlife areas, which house nearly 44 types of endangered and rare species of mammals and 14 types of reptiles and amphibia. Altogether 230 forms of mammals including species and sub-species have been recorded so far from Assam. There are 14 species of primates in Assam, which constitute 1/6th of the total primate species of the world. As many as 19 cat families are reported to be found in the state. Moreover, Assam holds the entire known world population of Pigmy hog, 75% of the world population of the Indian rhinoceros and Wild water buffalo and a sizable population of Asian elephants and tigers.

Biogeographically, the floodplains contain example of a grazing community once widespread in northern India, e.g. rhinoceros and swamp deer. The Brahmaputra valley has a variety of

floodplain biomes ranging from open swamp to grasslands, from tree swamps to deciduous, semi evergreen and evergreen forest. The grazing community contains elephant, rhinoceros, wild buffalo, swamp deer, hog deer, pygmy hog (*Sus salvanius*) and hispid hare besides the Bengal florican (*Houbaropsis bengalensis*). The swamps have important waterfowl communities. North of the river there is the golden langur in and around Manas tiger reserve. South of the river there is the hoolock gibbon in evergreen forests as well as elephants, tigers, gaur, and a diverse community of lesser cats.

The Assam hills province with a mixture of evergreen, deciduous and subtropical forests is botanically extremely rich and contains significant primate, carnivore and bird communities. The hills have a botanically distinct evergreen forest, which shows a gradation to subtropical and temperate forests. Elephant, tiger, lesser cats, gaur, sambar, barking deer, gibbon, pheasants, hornbills and a profusion of orchids are characteristic

The proximate causes of biodiversity loss in the state include (i) population growth and density, (ii) habitat destruction caused by anthropogenic factors, (iii) overgrazing, (iv) poaching, (v) flood and bank erosion, (vi) application of agrochemicals, (vii) biopiracy and (viii) political problems. (Rodgers and Panwar 1988).

Population density : 340 km⁻² (**Figure 40**)

Total protected area : 4.98 % (3909.8 km²)

Total forested area : 27938 km² (36% of total geographic area)

Major biogeographic zones: 1. North East (Brahmaputra Valley (9A) & North East Hills (9B))

Major ecoregions of Assam:

Eco Regions	Area (sq km)
Eastern Himalayan broadleaf forests	115
Lower Gangetic plains moist deciduous forests	389
Mizoram-Manipur-Kachin rain forests	2606
Meghalaya subtropical forests	6221
Brahmaputra valley semi-evergreen forests and Terai-Duar savanna and grasslands	10198

Temperature range : Minimum average 8° C, Maximum average 34.4° C

Precipitation : Mean 224 cm Range 181 to 313 cm

Tiger Habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 4%

Forested area of tehsils where tiger is currently reported: 25635 km² (91.76% of forested area) (**Appendix 7**)

Areas for tiger conservation priority (Figure 41) (Appendix 7):

Priority I : 4352 km²

Priority II : 16007 km²

Priority III : 6345 km²

Figure 40 Map of Assam showing distribution of human settlements, tiger reserves and human population densities

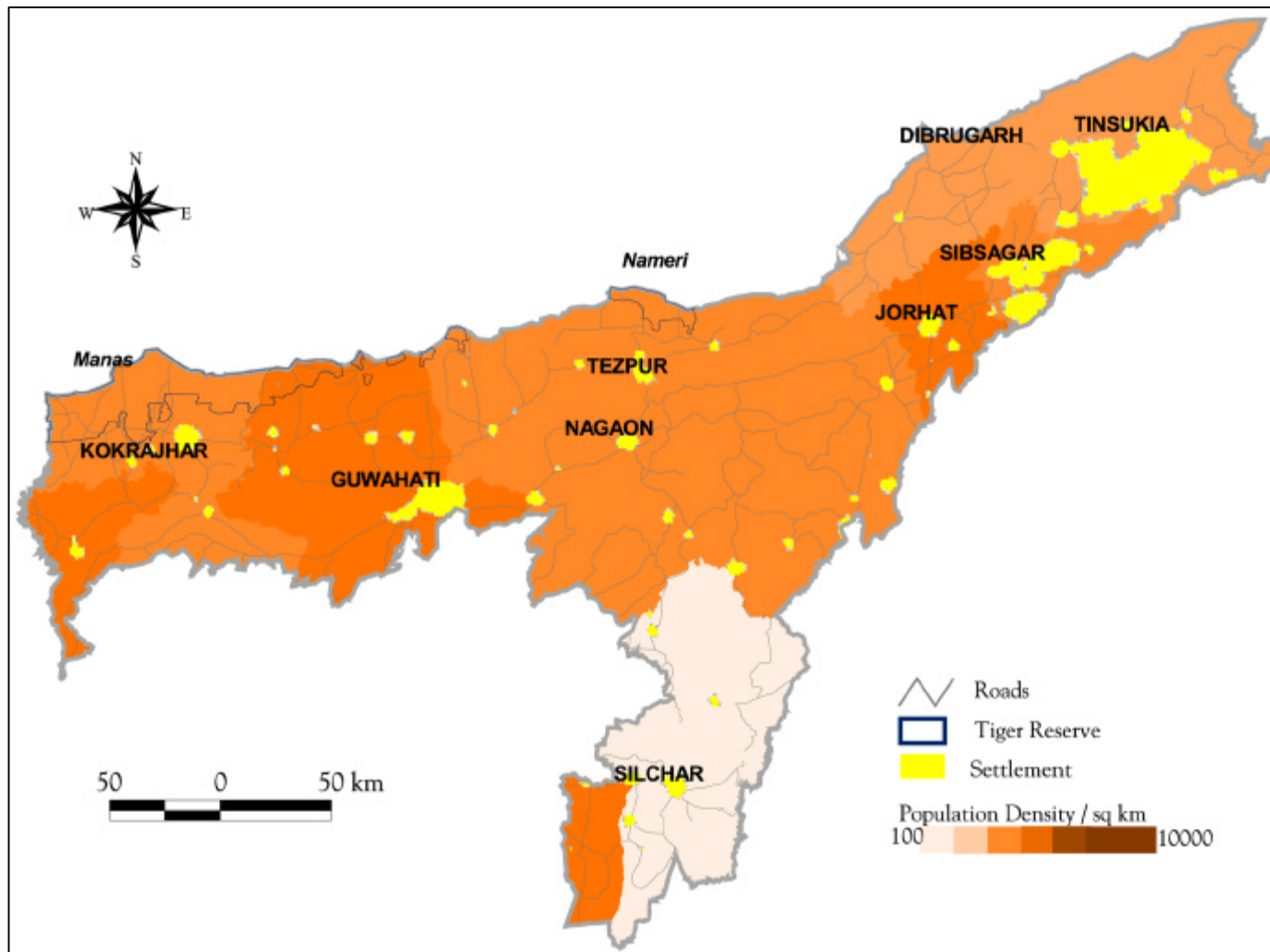
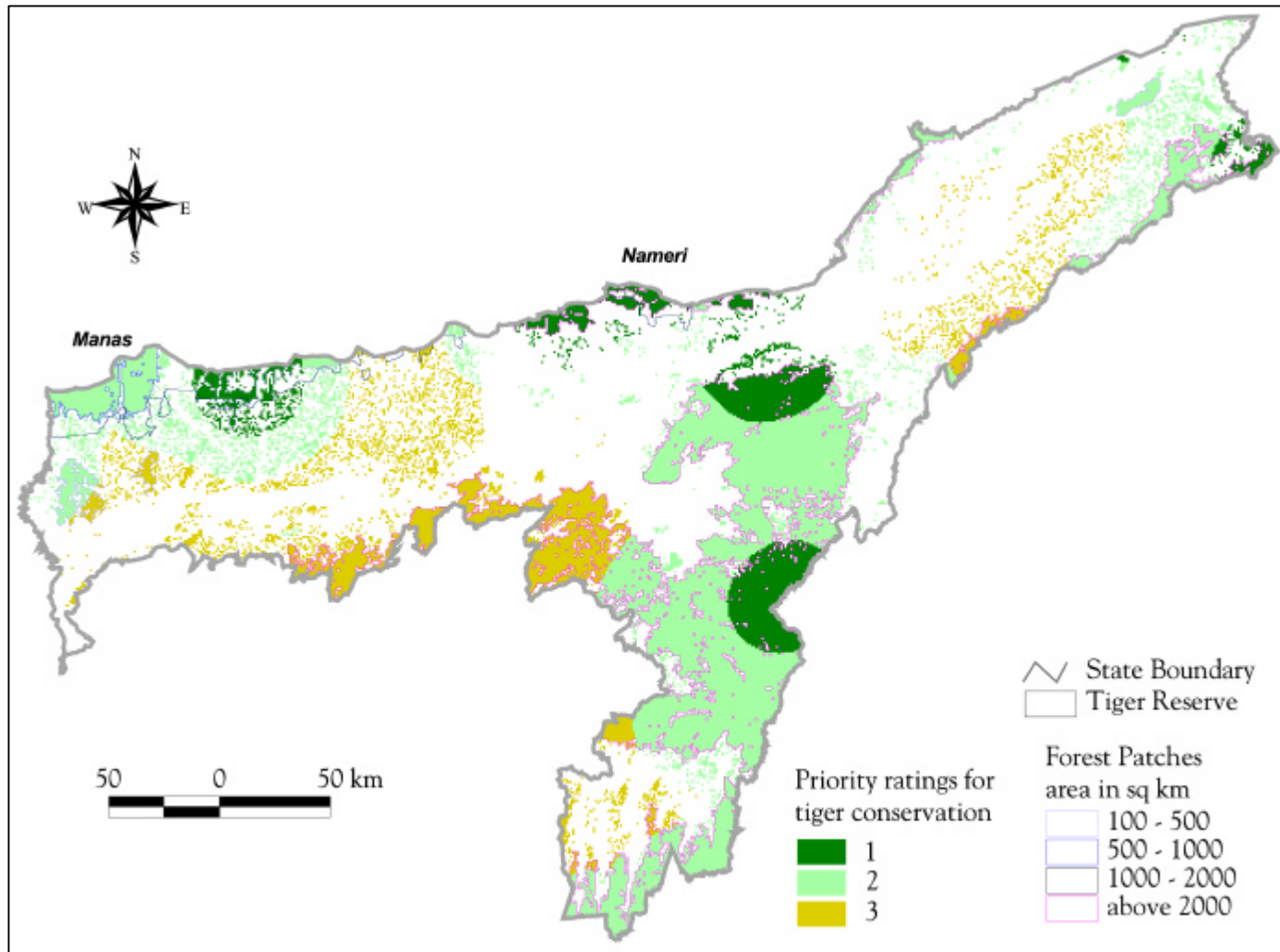


Figure 41 Priority areas within Assam for conservation of tiger source populations and maintaining connectivity



BIHAR

The state of Bihar falls in the biogeographic province of lower gangetic plain, further sub divided into northern Shivalik hills and southern flat plains. While the northern hills (part of Shivalik – Gangetic Plains landscape complex) still harbour wildlife of value, the plains (part of Central India landscape complex) are now densely settled. The Bhabar forests of north Bihar are adjacent to the Chitwan conservation areas of Nepal. The area still has a good tiger population and probably did once have rhinos and elephants. The Gandak River still has a low density gharial population.

There are about 250 rare plant species in the state including *Abrus pulchellus*, *Alysicarpus pubescens*, *A. hamosus*, *Crotalaria acicularis*, *Derris cuneifolia*, *Rhynchosia cana*, *Tacca leontopetaloides*, *Orobancha cernua*, *Brachiaria kurzii*, *Cynodon arcuatus*, *Leea alata*, *Drosera indica*. Orchids are mainly represented by *Zeuxine strateumatica*, *Vanda testacea* and *V. tessellata*. Significant weedy species introduced in the state include *Alternanthera paronychioides*, *A. philoxeroides*, *A. pungens*, *A. tenella*, *Chromolaena odorata*, *Euphorbia helioscopia*, *Parthenium hysterophorus*, *Rumex ambrosioides* and *Solanum viarum*, *Peperomia pellucida*, *Rumex spp.* Four genera of bamboo are indigenous or cultivated in Bihar. Most common species are *Bambusa balcoa*, *B. nutans*, *Dendrocalamus strictus* and endemic species is *Dendrocalamus sericeus*, which needs ex-situ conservation (NBSAP, 2000).

Gorgon nut or Fox nut commonly known as Makhana (*Euryale ferox Salibs*) of the family Nymphaeaceae is an unique, highly nutritious, non cereal food, which is extensively grown in the stagnant water of wetlands in Bihar. The state accounts for over 80% of makhana production of the country (NBSAP, 2000).

The plains themselves support a dense human population and natural vegetation is scarce and restricted to areas still non-cultivable. The flooded oxbow lakes and depressions are of international significance for waterfowl, and Bihar and adjacent west Bengal are part of a major flyway for migratory ducks. The larger rivers have turtles, fish and Gangetic dolphin (*Platanista gangetica*). The aquatic biodiversity of rivers like Ganges and Kosi has other significant values too. 175 species of algae, 50 of zooplankton, 33 of invertebrates, 89 species of fishes and about 30 species of other vertebrates are reported from these river systems. But these species have been increasingly threatened by habitat alteration and fragmentation due to construction of barrages, highways, road network, dams, over harvesting, indiscriminate killing of brood and juvenile fishes, pollution and introduction of alien species.

Challenges before the state include preventing the poaching of migratory waterfowl, cease the encroachment of agriculture into forested lands, stop cross-border smuggling of wildlife

products to Nepal and improve the management of existing Protected Areas (Rodgers and Panwar 1988).

Population density : 880 km⁻² (Figure 42)

Total protected area : 3.5 % (3284.8 km²).

Total forested area : 5842 km² (6% of total geographic area)

Major biogeographic zones : 1. Deccan Peninsula (Central Highlands (6A) & Chhatta-Nagpur (6B) and 2. Lower Gangetic Plain (7B)

Major ecoregions of Bihar:

Eco region	Area (sq km)
Upper Gangetic plains moist deciduous forests and Terai-Duar savanna and grasslands	50
Himalayan subtropical broadleaf forests	199
Chhota-Nagpur dry deciduous forests	1522
Lower Gangetic plains moist deciduous forests	2299

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 125 cm Range 80 to 173 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 75%

Forested area of tehsils where tiger is currently reported: 965 km² (16.5% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 43) (Appendix 7) :

Priority I : 604 km²

Priority II : 227 km²

Priority III : 35 km²

Figure 42 Map of Bihar showing distribution of human settlements, tiger reserves and human population densities

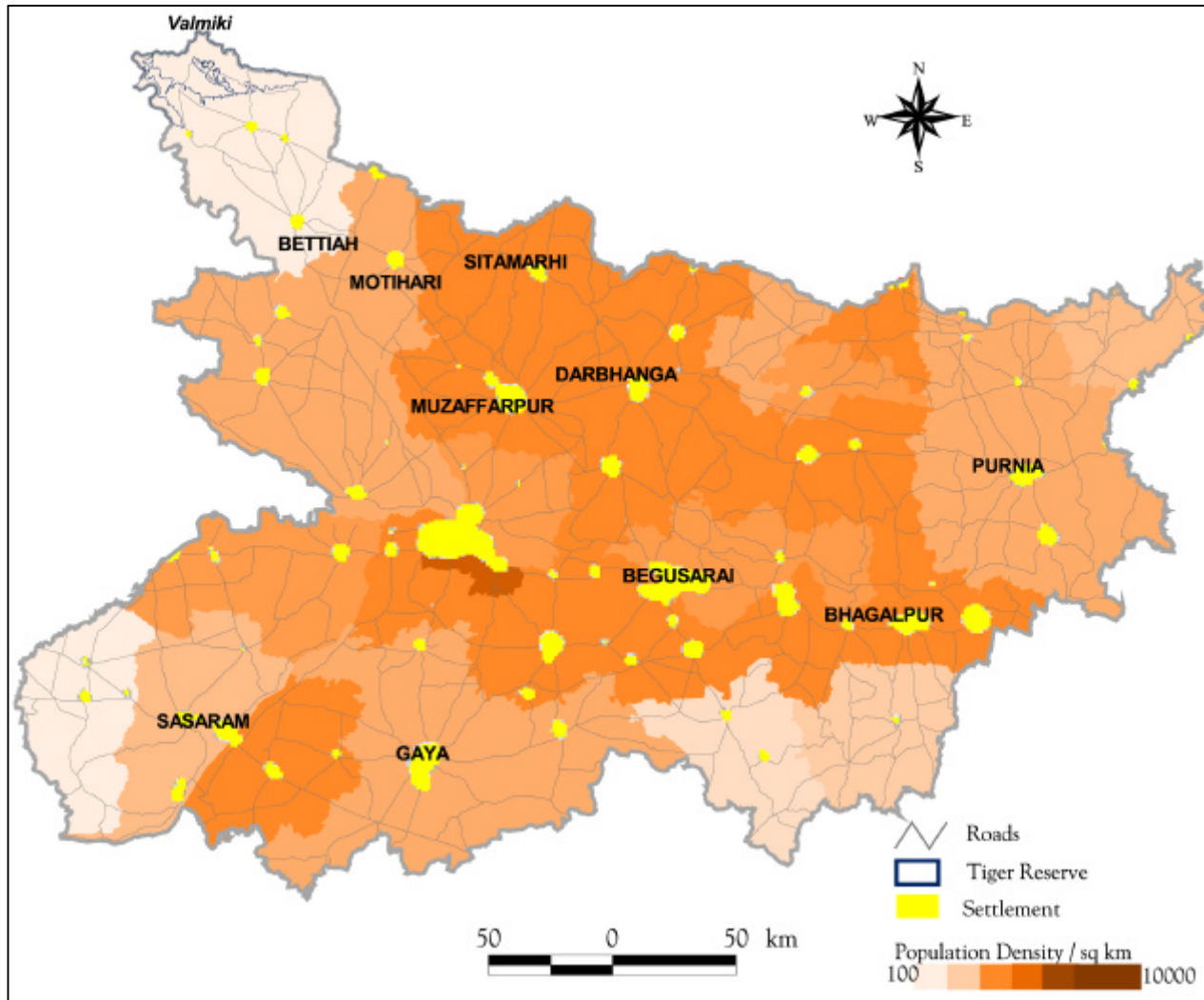
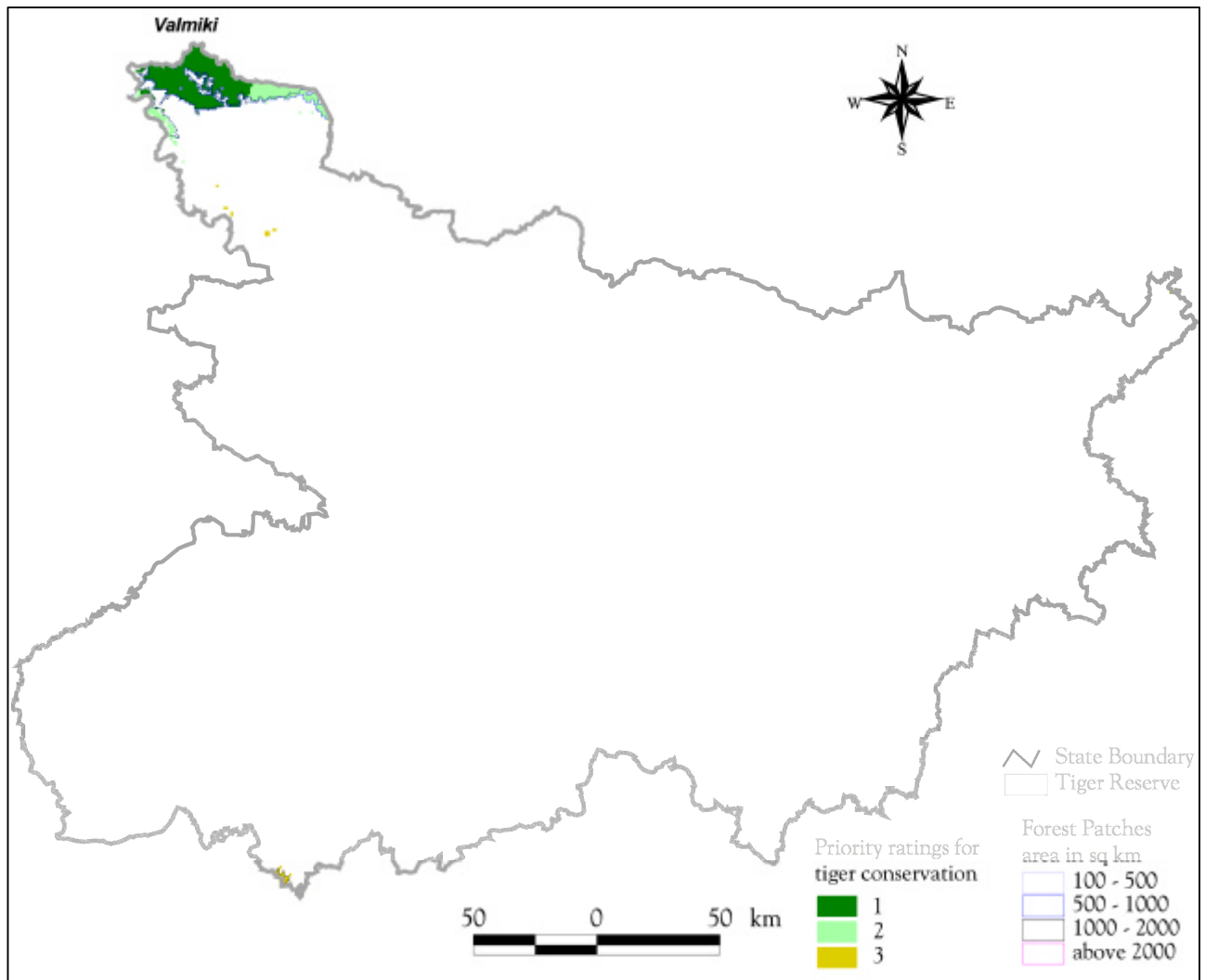


Figure 43 Priority areas within Bihar for conservation of tiger source populations and maintaining connectivity



CHATTISGARH

Chhatisgarh is endowed with a relatively high forest cover harbouring wildlife resources of significant values. The forests are principally dry and moist deciduous forests, with small areas of semi evergreen forest in the moister eastern side. Sal (*Shorea robusta*) and Teak (*Tectona grandis*) are two major tree species in the State dominating most of its forested landscape. Other notable overwood species are Bija (*Pterocarpus marsupium*), Saja (*Terminalia tomentosa*), Dhawra (*Anogeissus latifolia*), Mahua (*Madhuca indica*), and Tendu (*Diospyros melanoxylon*) etc. Aonla (*Emblica officinalis*), Karra (*Cleistanthus collinus*) and Bamboo (*Dendrocalamus strictus*) constitute a significant chunk of the middle canopy.

Unlike most states in India, it has a reasonably good distribution of PAs providing refuge to areas representative of the state's ecological diversity. Biogeographically, it falls within the biotic provinces Eastern highlands and Chhota Nagpur plateau (included in the Central India landscape complex of present study), - both historically rich areas supporting healthy populations of their respective faunal elements. The representative fauna of Central India including the Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Gaur (*Bos gaurus*), Sambhar (*Cervus unicolor*), Chital (*Axis axis*), Nilgai (*Boselaphus tragocamelus*) and Wild Boar (*Sus scrofa*) constitutes the conspicuous large mammals. The State also boasts of rare and endangered wildlife like a relict population of Wild Buffalo (*Bubalus bubalis*) and Hill Myna (*Gracula religiosa*) (Rodgers and Panwar 1988).

Population density : 154 km⁻² (**Figure 44**)

Total protected area : 4.7 % (6338.63 km²)

Total forested area : 56648 km² (42% of total geographic area)

Major biogeographic zones : Deccan Peninsula (Central Highlands (6A), Chotta-Nagpur (6B) & Eastern Highlands (6C))

Major ecoregions of Chattisgarh:

Eco Region	Area (sq km)
Narmada Valley dry deciduous forests	593
Northern dry deciduous forests	1495
Central Deccan Plateau dry deciduous forests	2145
Chhota-Nagpur dry deciduous forests	2578
Eastern highlands moist deciduous forests	29525

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 123 cm Range 87 to 172 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 41%

Forested area of tehsils where tiger is currently reported: 27967 km² (49.4% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 45) (Appendix 7):

Priority I : 6016 km²

Priority II : 20650 km²

Priority III : 21505 km²

Figure 44 Map of Chhattisgarh showing distribution of human settlements, tiger reserves and human population densities

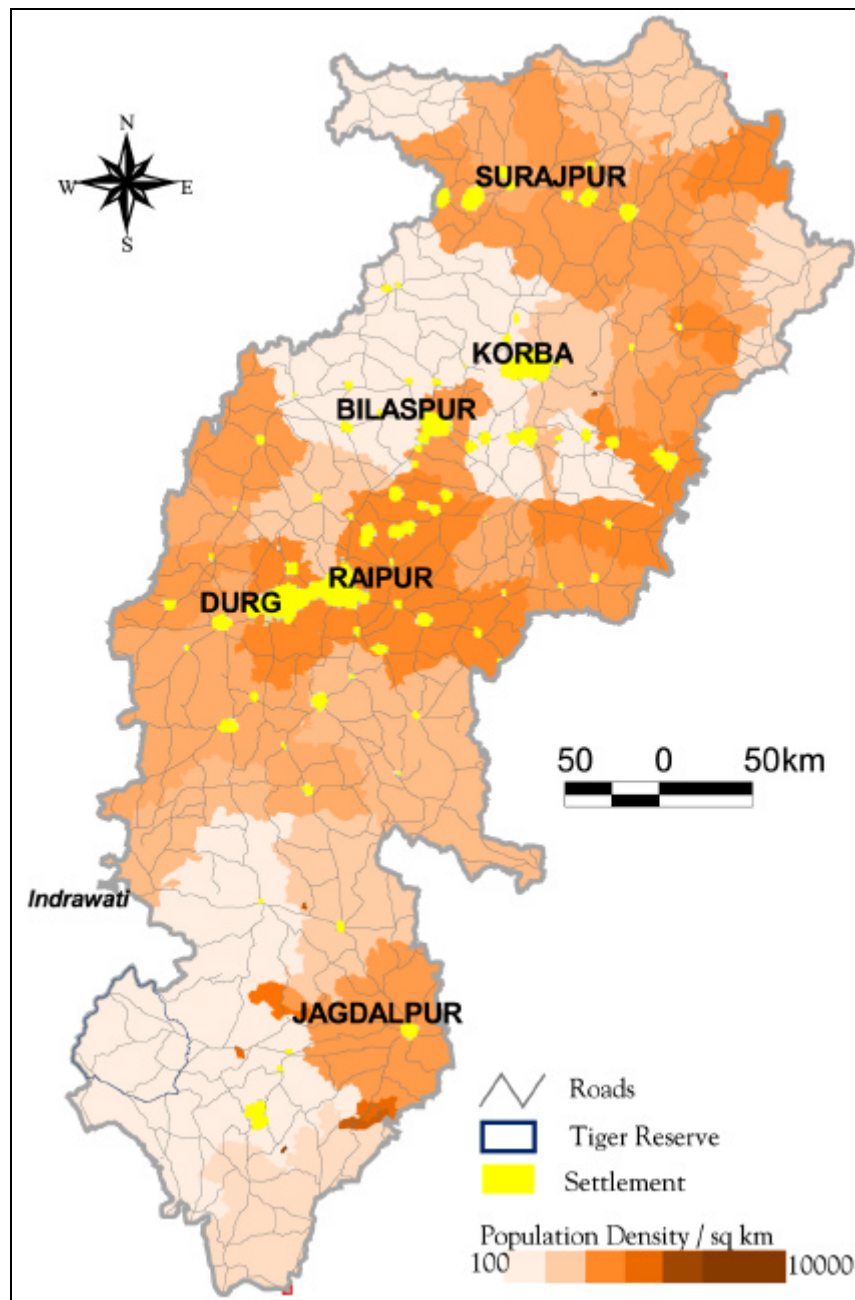
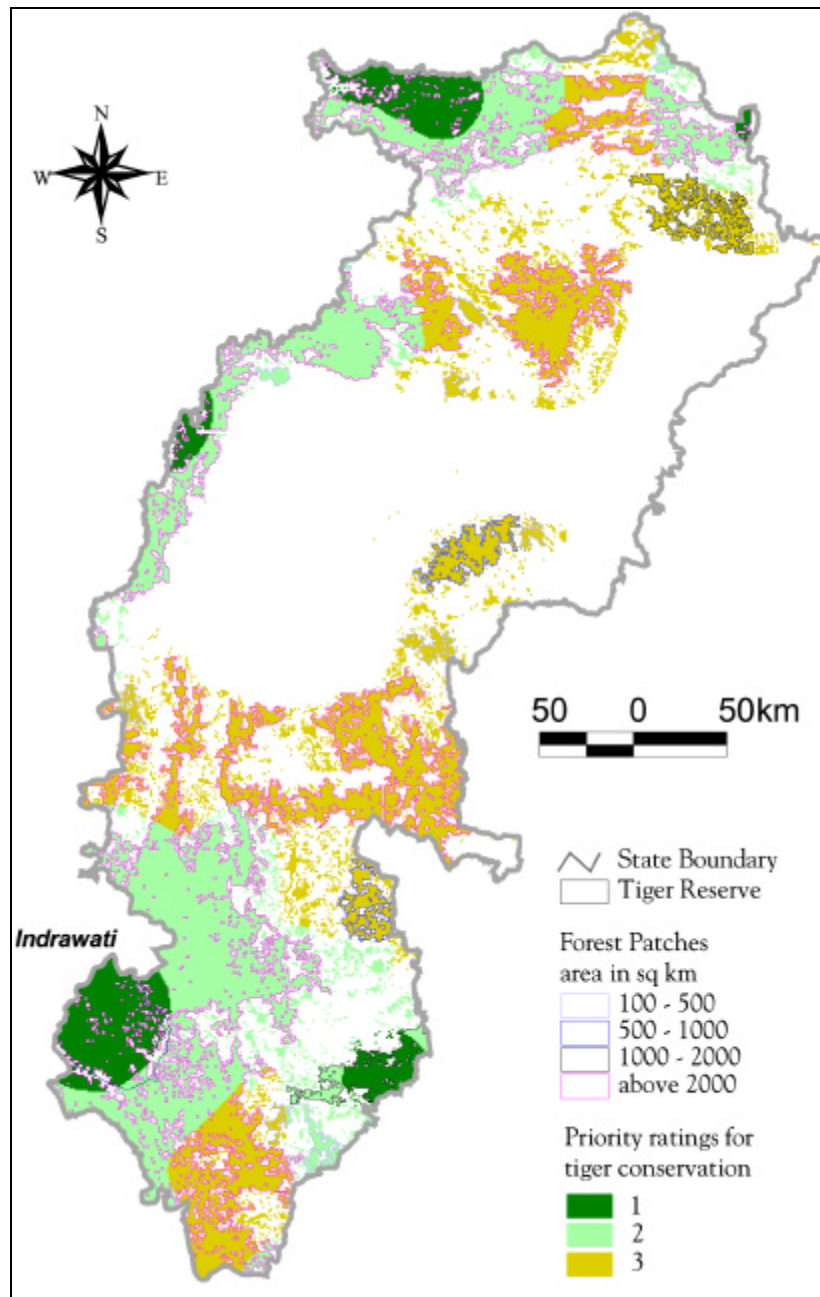


Figure 45 Priority areas within Chhattisgarh for conservation of tiger source populations and maintaining connectivity



JHARKHAND

Jharkhand falls within the wildlife rich biotic provinces of Central Highlands and Chota Nagpur Plateau, - part of the Central India landscape complex of present study. The relatively small state of Jharkhand is endowed with much biological and conservation values by virtue of its large, somewhat connected forest tracts and overall high proportion of forest cover. Nearly all the forest cover is deciduous in summer except in ravines and along streams. In the moist valleys and ravines on the northern face of the Rajmahal hills, the forest cover is fairly dense during monsoon months comprised of annual as well as perennial species. A few pockets in the state exhibit vegetation of xerophilous nature.

The Chota Nagpur forests have what some authorities consider to be the finest Sal forest in the country. *Shorea robusta* (Sal) is the principal tree species with a number of codominants like *Terminalia alata*, *Anogeissus latifolia*, *Careya arborea* and *Pterocarpus marsupium*. *Shorea robusta* and *Terminalia alata* associated with *Buchanania lanzan* (*chiraunji*), *Bridelia squamosa* and *Mallotus philippensis* (*sinduri*) occur almost throughout the area. Most common bamboo species in Jharkhand are *Bambusa balcoa*, *B. nutans*, *Dendrocalamus strictus* and an endemic species is *Dendrocalamus sericeus*, which needs ex-situ conservation.

The State is also rich in a large number of economically useful plants. The tribal populace depends upon plants like mahua, date palm, toddy palm, (country liquor, fan, mat, roof top), bamboo, *Bauhinia* (mat, basket and craft), bhelwa (fabric marker), palash, *Woodfordia fruticosa*, *sinduri* (dyes), *Casearia elliptica* (fish poison), *nirgundi*, *Ocimum* (insecticide) for their domestic use and livelihood. They collect and use medicinal plants like *Rauvolfia serpentina* (*sarpangandha*), *Tinospora cordifolia* (*guruchi*), *Helicteres isora* (*marorphali*), *Abrus precatorius* (*Ratti*), *Adhatoda zeylanica* (*vasaka*).

The moist and dry deciduous forests have tiger, leopard, elephant, gaur and other herbivore populations. However, exploitation of the rich mineral resources of the state continues to be a threat to the integrity of these wildlife habitats (Rodgers and Panwar 1988).

Population density : 338 km⁻² (**Figure 46**)

Total protected area : 2.63 % (2094.4 km²)

Total forested area : 23613 km² (30% of total geographic area)

Major biogeographic zones : 1. Deccan Peninsula (Chotta-Nagpur (6B)) and 2. Lower Gangetic Plain (7B)

Major ecoregions of Jharkhand :

Eco Region	Area (sq km)
Lower Gangetic plains moist deciduous forests	172
Eastern highlands moist deciduous forests	2881
Chhota-Nagpur dry deciduous forests	18295

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 133 cm Range 95 to 179 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 52%

Forested area of tehsils where tiger is currently reported: 8150 km² (34.5% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 47) (Appendix 7):

Priority I : 2623 km²

Priority II : 4487 km²

Priority III : 5143 km²

Figure 46 Map of Jharkhand showing distribution of human settlements, tiger reserves and human population densities

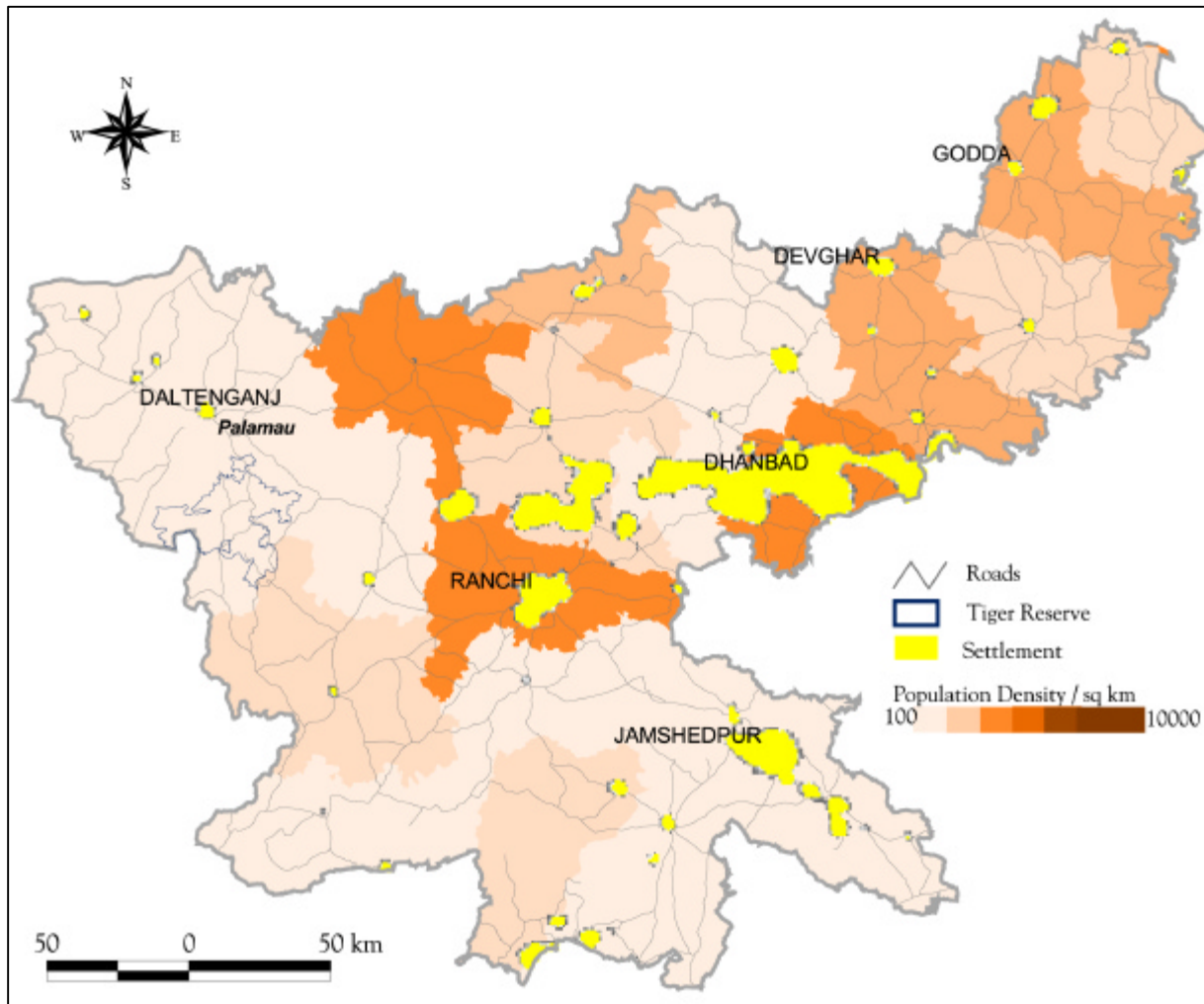
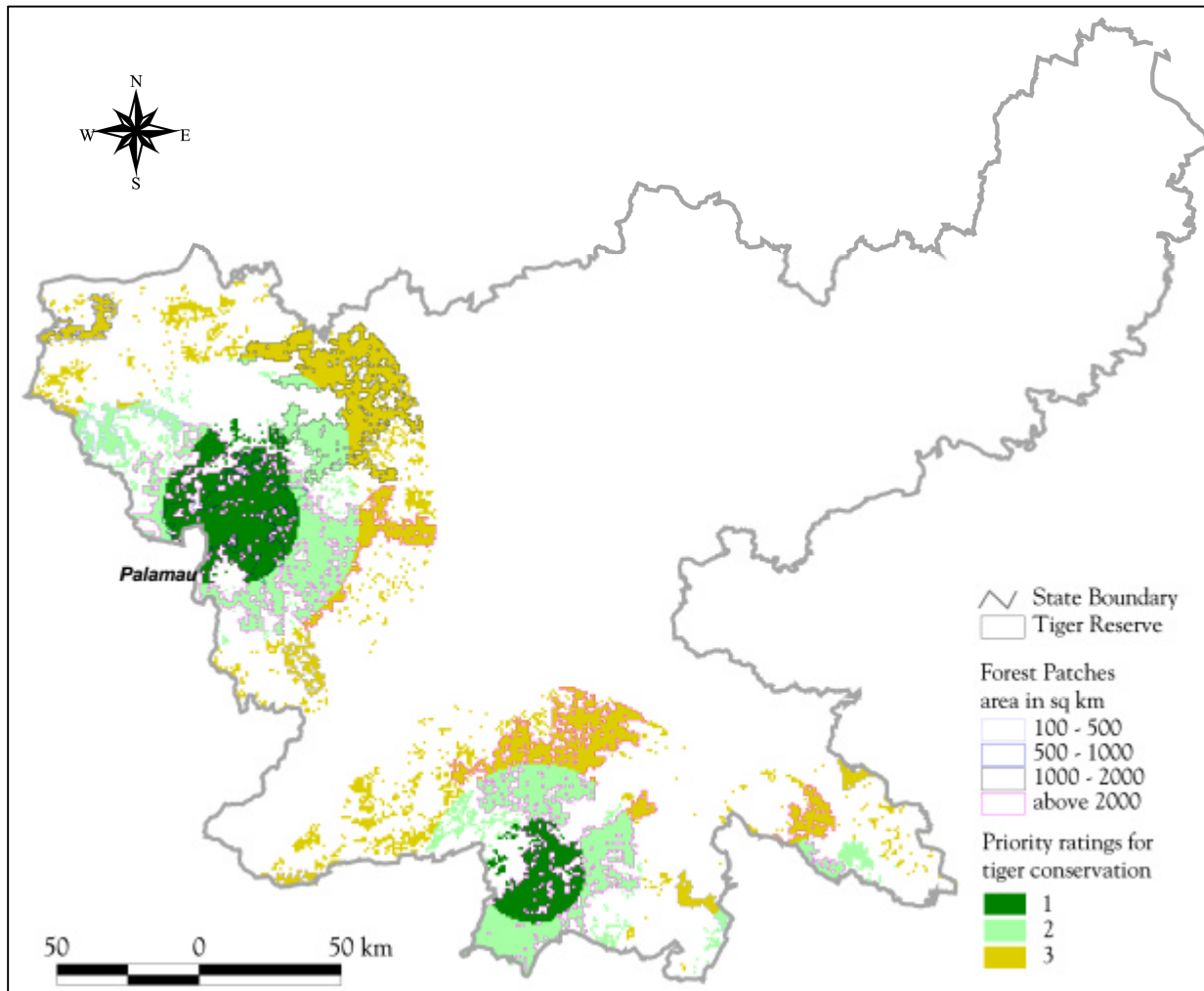


Figure 47 Priority areas within Jharkhand for conservation of tiger source populations and maintaining connectivity



KARNATAKA

The state of Karnataka safeguards a considerable portion of the nation's wildlife values, - both in the moist parts of the central western ghats and in the drier areas of the Deccan peninsula and Malabar plains. Large parts of the Western Ghats landscape complex of the present study fall within its peripheries. Topographically Karnataka shows 3 broad zones, viz., the narrow coast, the rising hills, and the flatter, elevated eastern zone that merges with the Deccan Plateau. The coastal zone is the most thickly populated. The hill chains of the Western Ghats, which run in the north-south direction, are precipitous towards their western aspect. At few points in the state, the hills run right into the sea, interrupting the continuity of the sea beaches, and providing ample rocky inter-tidal and subtidal habitats with their unique flora and fauna. The coastal region is unique where saline water intrusion is present within mangrove ecosystems. In this region sustainable traditional prawn cultivation is practiced. Forty five zooplankton species from the Karwar coast and 14 species of bivalves from the Aghanasihini river estuary (unique to the west coast) are reported. Karnataka has a tropical climate with a well-defined rainy season between June and October, when the South-west Monsoon winds bring down a lot of rain.

The Western Ghats are a biological treasure house with a variety of species rich forest communities, as well as being a major supplier of water, and hence power to southern India. Many species are endemic to the ghats, some are rare and restricted to small localities. Forest communities change with altitude, aspect (east and west faces of the ghats) and latitude, therefore forests of the state show a wide range of communities.

The biological riches of the Western Ghats have drawn attention away from the values of the dry deciduous and thorn forest communities in the east of the state. The hills of south Karnataka form the link between the western and eastern ghats, and still allow some wildlife movement, e.g. of elephants. The southern forests contain a variety of plant communities, while the isolated tracts of northern Karnataka maintain small open forest faunal assemblages. Faunal values include elephants, tigers, leopards, the endangered mammal Lion-tailed macaque and over 25 species of bats.

Wildlife, including of game-birds, was earlier plentiful. But habitat changes under aggressively practiced state forestry and the promotion of sports hunting by British marksmen and local *shikaris* saw the depletion of wildlife by the end of 19th century. At the same time hunting for crop protection and wild meat by the locals was severely regulated. The traditional pre-British period of forest management was village centered. Watershed forest such as the *kan* formed the heart and heritage centre of almost every village, more so in the hilly country. These *kans* were community heritage centres and were also rich in

biodiversity as their relics show to this day. The state-centred timber forestry basically lacked such traditional watershed based approach, with very undesirable consequences (NBSAP, 2000).

There are numerous varieties of wild fruits that are used by forest dwellers. These include wild mangoes, kokum, *uppage* jackfruits, jujube, black berries (*neerilu*), gooseberries etc. These are on the decline due to the decrease in forest diversity (Rodgers and Panwar 1988).

Population density : 275 km⁻² (**Figure 48**)

Total protected area : 3.32 % (6360.3 km²).

Total forested area : 40236 km² (21% of total geographic area)

Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B)), 2. Deccan Peninsula (Central Plateau (6D) & Deccan South (6E)) and 3. West Coast (8A)

Major ecoregions of Karnataka:

Eco region	Area (sq km)
Central Deccan plateau dry deciduous forests	239
South Western Ghats moist deciduous forests	937
South Western Ghats montane rain forests	2438
Malabar coast moist forests	3234
North Western Ghats moist deciduous forests	3743
South Deccan plateau dry deciduous forests	4537
Deccan thorn scrub forests	7957
North Western Ghats montane rain forests	10166

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation : Mean 157 cm Range 54 to 410 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 33%

Forested area of tehsils where tiger is currently reported: 15539 km² (38.6% of forested area) (**Appendix 7**)

Areas for tiger conservation priority (Figure 49) (Appendix 7):

Priority I : 6587 km²

Priority II : 17595 km²

Priority III : 4955 km²

Figure 48 Map of Karnataka showing distribution of human settlements, tiger reserves and human population densities

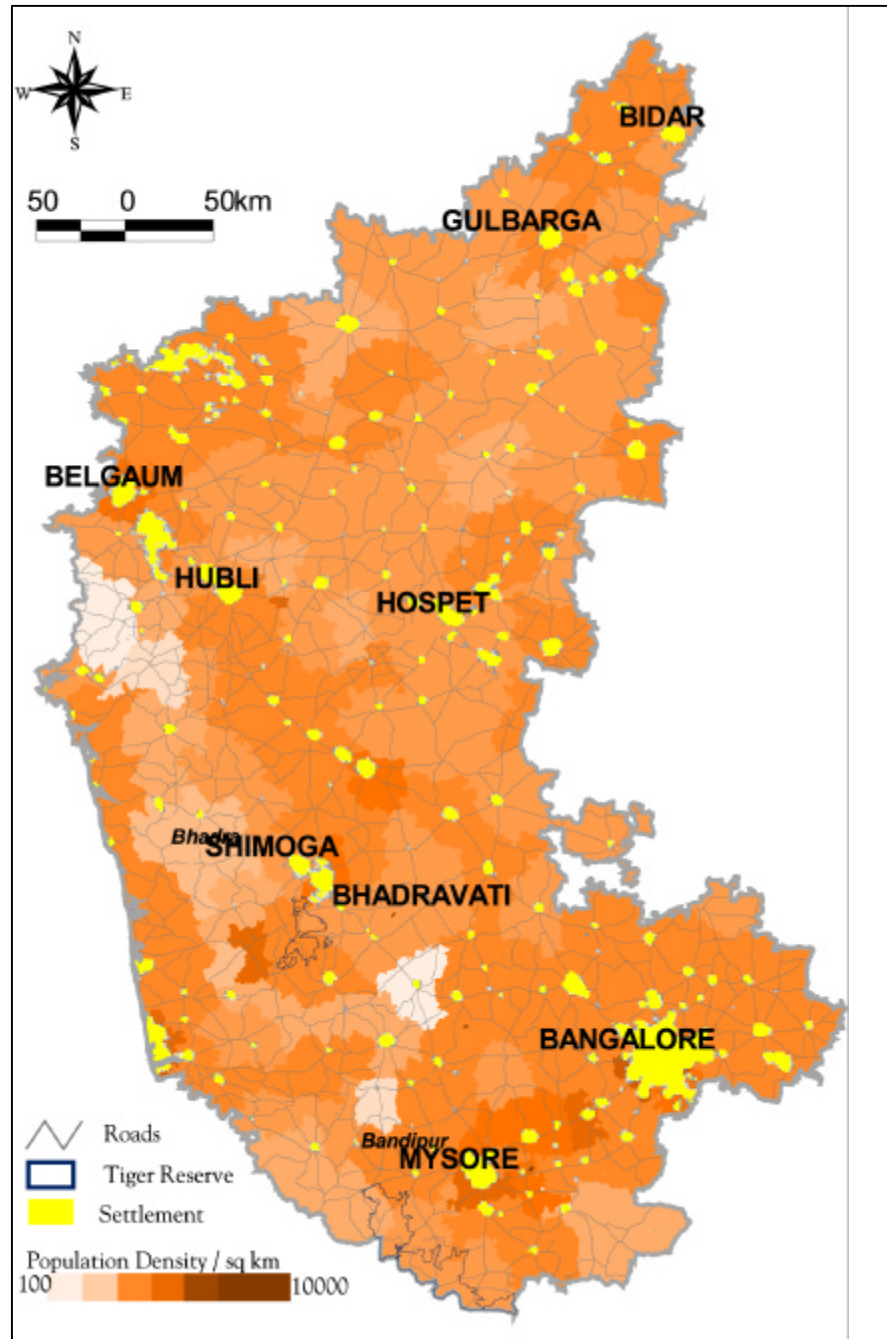
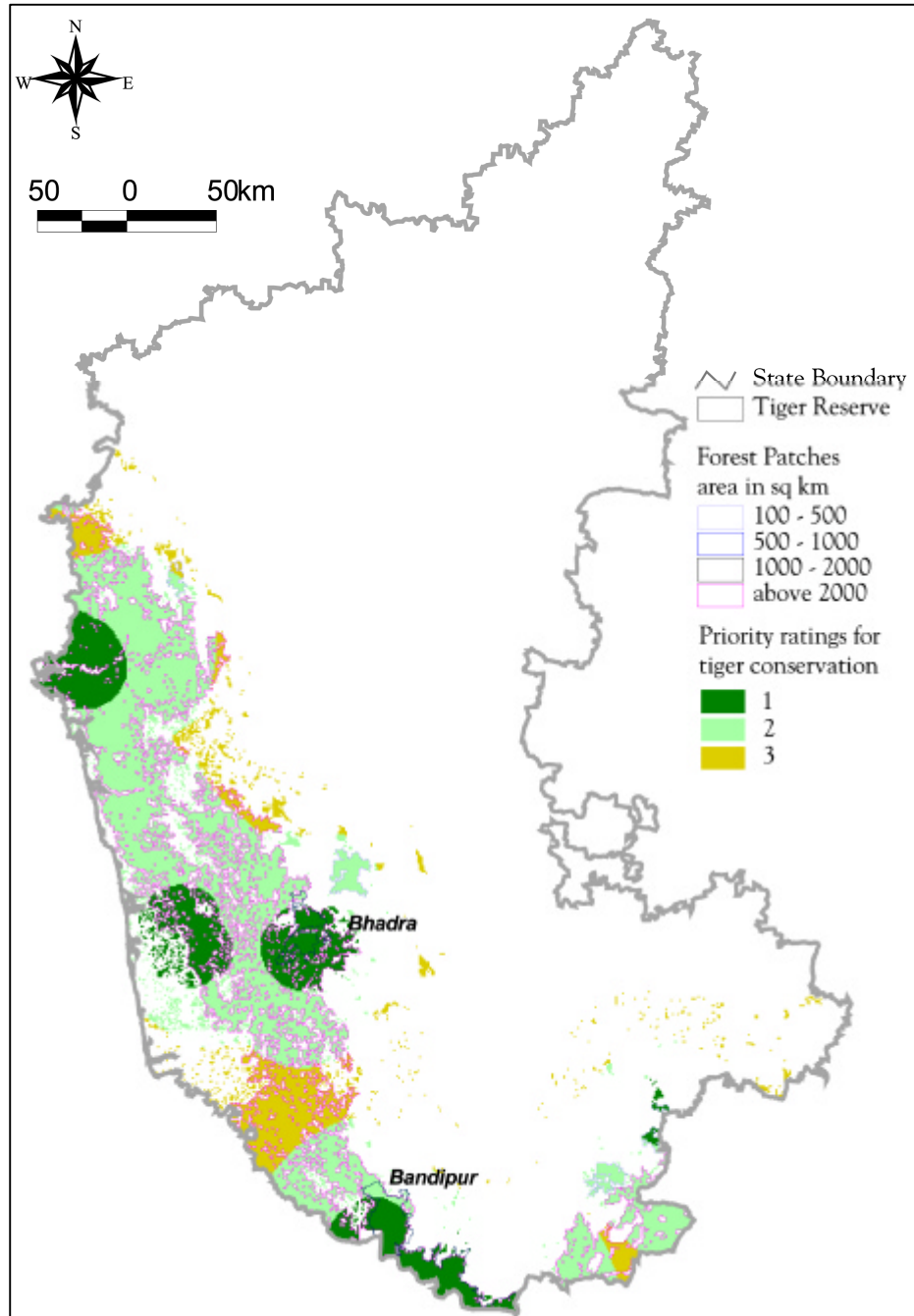


Figure 49 Priority areas within Karnataka for conservation of tiger source populations and maintaining connectivity



KERALA

For present study, whole of the state is considered to be under the Western Ghats landscape complex. The state of Kerala harbours one of the most important forest areas of India. Abundant rainfall in the seaward slopes of the Western Ghats has blessed the state with great variety of biological values. The great altitudinal variation coupled with the considerable latitudinal extent of the state gives rise to its ecological diversity. This difference of altitude present in Kerala influences the climate and distribution of vegetation.

The coast line is largely degraded, with long continuous rocky and sandy shores, broken by small creeks with remnant mangrove scrub, and some deciduous and evergreen communities. The coastal stretch falling within the low land region shows a few isolated scattered hillocks and rocky cliffs. Within this low land are distributed a string of 34 kayals (lagoons or estuaries), the largest among them is Vembanad lake, (205 sq. kms). The entire coastal zone is covered by coconut trees, paddy, extensive wetlands isolated remnants of mangrove vegetation etc.

The midland region form the inter junction between the coastal plain and the highland region consisting of deeply weathered and dissected hills generally showing a laterite cover. About 40% of the state falls within the highland region forming part of the western slopes of Western Ghats. A major part of this spectacular range is dissected by numerous west flowing rivers resulting in varied land forms.

However, it is in the Western Ghats that most wildlife values are to be found, and Kerala has the wettest and most biologically diverse portion of the whole mountain range. The steep and often abrupt topography creates great spatial variation in climate and soil parameters and many of the larger valleys have proved to be effective biological barriers, causing high levels of localised endemism. This great biological diversity and endemism is found in many a taxa. There are over 500 species of identified medicinal plants apart from many varieties of orchids etc. occurring in this part of Western Ghats. Over half of the country's amphibians are restricted to the Western Ghats. There are endemic reptiles, birds, and mammals. The state forests have significant populations of tiger, leopard, elephant, gaur and many lesser ungulates. The nilgiri tahr is characteristic of higher mountain grasslands.

The major challenges before the state are continual over-exploitation and degradation of natural ecosystems, lack of awareness on biodiversity related issues in common populace and forest staff and lack of adequate research on different aspects of biodiversity and its conservation. The main causes are lack of effective protection, lack of information on biodiversity values, lack of proper natural resource accounting, - with lack of man power aggravating it further (Rodgers and Panwar 1988).

Population density : 819 km⁻² (**Figure 50**)

Total protected area : 6.22 % (2417.2 km²)

Total forested area : 15631 km² (40% of total geographic area)

Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B) and 2. West Coast (8A)

Major ecoregions of Kerala:

Eco Regions	Area (sq km)
South Western Ghats moist deciduous forests	2288
Malabar coast moist forests	2513
South Western Ghats montane rain forests	3974

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation : Mean 269 cm Range 215 to 338 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : Nil

Forested area of tehsils where tiger is currently reported: 14298 km² (91.5% of forested area) (**Appendix 7**)

Areas for tiger conservation priority (Figure 51) (Appendix 7):

Priority I : 5330 km²

Priority II : 8037 km²

Priority III : 1305 km²

Figure 50 Map of Kerala showing distribution of human settlements, tiger reserves and human population densities

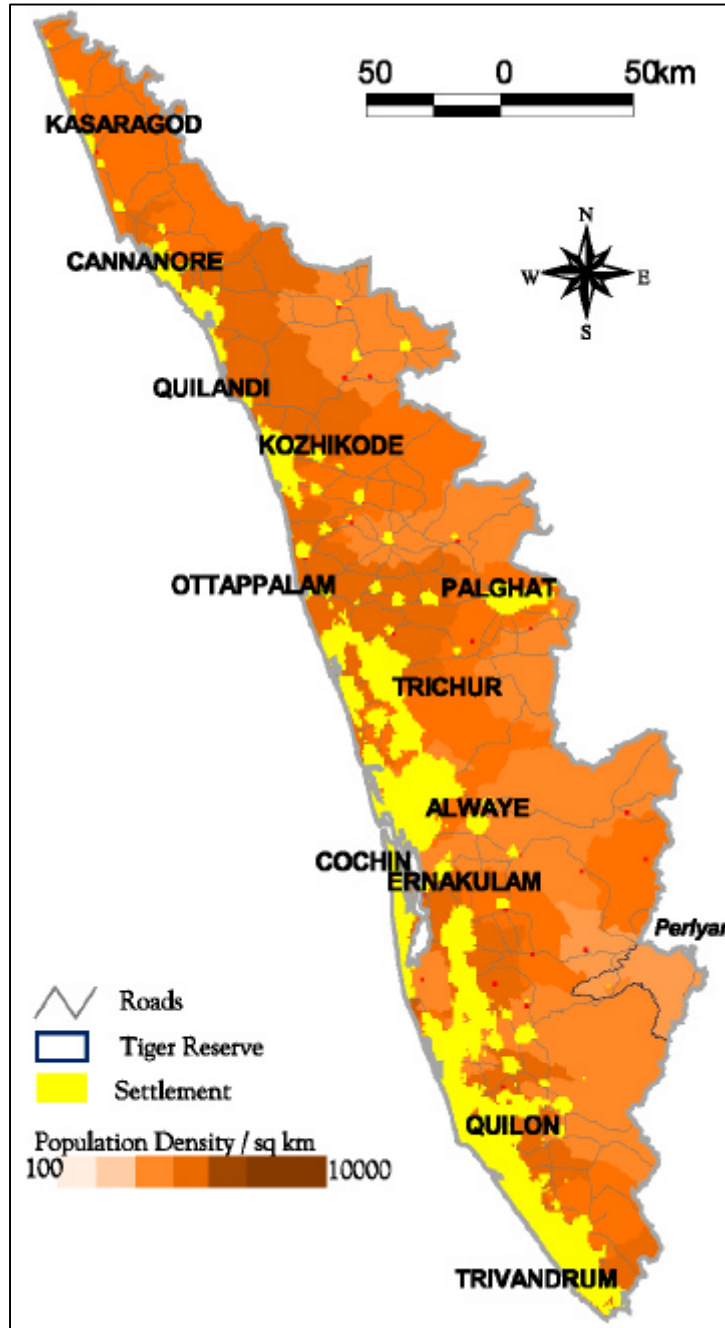
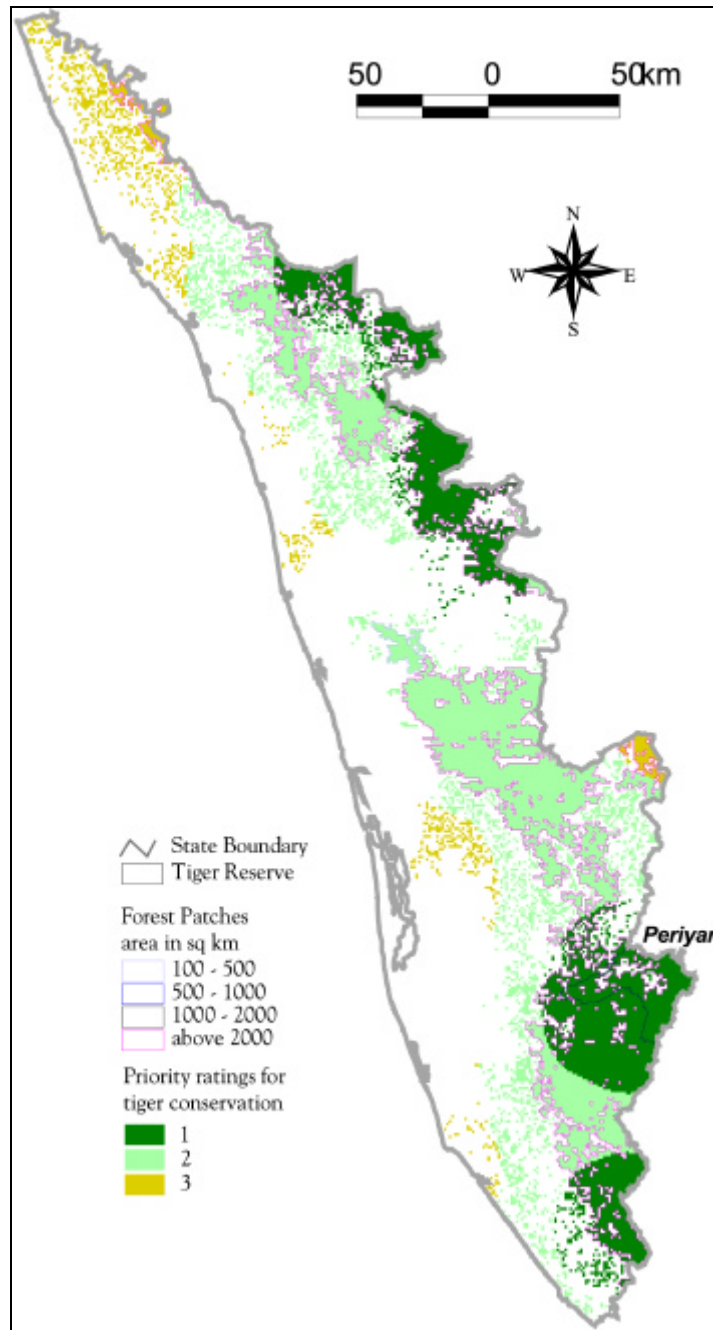


Figure 51 Priority areas within Kerala for conservation of tiger source populations and maintaining connectivity



MADHYA PRADESH

Whole of Madhya Pradesh falls within the Central India landscape complex of present study. Bulk of the state lies in Central India bounded by the Upper Gangetic plains in the north and the Godavari valley in the south, the plains of Gujarat in the west and Orissa and the Chhota Nagpur plateau in Bihar to the east. The state is traversed by the Vindhya, Satpura and Maikal hill ranges. The highest point in the state is at Dhupgarh near Pachmarhi in Hoshangabad district at 1,350 m. Most of the state has an elevation of 305 to 610 m above MSL. Low-lying parts of the state are in the narrow Narmada valley in the central and southern portions. The state is blessed to have a high percentage of forest cover with significant wildlife and ecological values. It also harbours a range of habitats from the semi arid tracts in its west to the Eastern highlands, Chhota Nagpur plateau and central highlands. Central, eastern and southern parts of the state are rich, whereas northern and western parts are relatively deficient in forest. Variability in climatic and edaphic conditions brings about significant difference in the forest types of the state. There are four important forest types viz. Tropical Moist, Tropical Dry, Tropical Thorn and Subtropical broadleaved Hill forests. Important tree species include Teak (*Tectona grandis*), Sal (*Shorea robusta*), Bija, (*Pterocarpus marsupium*), Tinsa (*Ougenia oojenensis*), Saja (*Terminalia tomentosa*), Haldu (*Adina cordifolia*), Anjan (*Hardwickia binata*), Mahua (*Madhuca indica*), Kardhai (*Anogiessus pendula*), Khair (*Acacia catechu*), Kullu (*Sterculia urens*), Salai (*Boswellia serrata*), Khejdi (*Prosopis specegera*), Babul (*Acacia nilotica*) Shisham (*Dalbergia paniculata*) and Sandal (*Santalum album*). Bamboo bearing areas are widely distributed in the state. Bamboo occurs as an under-storey in the dry and moist deciduous forests. The forests of Madhya Pradesh are rich in medicinal and aromatic plants. Nearly 500 species have been identified (NBSAP, 2000).

Tiger, leopard, swamp deer, gaur, etc. make the most conspicuous of the faunal elements. Non forested areas boast bustards, floricans, blackbuck, and gazelle, the rivers have gharial and mugger. The higher hills have sub tropical forests, the west and southern areas have teak and the moister east has Sal forests. Wildlife conservation through Protected Areas has generally been centered on a few key individual species or a umbrella group of species of animals that impart conservation value to a site. A lot of these Protected Areas are set up with the objective of 'featured species' management focussed around a critically endangered species e.g. Karera for Great Indian Bustard, Sailana for Lesser Florican and Chambal for Gharial and Gangetic Dolphin. There has been a lot of faunal diversity loss in the last century in Madhya Pradesh. The last Cheetah in India was shot in 1946 (Korea State, now Korea district, Chhatisgarh). Lion and Barasingha were once available in most parts of the State. However, and Lion are locally extinct in the State and the last population of Hard Ground Barasingha is surviving only in Kanha. Striped Hyena, Hill Myna, Lesser Florican, Great Indian Bustard, Dhole (Wild Dog) and Wolves are threatened due to habitat

shrinkage disturbances and poaching. Tiger, Chousingha, Blackbuck, Gaur and the Great Indian Bustard were once spread throughout the state are now found only in a few restricted pockets. A few species like Red and Grey jungle fowl, wild pig and wild mango have been genetically swamped and their wild gene pools contaminated by inter-breeding with domestic varieties (Rodgers and Panwar 1988).

Population density : 196 km⁻² (Figure 52)

Total protected area : 3.51 % (10814.76 km²).

Total forested area : 80717 km² (26% of total geographic area)

Major biogeographic zones : 1. Semi Arid (Gujarat Rajputana (4B)) and 2. Deccan Peninsula (a. Central Highlands (6A), Chotta- Nagpur (6B) & Central Plateau (6D)

Major ecoregions of Madhya Pradesh:

Eco Regions	Area (sq km)
Deccan thorn scrub forests	194
Central Deccan Plateau dry deciduous forests	234
Chhota-Nagpur dry deciduous forests	1156
Upper Gangetic Plains moist deciduous forests	3966
Eastern highlands moist deciduous forests	16100
Kathiawar-Gir dry deciduous forests	18586
Narmada Valley dry deciduous forests	33499

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 106 cm Range 61 to 160 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 13%

Forested area of tehsils where tiger is currently reported: 70010 km² (86.7% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 53) (Appendix 7):

Priority I : 9627 km²

Priority II : 30346 km²

Priority III : 25292 km²

Figure 52 Map of Madhya Pradesh showing distribution of human settlements, tiger reserves and human population densities

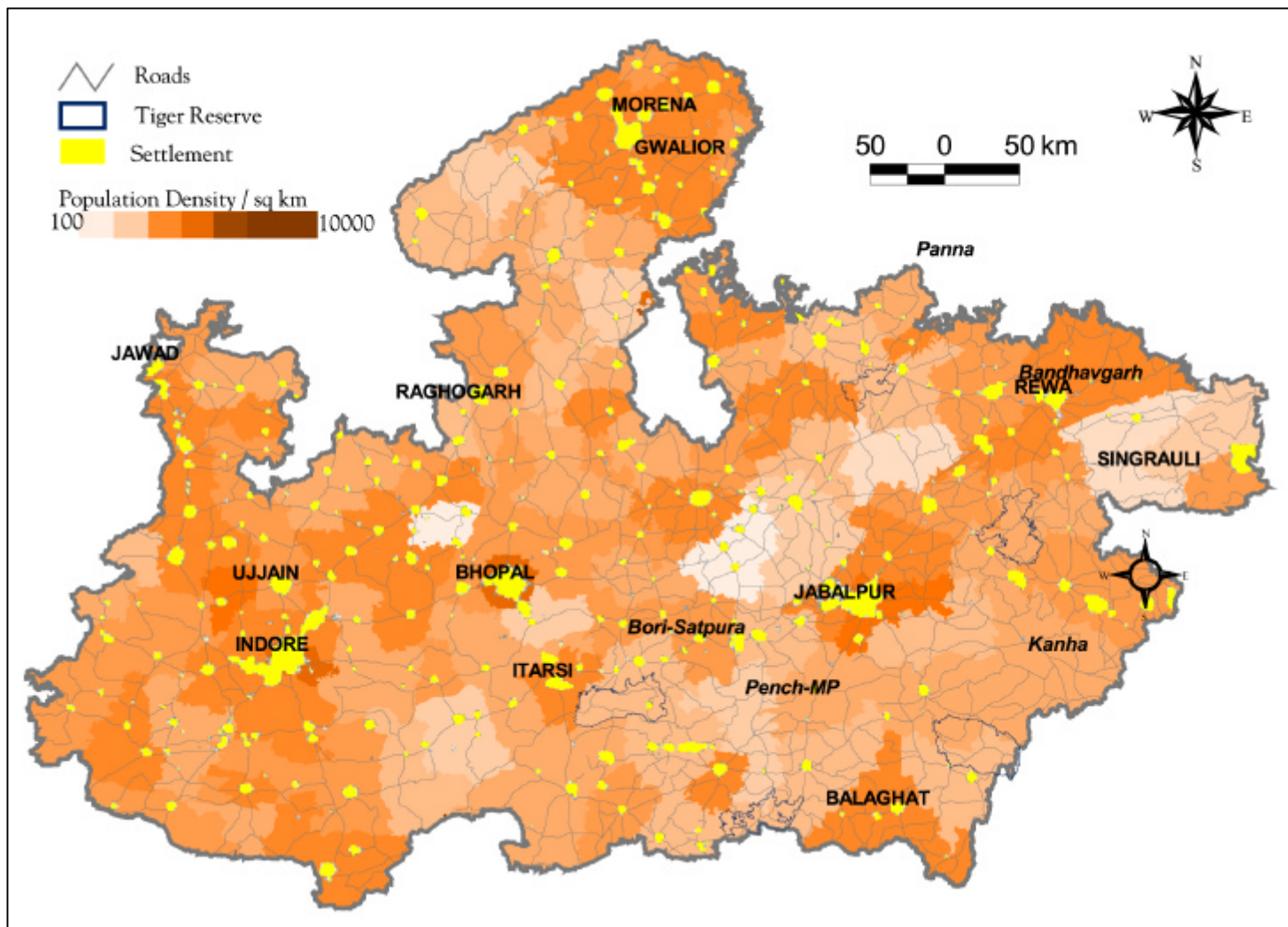
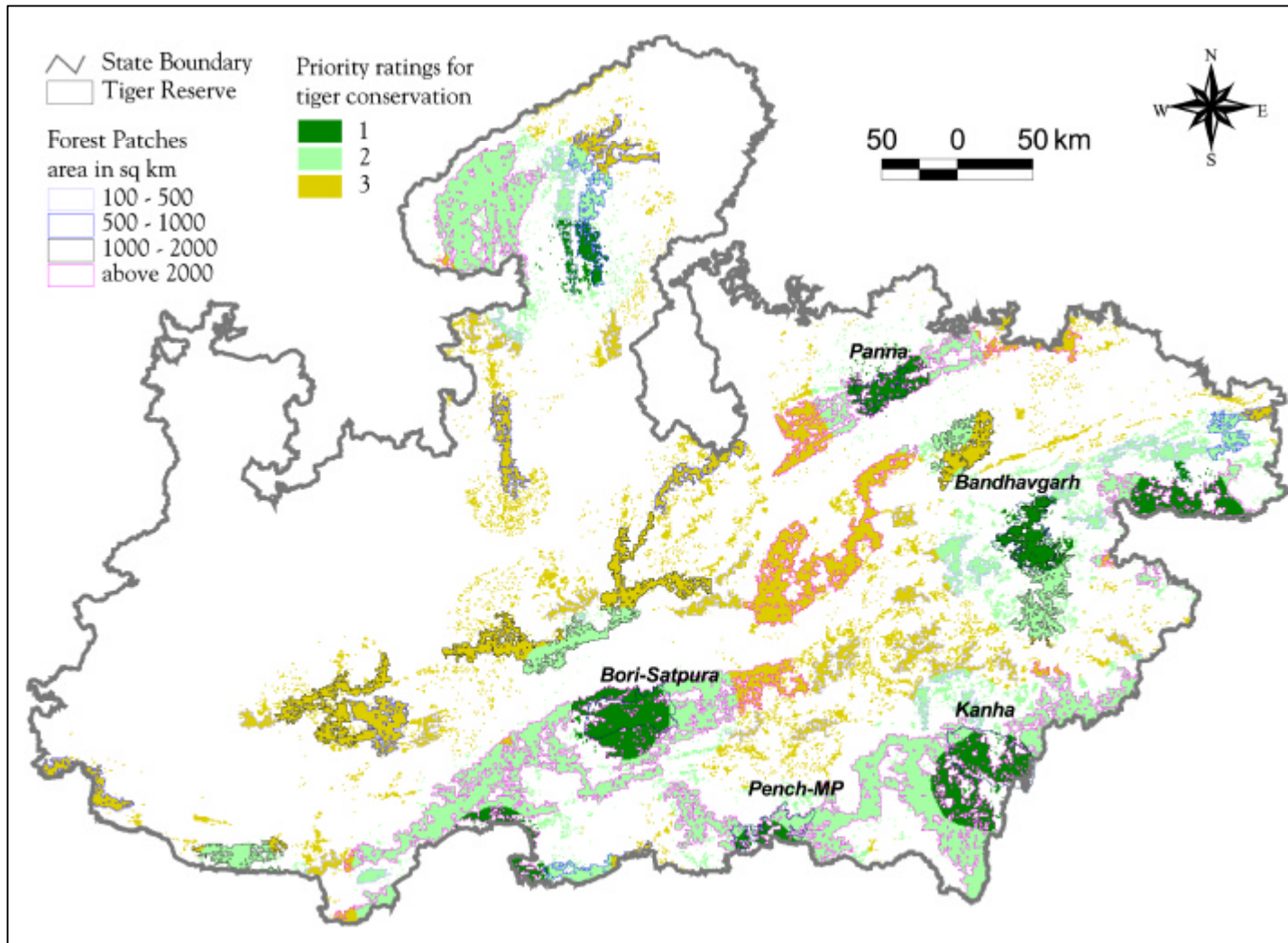


Figure 53 Priority areas within Madhya Pradesh for conservation of tiger source populations and maintaining connectivity



MAHARASHTRA

The state contains excellent examples of Deccan peninsula forests and wildlife, as well as the northern extremity of the richer forests of the Western Ghats. The state shows great variation in the Deccan zone with parts of 4 provinces represented. The Western Ghats evergreen forests are more fragmented at these latitudes, and some are increasingly degraded by human exploitation, but many areas of good forest remain, both on the hills and on the coastal plains. Thus the state includes parts of 2 landscape complexes of present study, - Western Ghats and Central India.

The Western Ghats evergreen, semi evergreen and moist deciduous biomes are rich in species, particularly of plants, birds and herpetofauna. From the 650 plant species enlisted in the Red Data Book of Indian Plants, about 80 are found in Maharashtra with about 50 being endemic to Maharashtra. Few are endemic to particular sites like parts of Western Ghats and the western coast. Unexplored parts of Satpuras and parts of Chandrapur could also be locations of high biological diversity. Apart from forest areas, isolated valleys in Sahyadris, Satpuras, mangrove and coastal vegetation, are areas of special significance and of immense conservation value as they have high numbers of endemic floral species. Tiger, panther, dhole, rusty spotted cat (*Prionailurus rubiginosus*), gaur, etc are among the more significant mammalian species found in this state.

The Deccan is a mixture of dry and moist deciduous forests, with thorn forest, scrubland, and dry grasslands. In the far east, there are alluvial grasslands. The drier forests offer extensive tiger, gaur, sambar, chital, chowsingha populations, and the more open areas have chinkara, wolf and great Indian bustard (*Ardeotis nigriceps*). The many tanks and reservoirs have important waterfowl resources, and often mugger and turtle populations.

The coast has a varied topography, giving rise to mangroves, raised coral and sandy beaches. There are scattered low density turtle nesting beaches and crocodile in the river mouths (Rodgers and Panwar 1988).

Several parts of Amaravati, Akola, Pune, Ahmednagar, Beed etc are confronted with severe man-animal conflicts where incidents of large-scale crop depredation by blackbuck, nilgai, wild boar and occasionally gaur. There are instances of straying carnivores, especially leopards into human habitations killing domestic cattle and causing fatalities to humans. As a consequence there is an increase in poaching due to poisoning of carcasses by the local people. The panthers straying out of the Sanjay Gandhi National Park, Borivili, Mumbai, to the surrounding human settlements in Thane are quite common. Wildlife authorities have captured and released the animals in the forests on many occasions, - but a long term solution still eludes them.

Population density : 314 km⁻² (**Figure 54**)

Total protected area : 5.01 % (15417.6 km²)

Total forested area : 53619 km² (17% of total geographic area)

Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B)) and 2. Deccan Peninsula (Central Highlands (6A), Central Plateau (6D) & Deccan South (6E))

Major ecoregions of Maharashtra:

Eco Regions	Area (sq km)
Malabar coast moist forests	2252
Eastern highlands moist deciduous forests	2502
North Western Ghats montane rain forests	4241
Narmada valley dry deciduous forests	6672
Deccan thorn scrub forests	7496
North Western Ghats moist deciduous forests	7761
Central Deccan plateau dry deciduous forests	16359

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 129 cm Range 49 to 365 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct: 51%

Forested area of tehsils where tiger is currently reported: 13702 km² (25.6% of forested area) (**Appendix 7**)

Areas for tiger conservation priority (Figure 55) (Appendix 7):

Priority I : 9349 km²

Priority II : 14435 km²

Priority III : 8342 km²

Figure 54 Map of Maharashtra showing distribution of human settlements, tiger reserves and human population densities

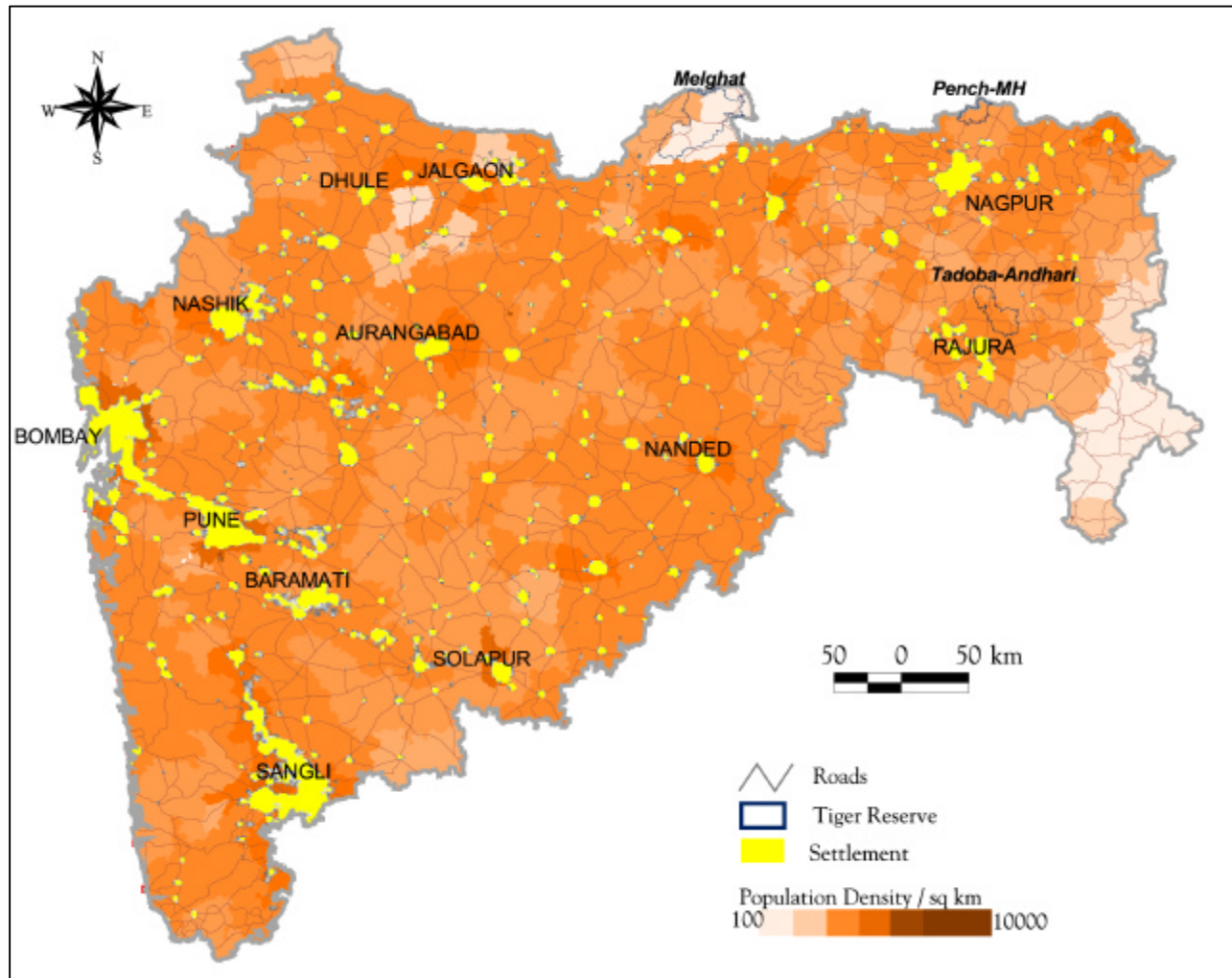
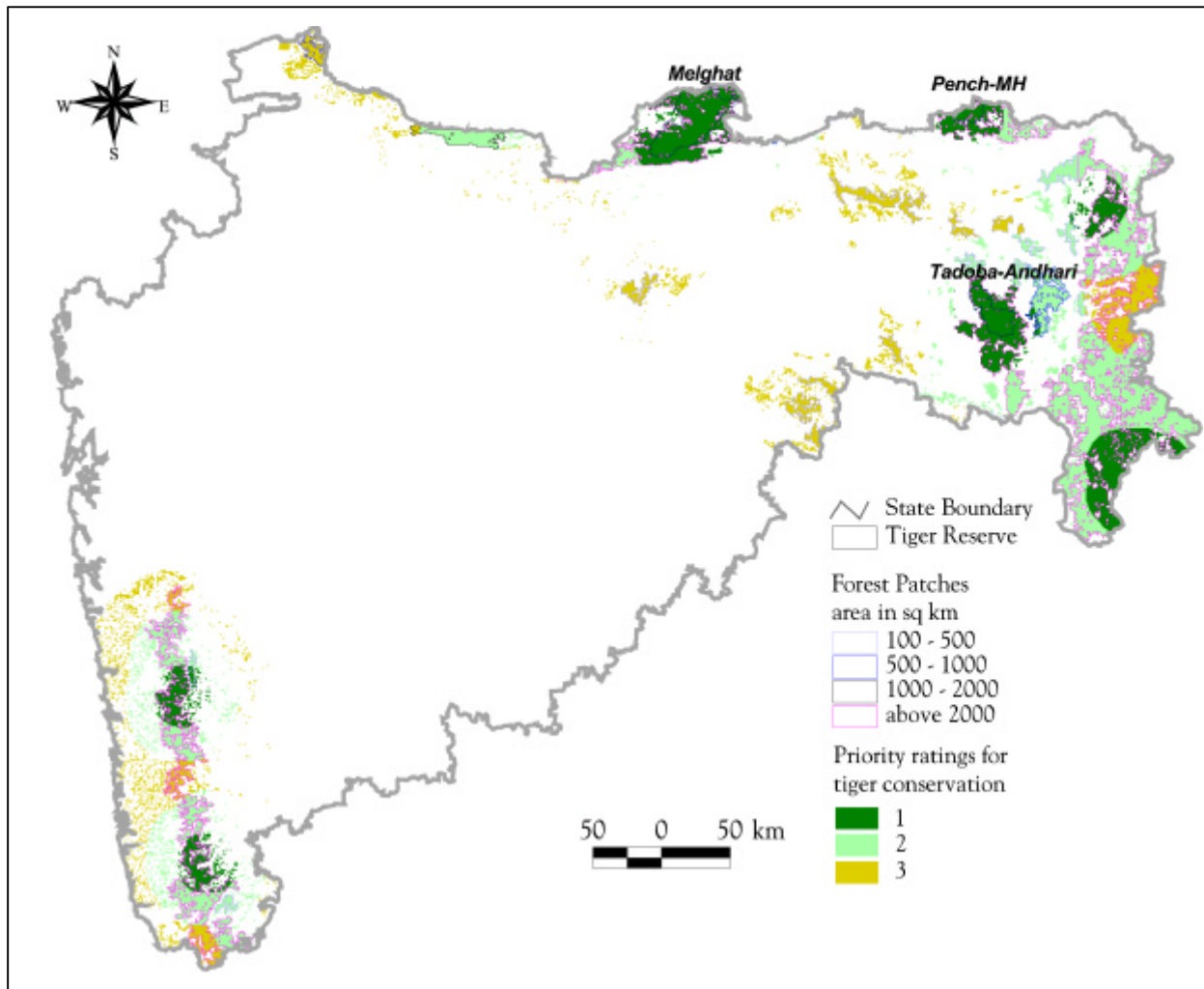


Figure 55 Priority areas within Maharashtra for conservation of tiger source populations and maintaining connectivity



MIZORAM

Mizoram, a small state in the southern part of the Assam hills biotic province, is one of the least documented states in the country in terms of biological wealth. The high forest cover of Mizoram and altitudinal variation of the forests gives rise to its tremendous wealth. Mizoram has vast natural forest resources owing to its biogeographical affiliations. More than 400 ethnomedicinal plants have been recorded in the State. Of these, 65 species are categorized as rare and threatened species at the local (State) level, and 64 species are new records of ethnomedicinal plants. There are about 20 species of bamboo reported from the State. They occupy a large area of the forest, support numerous human needs including small scale and cottage industries and contributing a good amount of revenue to the State exchequer. In the context of private landownership in north east India, value of the largely government owned forests of Mizoram are all the more significant. The state forms part of the North East Hills and Brahmaputra Flood Plains landscape complex of present study, - having contacts with similar habitats both in Myanmar and in Chittagong of Bangladesh.

Forests vary from low-level evergreen communities to temperate forests over 2500 mts in altitude in the 'Blue Mountains'. Wetlands like Palak Lake add diversity to these forests. Large mammal values include a small population of elephant, gaur, serow, goral, tiger, lesser cats and gibbon. Significant bird resources include pheasants, hornbill species and waterfowl species in lakes (Rodgers and Panwar 1988).

However, in the last few decades, the immense diversity of Mizoram has faced tremendous pressures. Habitat loss, hunting and over-exploitation of resources, introduction of exotic species in river ecosystems, poisoning and other factors including progressive disempowerment of local communities, population growth and destabilization of Mizo traditional management systems, have caused this loss. The hitherto acceptable practice of shifting cultivation has now been deemed unsustainable due to its present large scale and shrinking of forested habitats. Vast areas comprising valuable timber trees and other forest resources have been converted into degraded land. The dimensions of the loss is as yet unclear, as baseline data, research and monitoring accounts are few. All of this silent erosion is not necessarily due to anthropogenic factors, but often due to complex and less understood environmental factors. Thus, for conservation measures to be implemented effectively, it is imperative to have a basic understanding of the flora and fauna of the State, beginning with status surveys.

Population density : 42 km⁻² (Figure 56)

Total protected area : 4.70 % (990.8 km²).

Total forested area : 17961 km² (85% of total geographic area)

Major biogeographic zones : 1. North East Hills (9B)

Major ecoregions of Mizoram:

Eco Regions	Area (sq km)
Mizoram-Manipur-Kachin rain forests	180.00

Temperature range : Minimum average 8° C, Maximum average 34.4° C

Precipitation : Mean 206 cm Range 149 to 280 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct: Nil

Forested area of tehsils where tiger is currently reported: 256 km² (1.4% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 57) (Appendix 7):

Priority I : 538 km²

Priority II : 8546 km²

Priority III : 9010 km²

Figure 56: Map of Mizoram showing distribution of human settlements, tiger reserves and human population densities

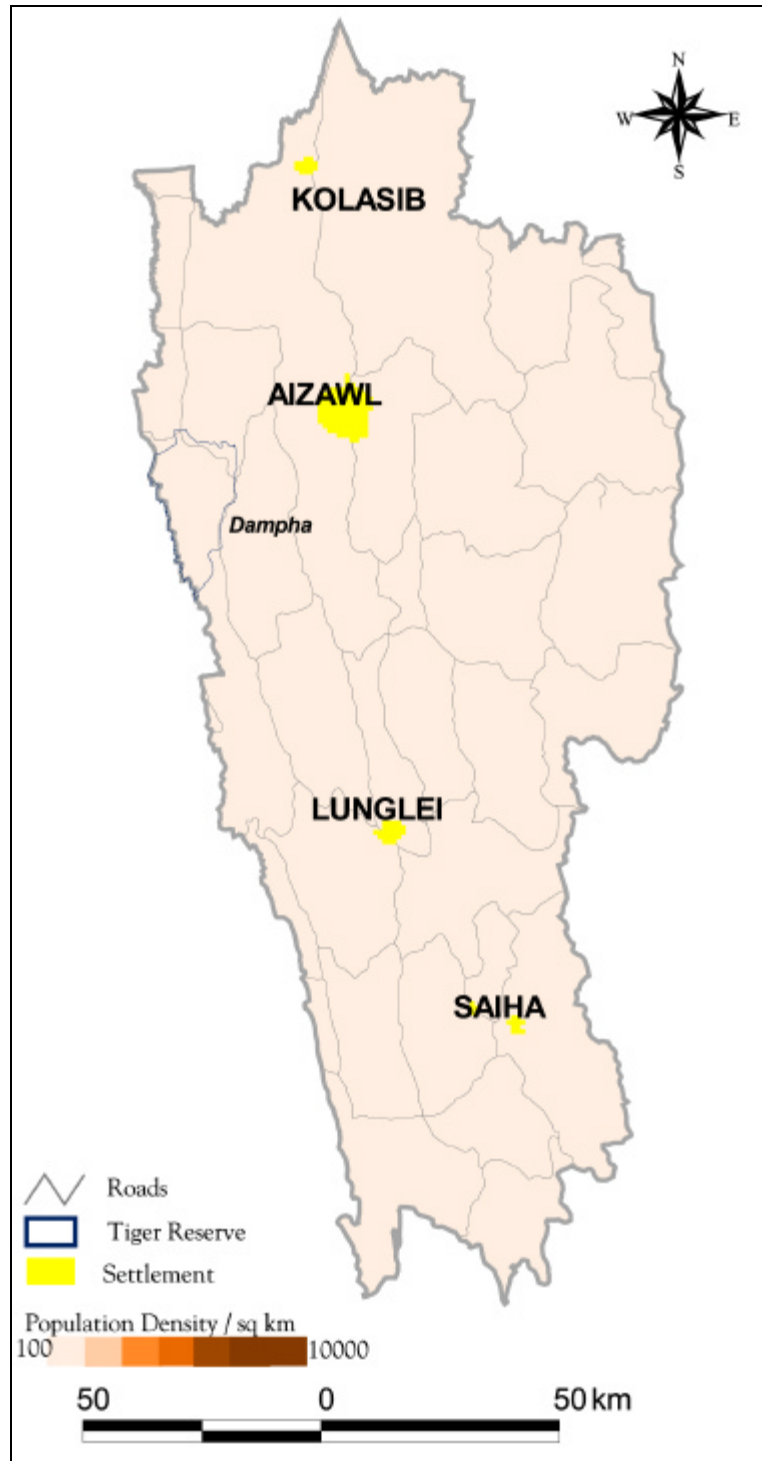
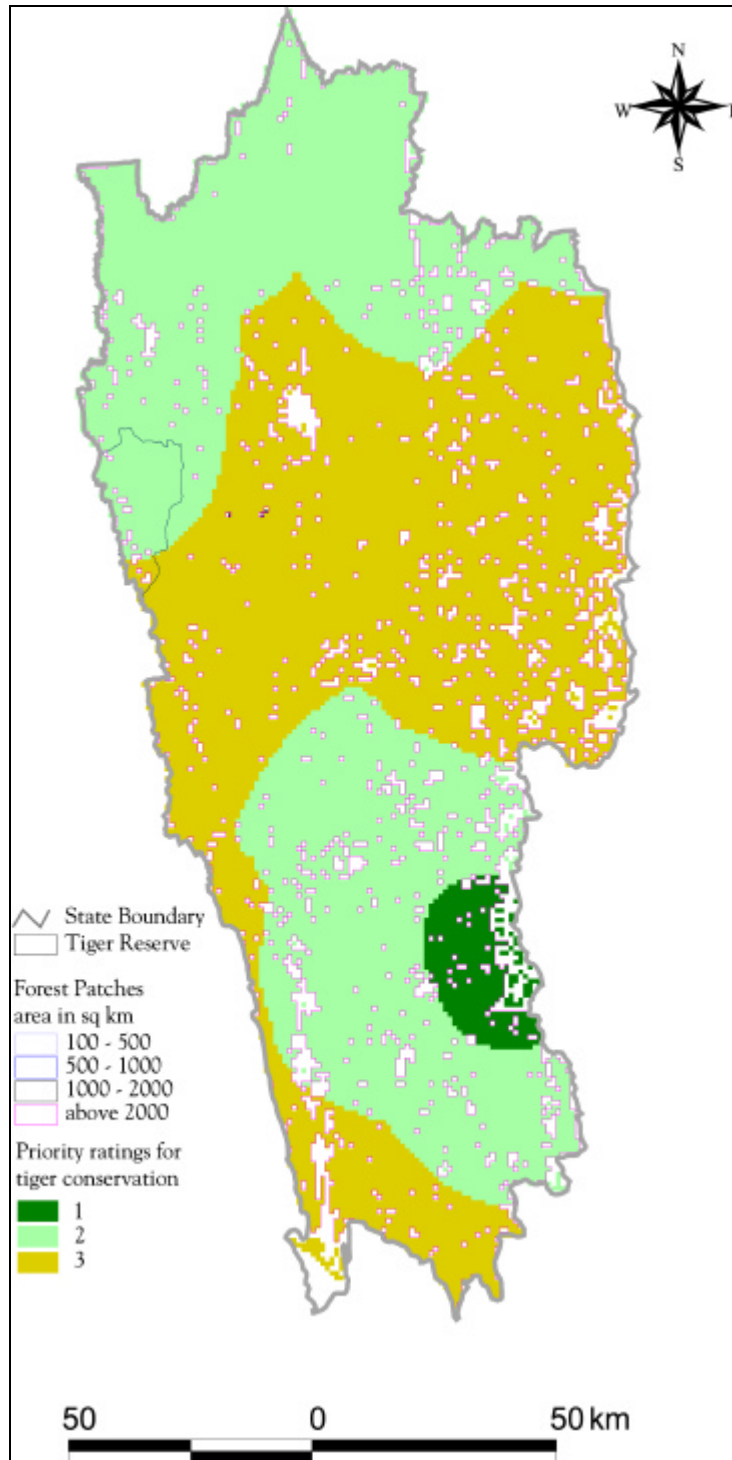


Figure 57 Priority areas within Mizoram for conservation of tiger source populations and maintaining connectivity



ORISSA

Orissa is blessed with immense biodiversity, especially floral wealth, by virtue of parts of the Eastern Ghats being within its boundaries. Of an estimated 1,200 species of orchids in India, 129 species are endemic to Orissa. Small remnants of erstwhile rain forests are found in patches. Semi-evergreen forests are now more extensive than evergreen forests partly because evergreen forests tend to degrade to semi-evergreen with human interference.

The state contains significant wildlife resources of both the coastal and the Deccan peninsula biogeographic zones. The state is of ecological interest in that it is the wettest part of the Deccan zone and has, for example, elephant populations existing in deciduous forest situations as they would have done all across central India in times of moister climate. The moist forests of the eastern ghats in south east Orissa have communities of considerable biological interest, including few endemic species. In the north of the state, the Similipal massif is a biological refuge of great value. With slight variation to conventional classifications, Orissa has been kept in the Central India landscape complex of present study.

The moist forests of the isolated hills of Similipal and the Eastern Ghats have a rich flora and fauna with many endemic species. These forests, which include many semi evergreen elements, are important biogeographic stepping zones in the link between the forest species of north east and south west India.

The State of Orissa has coastline of about 480 km stretching over Balosore, Bhadrak, Kendrapara, Jagatsinghpur, Cuttack, Puri and Ganjam districts and is interrupted by several rivers, rivulets and lagoons of which Mahanadi, Brahmani, Baitarani, Budhabalang, Rushikulya and brackish water Chilika lake deserve special mention. This interruption has greatly influenced the coastal vegetation of Orissa to give rise to a richest variety of mangrove communities.

Wildlife values include a fragmented series of elephant sub-populations. Tiger and other carnivores, gaur, sambar, etc. have good populations and are reasonably well distributed in the state. However, there is documented loss in faunal diversity in the last few decades. Some of the last cheetahs were reported on Orissa- Andhra border at Malkangiri by James Milne in 1952. Two species of mammal (Cheetah and Hard Ground Barasingha) and four species of birds (Pink- headed duck, the Great Indian Bustard, European white stork and Common crane) are now extinct from Orissa and occurrence of wild buffalo, marbled cat, caracal, batagur terrapin and Forest spotted owlet is either highly threatened or doubtful (Rodgers and Panwar 1988).

Population density : 236 km⁻² (Figure 58)

Total protected area : 5.1 % (7959.9 km²)

Total forested area : 54620 km² (35% of total geographic area)

Major biogeographic zones : 1. Deccan Peninsula (Chhota-Nagpur (6B) & Eastern Highlands (6C), 2. East Coast (8B) and 3. Lower Gangetic Plain (7B)

Major ecoregions of Orissa:

Eco regions	Area (sq km)
Lower Gangetic Plains moist deciduous forests	57
Goadavari-Krishna mangroves	150
Chhota-Nagpur dry deciduous forests	1556
Orissa semi-evergreen forests	3850
Northern dry deciduous forests	13012
Eastern highlands moist deciduous forests	25240

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation : Mean 145 cm Range 101 to 192 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 7%

Forested area of tehsils where tiger is currently reported: 27424 km² (50.2% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 59) (Appendix 7):

Priority I : 2818 km²

Priority II : 6553 km²

Priority III : 29553 km²

Figure 58 Map of Orissa showing distribution of human settlements, tiger reserves and human population densities

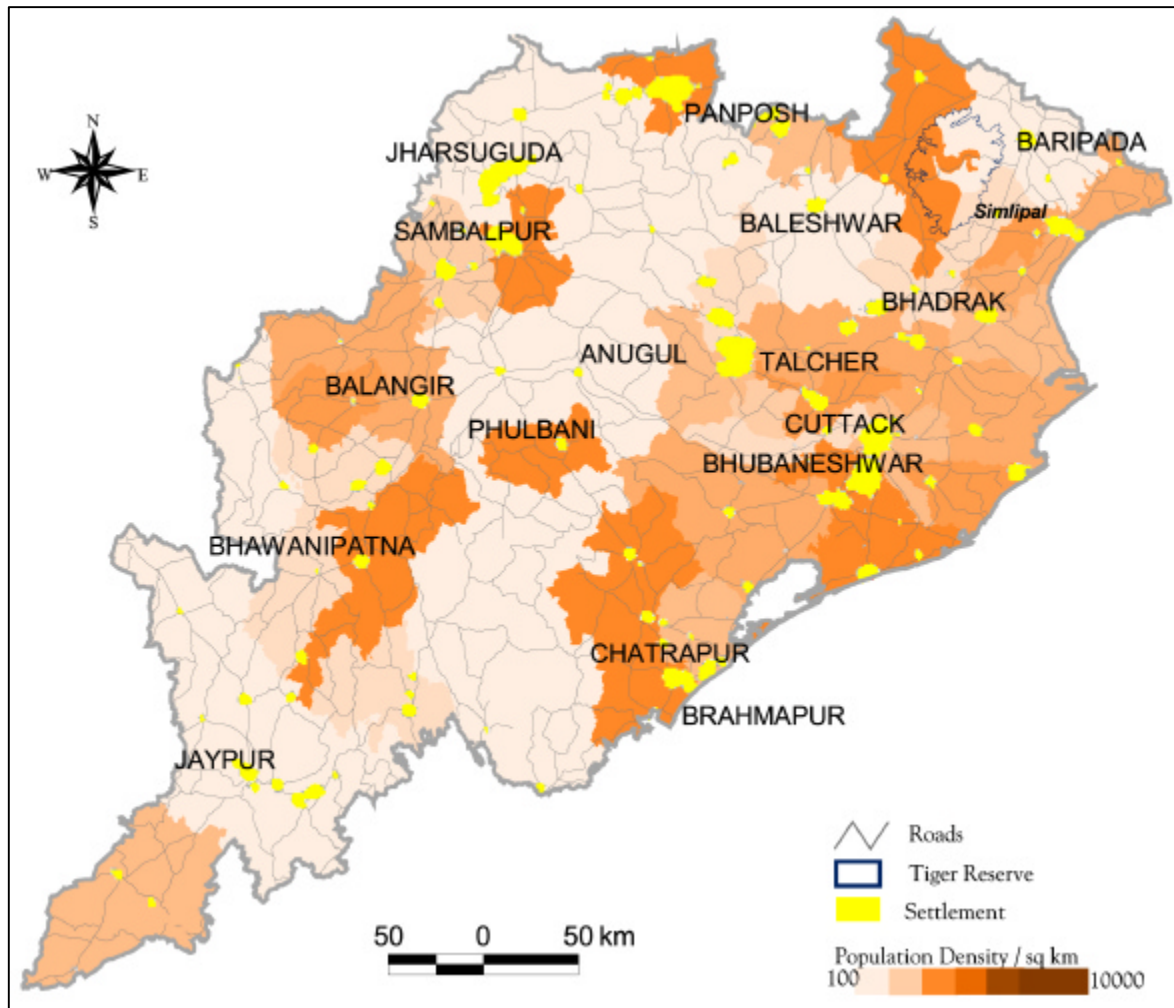
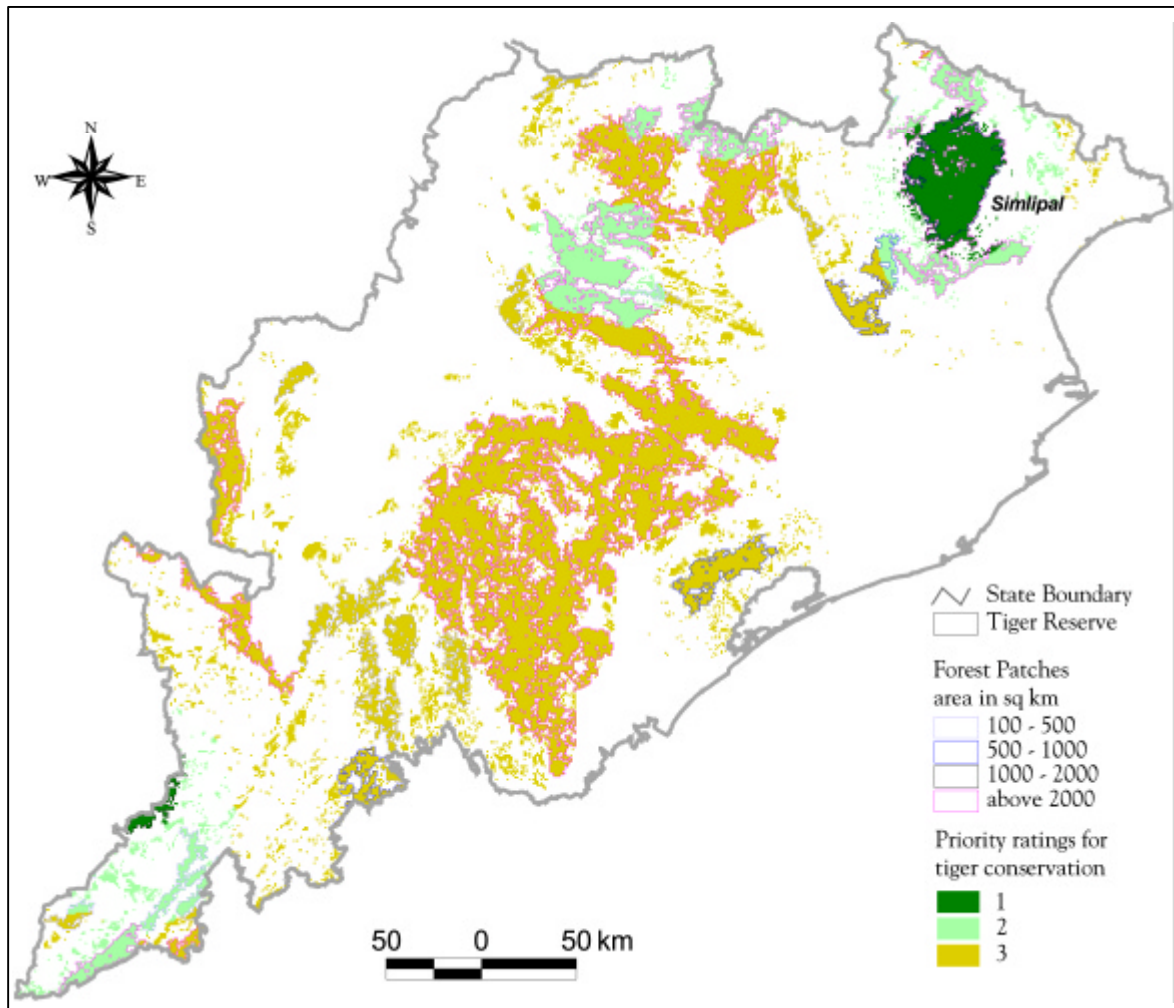


Figure 59 Priority areas within Orissa for conservation of tiger source populations and maintaining connectivity



RAJASTHAN

The desert areas of Rajasthan have been recognised nationally and internationally as key areas of natural resource conservation. Besides these values, the eastern part of Rajasthan is classified as semi-arid, and the wooded hill slopes of the Aravalli hills contain a couple of the nation's finest protected areas, - which forms part of the Central India landscape complex of present study.

The semi arid zone is a large transition area between the true desert and the seasonally wet peninsular India. The preponderance of grass and edible shrubs allow the development of relatively high ungulate densities, e.g. chital, nilgai, sambar and their associated carnivores.

In spite of an arid climate and extensive desert area, the state has many ecologically significant and unique wetlands. There are 55 major wetlands which occupy 1230 sq km of area scattered all over the state. Two of the state's wetlands (Keoladeo National Park Ghana in Bharatpur district and Sambhar Lake in Nagaur district) have been listed under the Convention on Wetlands of International Importance (popularly known as Ramsar Conventions). The former has also been listed as a World Heritage Site under the World Heritage Convention of the Man & Biosphere Programme (MAB) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

The phytogeographic composition of the state consists of four distinct elements: Indian element (33%), Perso-Arabian element (30%), Indo-Malayan element (13%), general element (24%). There are 1974 angiosperms, one gymnosperm, 35 pteridophytes, 37 thallophytes, and 42 mosses that are known to be indigenous to the state.

Several faunal species of great conservation significance have major populations in Rajasthan, even if they are not restricted to the state or to the arid or semi arid biogeographic zones. Such species include caracal, wolf, jungle cat, leopard, tiger, chowsingha, gazelle, blackbuck, lesser florican and the great Indian bustard.

Even though the state is characterised by great aridity, the wildlife values of the few large wetlands are spectacular. While Bharatpur is a good example of Indus plain shrub lands, Chambal River has viable populations of gharial, mugger, dolphin, and several species of turtles.

Adverse impacts of human activities (threats) manifest themselves through habitat destruction, overharvesting, desertification, environmental pollution, commercial trade of plant and animal species, introductions of non-native (alien) species, monoculture and intensive agriculture practices (Rodgers and Panwar 1988).

Population density : 165 km⁻² (Figure 60)

Total protected area : 2.8 % (9569.36 km²)

Total forested area : 21292 km² (6% of total geographic area)

Major biogeographic zones : 1. Thar Desert (3A) and 2. Semi Arid (Punjab Plains (4A) & Gujarat Rajputana (4B))

Major ecoregions of Rajasthan:

Eco Regions	Area (sq km)
Upper Gangetic Plains moist deciduous forests	757
Northwestern thorn scrub forests	4038
Thar desert	5228
Kathiawar-Gir dry deciduous forests	8369

Temperature range : Minimum average 6.6° C, Maximum average 41.3° C

Precipitation : Mean 49 cm Range 12 to 97 cm

Tiger habitat status:

Percent are of the state in terms of districts from which tigers have become locally extinct : 60%

Forested area of tehsils where tiger is currently reported: 1835 km² (8.6% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 61) (Appendix 7) :

Priority I : 593 km²

Priority II : 1430 km²

Priority III : 1603 km²

Figure 60 Map of Rajasthan showing distribution of human settlements, tiger reserves and human population densities

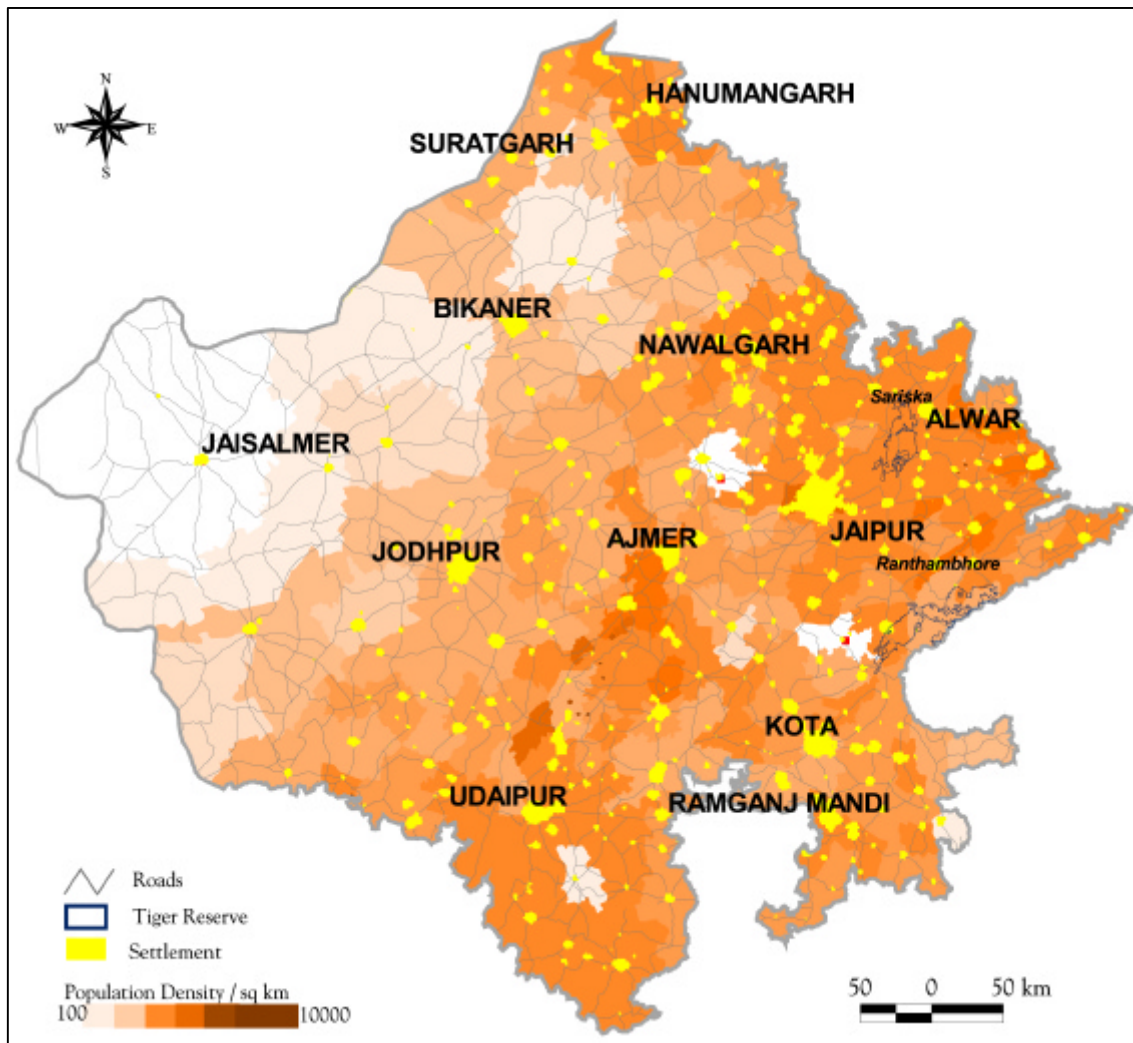
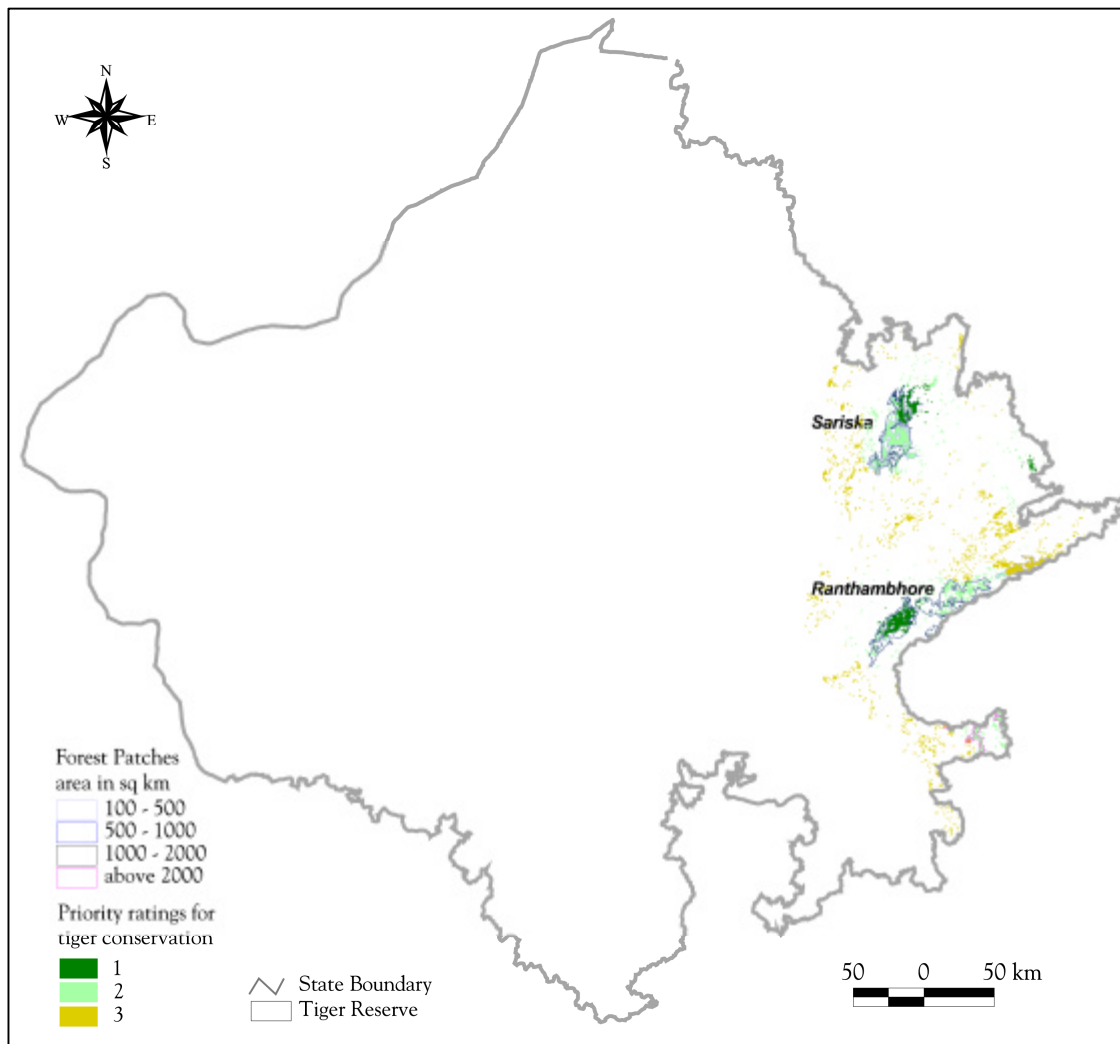


Figure 61 Priority areas within Rajasthan for conservation of tiger source populations and maintaining connectivity



TAMIL NADU

The location of Tamil Nadu gives a tremendous diversity of habitat to the natural resources of the state. Situated in the south east corner of the peninsula, the state has an extensive and varies coast line, an inland dry plain which is crossed by the southern portion of the Eastern Ghats, and finally the eastern ridges and slopes of the Western Ghats themselves. However, for the purposes of the present study Tamil Nadu is included in the Western Ghats landscape complex.

The well documented biological values of the Western Ghats include exceptionally high levels of endemism in the plants, invertebrate and lesser vertebrate fauna. Besides the obvious floral richness of the Western Ghats, in Tamil Nadu it is home to a large proportion of rare and endemic mammals, birds and herpetological fauna. Of the Indian amphibian species 1/3 rd (32.3%) are endemic and are mostly confined to Tamil Nadu. Out of the 120 species reported to occur in the Western Ghats 83 are endemics (69.45%). A majority of the endemic forms are found in the rain forests and almost all the endemics are confined to it and are mostly in Tamil Nadu. A recent study reveals that amphibian distribution in the forests floor was found to be largely restricted to the forests of adjoining streams and mountains flanking the valleys (Kumar et. al, 2002). This study clearly ascertains the need for the protection of each and every hill stream from any disturbances (natural or man-made) for the sustenance of amphibians. It seems Tamil Nadu still harbours many faunal species, particularly of herpetofauna and terrestrial invertebrates, that are not yet known to science.

Tamil Nadu has nearly 150 species of mammals, the uncertainty in exact number resulting from taxonomic ambiguities and imperfect knowledge on distribution. Taxonomic ambiguities are due to the validity of some species (primarily rodents) and recent revisions in taxonomy as in the case of primates. Imperfect knowledge of distribution hounds conservation attempts in case of bats and marine mammals. Large mammal communities are also extremely rich, and there are extensive populations of large mammals of conservation significance, - tiger, elephant, tahr, gaur, primates, etc.

Vegetation in the dry inland plains and lower hill ranges is a mix of dry deciduous and southern thorn communities, - with some forests containing sandalwood. Just inland from the coast are remnant patches of tropical dry evergreen forest, - with a typical fauna of blackbuck, chinkara, hare, leopard, wolf, jackal, etc. Sambar and chowsingha inhabit the better hill jungles, as do elephants in the better watered tracts.

The coast has mangrove, sandy beaches, mudflats, coral reef and sea grass pastures. The saltflat pastures of Point Calimere have south India's largest blackbuck population. The Gulf

of Mannar with its chain of tiny islands is a major turtle feeding grounds and did have a significant dugong population (Rodgers and Panwar 1988).

Population density : 478 km⁻² (**Figure 62**)

Total protected area : 2.2 % (2847.66 km²)

Total forested area : 24662 km² (19% of total geographic area)

Major biogeographic zones : 1. Western Ghats (Malabar Plains (5A) & Western Ghats Mountains (5B)) & 2. Deccan Peninsula (Deccan South (6E)) and 3. East Coast (8B)

Major ecoregions of Tamilnadu:

Eco Regions	Area (sq km)
Malabar coast moist forests	388
East Deccan dry-evergreen forests	1932
South Western Ghats montane rain forests	1975
South Western Ghats moist deciduous forests	3660
Deccan thorn scrub forests	3954
South Deccan Plateau dry deciduous forests	9873

Temperature range : Minimum average 13.4° C, Maximum average 40.5° C

Precipitation : Mean 92 cm Range 67 to 125 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : Nil

Forested area of tehsils where tiger is currently reported: 5129 km² (20.8% of forested area) (**Appendix 7**)

Areas for tiger conservation priority (Figure 63) (Appendix 7):

Priority I : 3785 km²

Priority II : 4619 km²

Priority III : 3480 km²

Figure 62 Map of Tamil Nadu showing distribution of human settlements, tiger reserves and human population densities

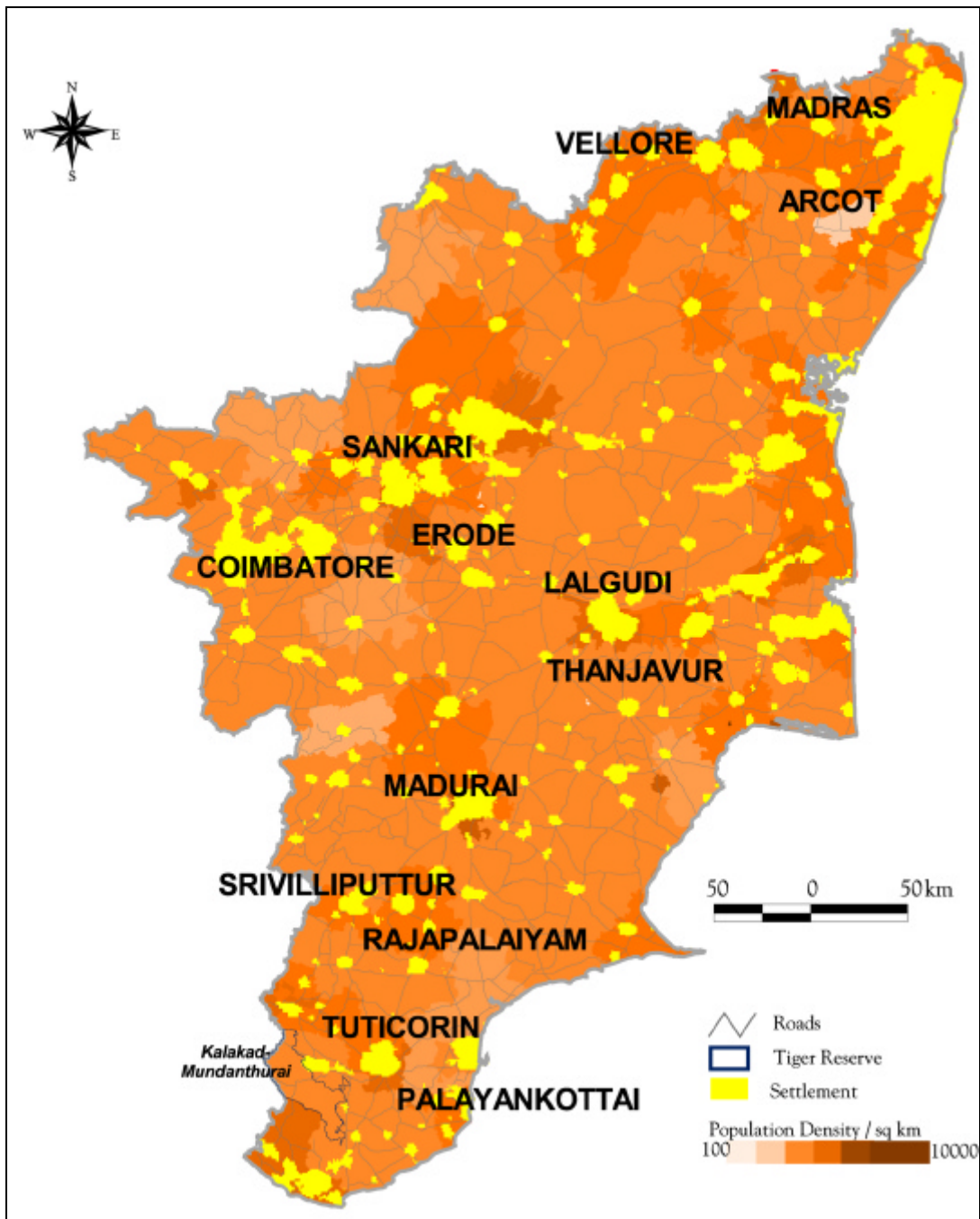
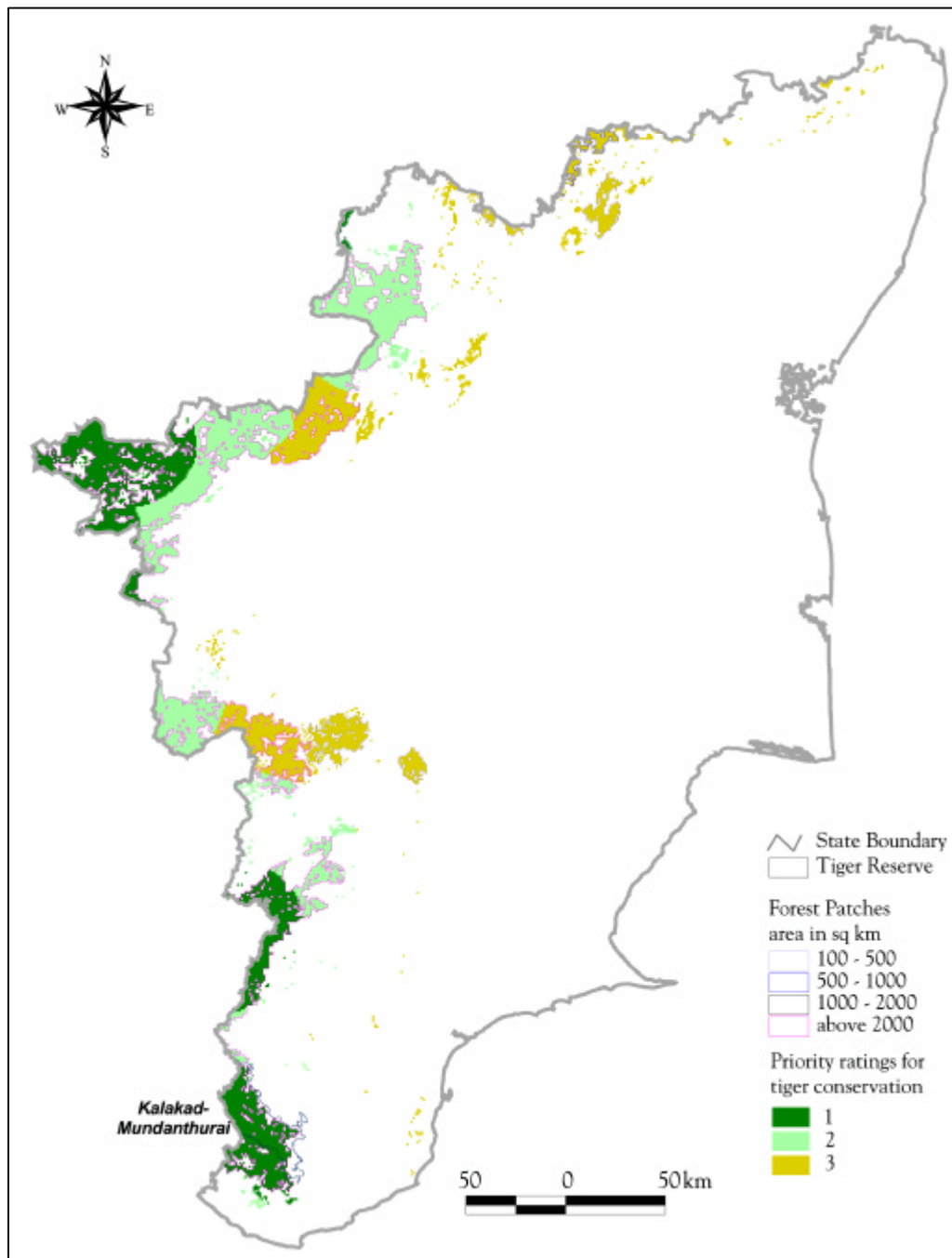


Figure 63 Priority areas within Tamil Nadu for conservation of tiger source populations and maintaining connectivity



UTTARANCHAL

The small state of Uttarakhand has perhaps the most diverse set of wildlife habitats in India, ranging from the permanent snow and ice of the alpine reaches to the subtropical and deciduous forests of the foothills, and the rich Terai and Bhabar tracts beyond that. Biogeographically, the state lies in the provinces of North West Himalayas and the upper gangetic plain. Parts of the Shivalik–Gangetic plains landscape complex forms its southern peripheries.

The Himalayas still hold all species characteristic of this zone, although many populations are so fragmented that they are of doubtful long term viability. Snow leopard, bharal, tahr, serow, goral, musk deer and cheer, monal, koklass, tragopan and kaleej pheasants are characteristic temperate and alpine species.

The Shivalik-Bhabar-Terai forests and grasslands still harbour major wildlife resources, - tiger, elephant, swamp deer, hog deer and extensive chital-sambar populations (Rodgers and Panwar 1988).

In this young state, biodiversity conservation outside the Protected Areas (PAs) is being envisaged by programmes like working plan code amendment, enlarge scope of wildlife overlapping circles, declaration of community and Conservation Reserves, creation of wildlife ranges in territorial/social forestry divisions, creation of mini biodiversity cores in forest divisions and management of wildlife populations in the plains.

Overall management of the state's biodiversity is envisaged by habitat improvement (weed control, control of exotics, polyculture plantations, protection of springs in the outer Himalayas, fire protection and water management); anti-poaching strategies (implementing Subramaniam committee recommendations, GOI, 1994); resolving trans border issues (poaching and illegal trade). Besides, land use practices and their management, forestry considerations and adoption of silvicultural prescriptions for reserve forests will enhance management of forest areas including their transfer to JFM/Van Panchayats. This will ensure effective management of forest plantations in combination with judicious forest management aimed at regenerating degraded areas and prevention of soil erosion.

Encouraging the plantation of fodder and other multipurpose trees on agricultural lands to meet people's forest based needs, to revive the silviculture division at Haldwani to promote farm forestry in the foothills and Terai, using the resources of non-wood forest products including medicinal plants, and use of alternative energy technologies and interventions and sustainable agricultural practices are also in the government agenda.

Population density : 159 km⁻² (Figure 64)

Total protected area : 13.4 % (7138.8 km²)

Total forested area : 24536 km² (46% of total geographic area)

Major Biogeographic Zones : 1. West Himalaya (2B) and 2. Lower Gangetic Plain (7A)

Major ecoregions of Uttaranchal:

Eco Regions	Area (sq km)
Western Himalayan sub alpine conifer forests	446
Terai-Duar savanna and grasslands	717
Upper Gangetic plains moist deciduous forests	1879
Western Himalayan broadleaf forests	3962
Himalayan subtropical pine forests	6677

Temperature range : Minimum average 6.6° C, Maximum average 41.3° C

Precipitation : Mean 217 cm Range 124 to 259 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 28%

Forested area of tehsils where tiger is currently reported: 13954 km² (56.9% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 65) (Appendix 7):

Priority I : 3358 km²

Priority II : 9690 km²

Priority III : 8252 km²

Figure 64 Map of Uttaranchal showing distribution of human settlements, tiger reserves and human population densities

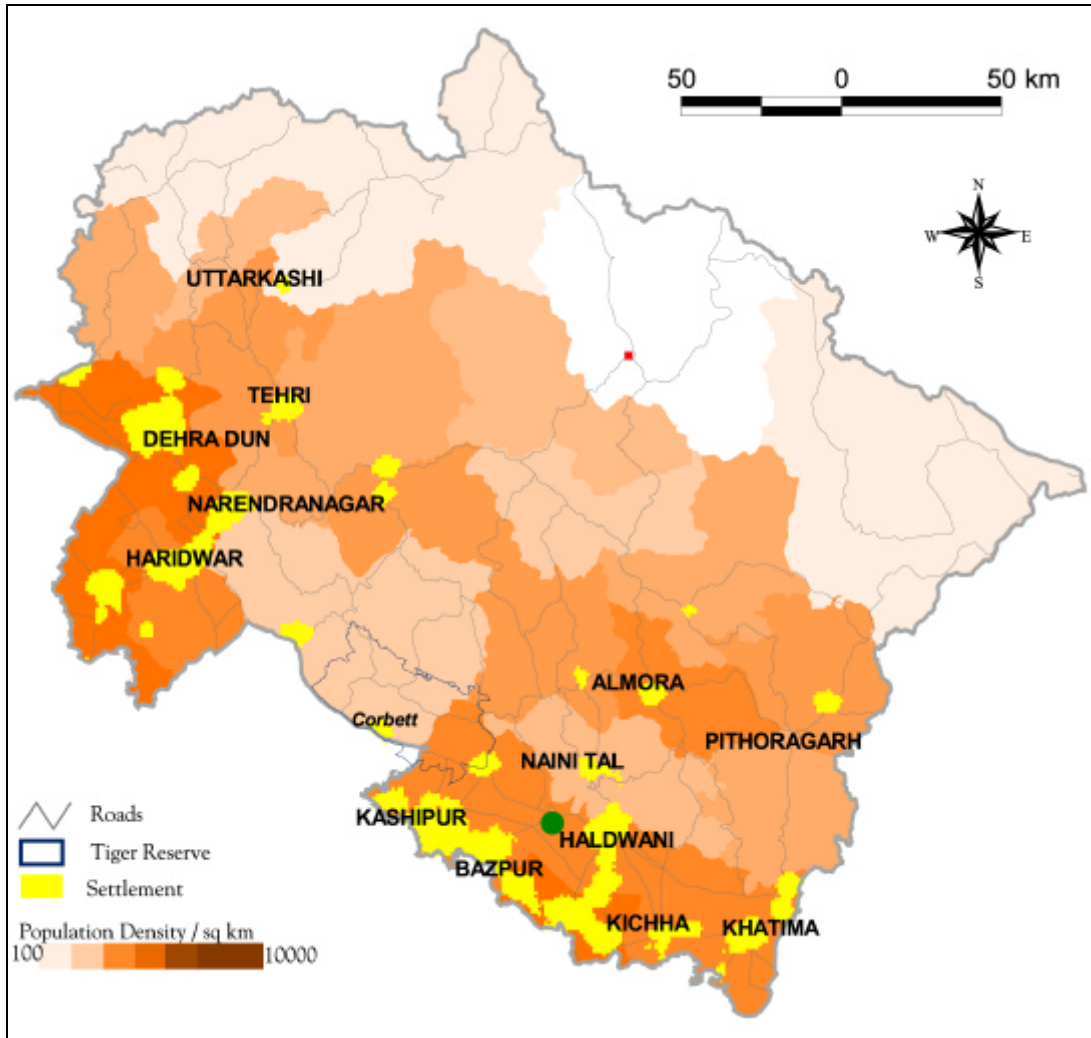
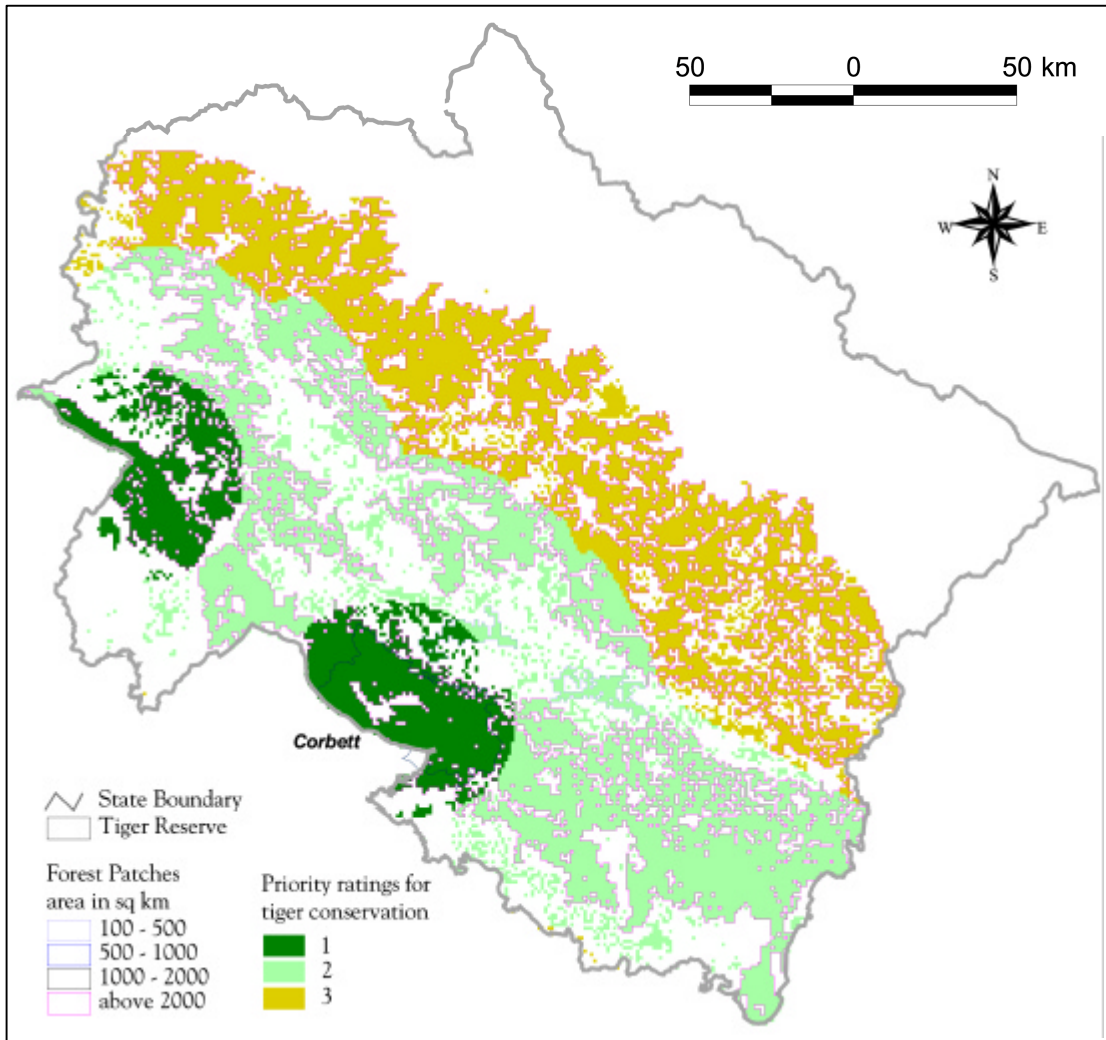


Figure 65 Priority areas within Uttarakhand for conservation of tiger source populations and maintaining connectivity



UTTAR PRADESH

Most of the state is dominated by the Gangetic plain biogeographic zone, - one of the most fertile areas in the world. To its north is to be found parts of the recently uplifted Shivalik hills and adjacent bhabar and terai tracts. While most of the original vegetation of the plains are converted into croplands, - patches of deciduous forest and attendant wildlife are still to be found in the terai-bhabar tracts. These tracts form the largest part of the Shivalik – Gangetic plains landscape complex of present study.

Centuries ago the area was rich in wildlife but most populations have disappeared before almost total agricultural land use. Western areas still hold small relict population of nilgai, blackbuck, and chinkara interspersed with dense cultivation. The northern terai grasslands comprise of a mosaic of dry and moist deciduous forests, scrub savannah and productive alluvial grasslands. These parts still hold small relict populations of diverse and rich fauna including a few globally endangered species like the tiger, elephant, one-horned rhinoceros and swamp deer. Other endemic and obligate species found in this Landscape are hog deer, hispid hare, Bengal florican and swamp francolin.

Once a safe repository of the biodiversity of the rich Gangetic plains, - now a lot of problems pester the conservation scenario of this state. Just a little over 7% of land area in the State is under forest cover. This is indicative that the State lacks natural wildlife habitats. Even in this, the PA coverage (< 2%) is far less than the desired norms. Also, due to unresolved issues of settlements of rights and lack of proper plans for most PAs, cause great impediment in achieving the desired goals. On account of depletion and fragmentation of natural habitats various floral and faunal species in the State have been listed under threatened category. These species, presently do not find desired conservation inputs from State/Central Government. The State faces heavy livestock pressure (density 283 animal per km²) on land and biological resources. However, the productivity level of the cattle is low due to poor quality of the animals. Since most of the Biodiversity rich forests also contain the mineral wealth and also the best sites for water impoundment, mining and developments projects in such areas have often led to destruction of habitats. Poaching and illegal trade of wildlife products too have adversely affected biological diversity in the State.

Population density : 689 km⁻² (Figure 66)

Total protected area : 2.4 % (5712.5 km²)

Total forested area : 14424 km² (6% of total geographic area)

Major biogeographic zones : 1. Semi Arid (Punjab Plains (4A) & Gujarat Rajputana (4B), 2. Deccan Peninsula (Central Highlands (6A) & Chotta-Nagpur (6B) and 3. Upper Gangetic Plain (7A)

Major ecoregions of Uttar Pradesh :

Eco Regions	Area (sq km)
Himalayan subtropical pine forests	23
Kathiawar-Gir dry deciduous forests	119
Terai-Duar savanna and grasslands	527
Himalayan subtropical broadleaf forests	585
Narmada valley dry deciduous forests	1000
Lower Gangetic plains moist deciduous forests	1198
Chhota-Nagpur dry deciduous forests	1204
Upper Gangetic plains moist deciduous forests	19075

Temperature range : Minimum average 6.6° C, Maximum average 41.3° C

Precipitation : Mean 94 cm Range 56 to 150 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 53%

Forested area of tehsils where tiger is currently reported: 8615 km². (59.7% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 67) (Appendix 7):

Priority I : 1264 km²

Priority II : 1911 km²

Priority III : 4984 km²

Figure 66 Map of Uttar Pradesh showing distribution of human settlements, tiger reserves and human population densities

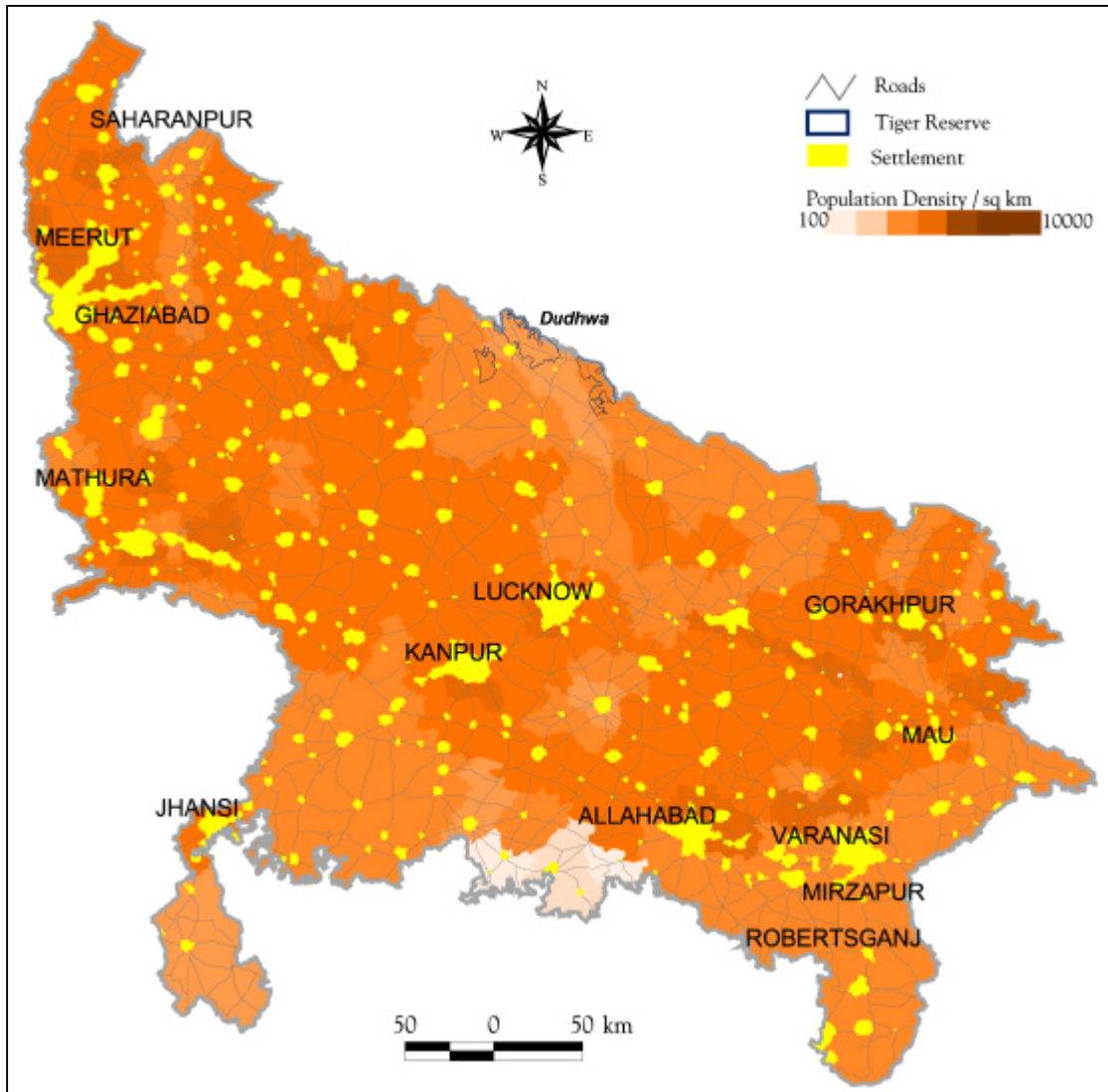
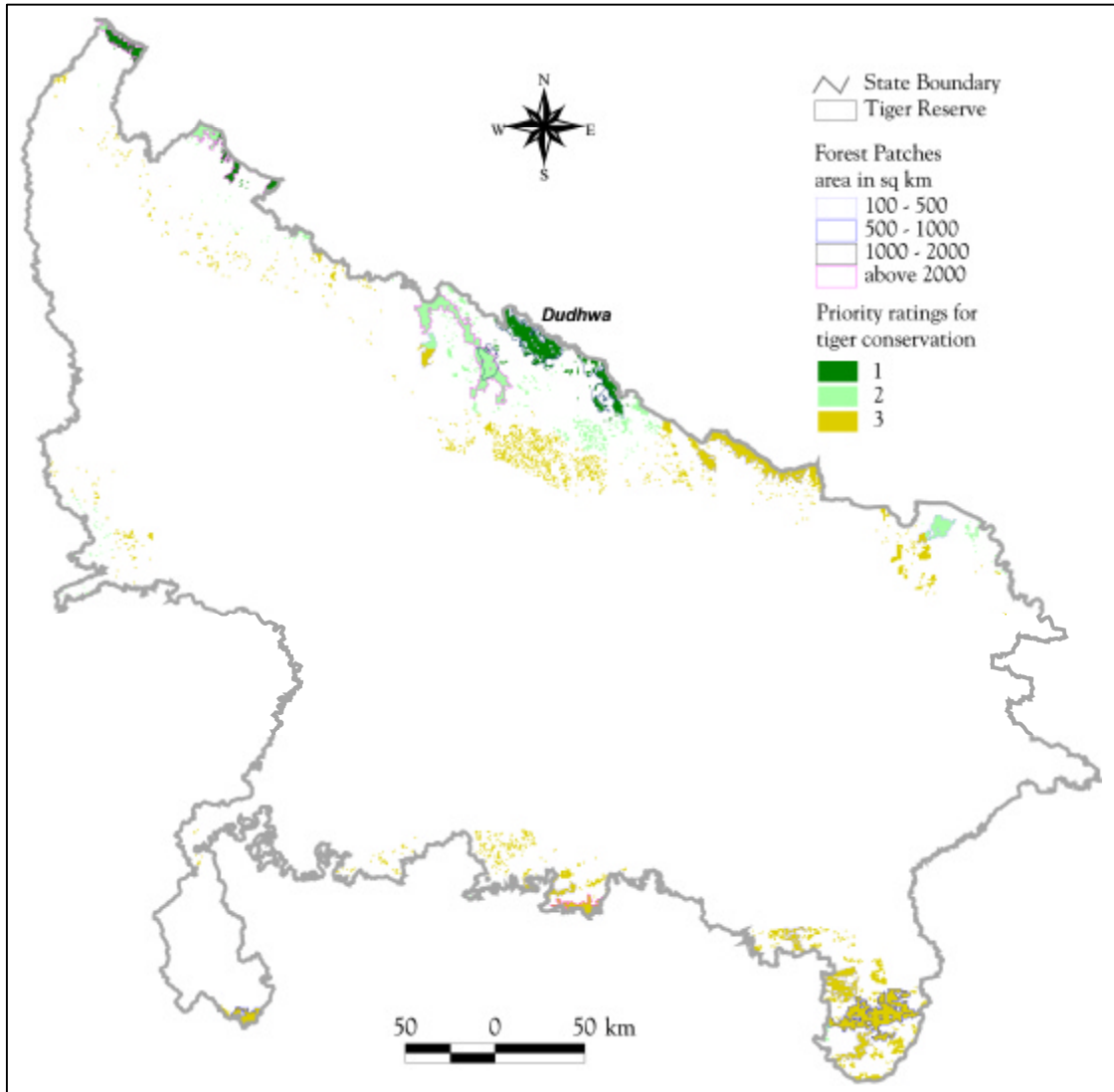


Figure 67 Priority areas within Uttar Pradesh for conservation of tiger source populations and maintaining connectivity



WEST BENGAL

The relatively small size of west Bengal belies its biological diversity due to the altitudinal changes from the Himalayas through the duars forests to the plains of lower Bengal and the mangroves of the Sunderbans. It is corroborated by the fact that there are as much as 4 biogeographic zones within its periphery. In context of the present study, West Bengal harbours two landscape complexes, - whole of the Sunderbans, and a tiny bit of the North East Hills and Brahmaputra Flood Plains at its northern reaches.

The state has a profusion of biological values. The Himalayas are important for their vegetation cover, and for the great range of vegetation varying with altitude. West Bengal harbours a fair share of the vast Himalayan biodiversity. About 40% of total Himalayan flora is endemic with the majority occurring in the eastern flank. Of the Gymnosperms, 15 species occur in eastern Himalayas with at least 5 genera being confined only to the region. Of the Pteridophytes (fern and fern allies), 70% of polypodiaceous taxa of India are concentrated in Eastern Himalayas. Among Bryophytes, nearly 20% of 2800 Indian moss species are known from this region. More than 15 species of carnivorous plants (*Drosera*, *Aldrovanda*, *Urticularia* etc.) are recorded from the zone. These forests are also rich in birds and smaller mammalian communities. The duars or Himalayan foothill forests and grasslands have an abundance of large mammal species, including tiger, elephant, rhino and gaur. These forests are part of a continuous wildlife system from Arunachal Pradesh through Bhutan and Assam to West Bengal.

West Bengal represents 9% of the faunal species recorded in India. Study of the mammalian fauna of West Bengal revealed 175 species belonging to 108 genera, 34 families and 12 orders. Species richness is obvious from the fact that West Bengal is only 11th among the states of India as far as the area is concerned, but houses about 44.8% of the mammalian species of the country.

The plains are intensely settled with little remaining natural grasslands or forests. The swamps however, do harbour significant populations of migratory waterfowl.

The Sunderbans mangrove is part of the subcontinent's largest mangrove system and contains the country's largest tiger population in a unique ecological setting. These forests have significant saltwater crocodile, estuarine and marine turtle and bird populations (Rodgers and Panwar 1988).

Population density : 904 km⁻² (**Figure 68**)

Total protected area : 3.26 % (2896.5 km²)

Total forested area : 10842 km² (excluding mangroves) (12% of total geographic area)

Major biogeographic zones : 1. Central Himalaya (2C), 2. Deccan Peninsula – Chotta Nagpur (6B), 3. Lower Gangetic Plain (7B) and 4. East Coast (8B)

Major ecoregions of West Bengal :

Eco Regions	Area (sq km)
Brahmaputra valley semi-evergreen forests	14
Eastern Himalayan sub alpine conifer forests	18
Himalayan subtropical broadleaf forests	109
Himalayan subtropical pine forests	112
Eastern Himalayan broadleaf forests	251
Eastern highlands moist deciduous forests	252
Terai-Duar savanna and grasslands	585
Sundarbans mangroves	813
Sundarbans freshwater swamp forests	948
Lower Gangetic plains moist deciduous forests	2046
Chhota-Nagpur dry deciduous forests	4440

Temperature range : Minimum average 7.4° C, Maximum average 40.8° C

Precipitation : Mean 207 cm Range 108 to 318 cm

Tiger habitat status:

Percent area of the state in terms of districts from which tigers have become locally extinct : 47%

Forested area of tehsils where tiger is currently reported: 2649 km² (24.4% of forested area) (Appendix 7)

Areas for tiger conservation priority (Figure 69) (Appendix 7) :

Priority I : 2977 km²

Priority II : 2539 km²

Priority III : 1228 km²

Figure 68 Map of West Bengal showing distribution of human settlements, tiger reserves and human densities

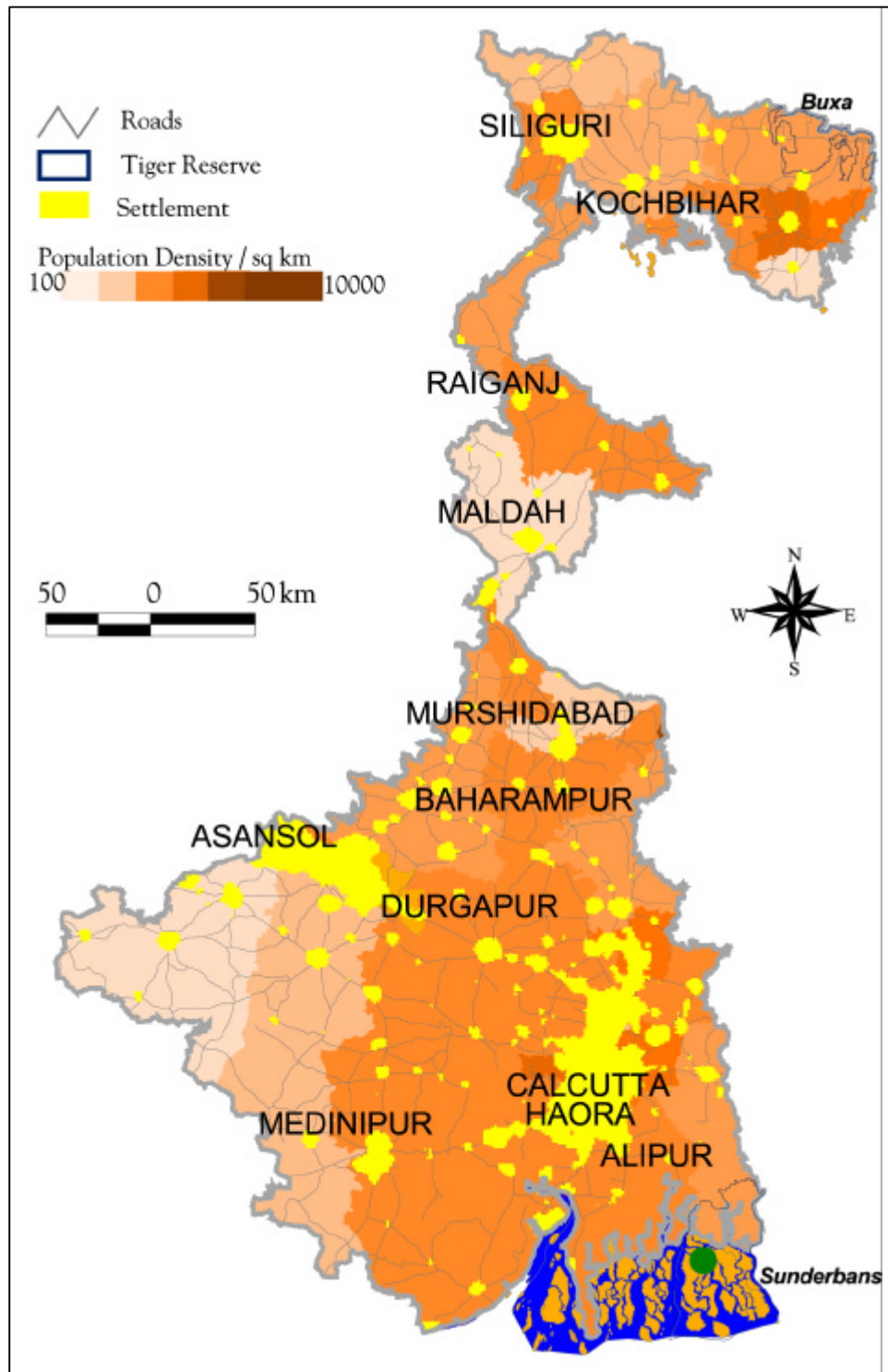
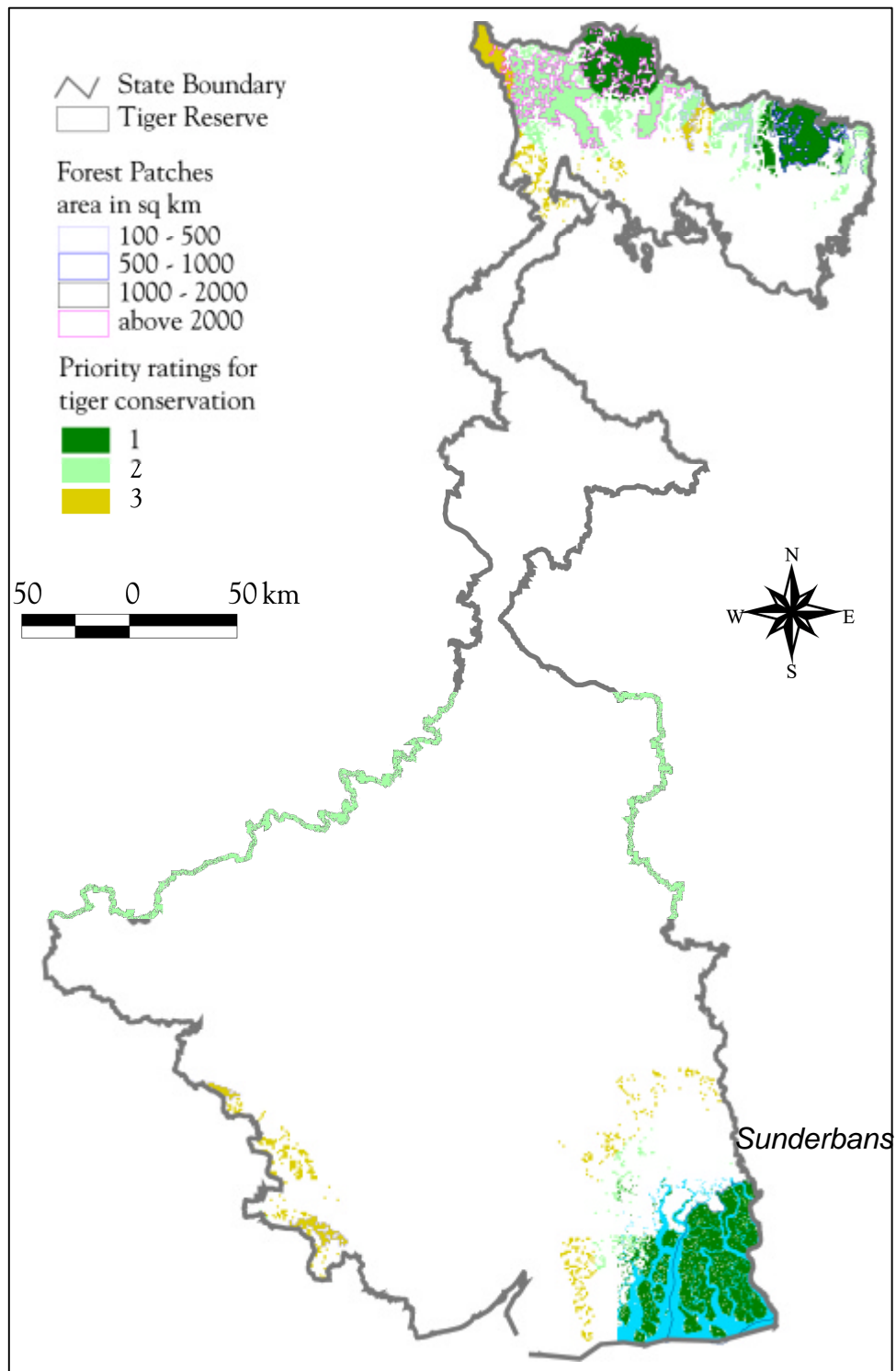


Figure 69 Priority areas within West Bengal for conservation of tiger source populations and maintaining connectivity



Scope and Application of the Study

With increasing human population and demand for land, conserving existing forests both in terms of extant and quality would be a difficult task. If resources for conservation become limiting, advance priority setting becomes a prudent strategy.

The current report has use in identifying landscape units within each landscape complex and State, which have the potential to sustain meta- populations and demographically viable individual populations of tigers. The report identifies the weak links within and between landscapes that need to be secured for maintaining or enhancing currently existing corridors. The report classifies forests within landscape units into 3 priority criteria (1) Priority-I areas are extremely important as source population habitats that need to be secured and safeguarded. The value of a landscape for tigers is dependent on these Priority-I areas from where tigers disperse to populate less suitable areas. Priority I areas are by themselves too few and small for long term tiger population persistence due to demographic and genetic stochasticity. If the Priority I areas become further isolated due to loss of Priority II and III habitats, long term survival of the tiger in the landscape is doubtful. Priority II forests primarily serve to sustain tigers dispersing from the source and serve as low density sources. Priority II forests alongwith Priority-III forests form vital links within the landscape. These are lifelines for tigers to exchange genetic material between two or more source populations.

The analysis at this low resolution has shown that even though the tiger has lost ground during the past 100-150 years, there is still substantial habitat available in India for the species. Tigers have occupied and uniquely adapted ecologically and behaviorally within each landscape complex. It is not only important to conserve tigers as a species, but also to conserve tiger populations with these unique adaptations. Thus, tiger populations in each landscape complex are equally important for conservation.

Considering landscape characteristics alone, the North-Eastern Hills and Bhramaputra plains, Central Indian landscape complex, and Western Ghat complex have a high potential for long term conservation of tigers. Each of these landscapes (especially Central Indian and Western Ghats complex) have several source populations with a potential of demographic and genetic exchange between these sources. The limiting factors, therefore, seem to be habitat quality in terms of prey availability and poaching of tigers. Many of the Tiger Reserves and National Parks (barring a few that have problems of insurgency and therefore control of areas) are secured as source populations of tigers. These sources need to be offered continued maximum protection. However, what seems crucial for the future survival of tigers is the connectivity between these source populations within landscape units, and

between landscapes in a meta-population framework. These connectivities primarily exist outside of the protected area network and are fast disappearing. The time has come to look beyond the protected area network, at the linkages within landscapes for effective conservation. Securing these crucial linkages by ecologically sensitive land use is the need of the hour. This report helps in identifying these linkages that need to be targeted for conservation efforts.

A major limitation of this report is the resolution of the data sets. Tiger and prey presence/absence is inferred at the resolution of a tehsil. If a small part of the tehsil is forested and has tigers, then the entire tehsil is scored as tiger occupied thereby increasing “noise” in the data. Another limitation of the current analysis is that we primarily use landscape characteristics to understand patterns governing occupancy of an area by tigers. Though we used prey presence/absence as an explanatory variable in estimating potential tiger occupancy of a 10 x 10 km grid, this data set also suffers from the same resolution problem discussed earlier for the tiger data. In the absence of high resolution data, inferences of this report can only be viewed in the broader landscape resolution context.

A better approach would be to infer tiger occupancy of smaller spatial units with associated explanatory variables also obtained at the same scale. Since a rapid assessment was required for identifying potential tiger habitat to set priorities for conservation at a broad landscape scale we used the data obtained by a questionnaire survey to arrive at this coarse level inference. A more detailed and reliable site specific analysis would be attempted from the data generated during the “phase-I” exercise of the all India tiger status survey conducted at the fine resolution of a forest beat (20 km² on the average) along with tiger prey and habitat status (Jhala et al. 2005).

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APPENDIX 1 References for evaluating the historical distribution of tigers in India

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APPENDIX 2 **Details of spatial and attribute data used for assessing patterns of tiger distribution**

Biogeography

We have used biogeographic classification based on Rodgers and Panwar (1988) and Ecoregion classification by Wikramanayake et al. (2002).

Biogeographic Classification of India

BIOCODE	ZONE	PROVINCE
1A	Trans Himalaya	Ladakh Mountains
1B	Trans Himalaya	Tibetan Plateau
2A	Himalaya	North-West Himalaya
2B	Himalaya	West Himalaya
2C	Himalaya	Central Himalaya
2D	Himalaya	East Himalaya
3A	Desert	Thar
3B	Desert	Katchchh
4A	Semi-Arid	Punjab Plains
4B	Semi-Arid	Gujarat Rajputana
5A	Western Ghats	Malabar Plains
5B	Western Ghats	Western Ghats Mountains
6A	Deccan Peninsula	Central Highlands
6B	Deccan Peninsula	Chotta Nagpur
6C	Deccan Peninsula	Eastern Highlands
6D	Deccan Peninsula	Central Plateau
6E	Deccan Peninsula	Deccan South
7A	Gangetic Plain	Upper Gangetic Plain
7B	Gangetic Plain	Lower Gangetic Plain
8A	Coasts	West Coast
8B	Coasts	East Coast
8C	Coasts	Lakshadweep
9A	North-East	Brahmaputra Valley
9B	North-East	North-East Hills
10A	Islands	Andaman
10B	Islands	Nicobar

Table 1 Details of remotely sensed data used for analyzing patterns governing tiger occupancy.

	<i>Dataset</i>	<i>Sensors</i>	<i>Spatial Resolution</i>	<i>Radiometric Resolution</i>
1	Forest Cover	IRS 1D LISS III	23.5 m	4 Multispectral bands
2	Normalized Difference Vegetation Index (NDVI)	Advanced Very High Resolution Radiometer (AVHRR)	1000 m	3 Multispectral bands
3	Digital Elevation Model (DEM)	Shuttle Radar Topography Mission (SRTM)	90 m	2 bands
4	<i>Night-time visible lights</i>	US Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS)	1000 m	1 band

Night Light Data

Night light data was obtained from NOAA/NGDC using the Defense Meteorological Satellite Program's Operational Line-scan system (DMSP/OLS) for a pixel size of 2.7 km x 2.7 km. The visible (0.47 - 0.95 μm) and near-infrared (VNIR) spectral bands which are sensitive to the night-time light of cities, towns, fires, lightning, etc. are useful for mapping human habitation (Elvidge et al. 1997b). The high contrast between lit and unlit areas and the sensor's spatial resolution makes it a useful tool to identify regions of intense human activity (Croft 1973, 1978).

AVHRR-NDVI

Normalized difference vegetation index (NDVI) composites with 10-day interval for four years were derived from the 1-kilometer (km) advanced very high resolution radiometer (AVHRR) data acquired by the National Oceanic and Atmospheric Administration's (NOAA) Television Infrared Observation Satellite (TIROS) (Townsend 1995).

Advanced Very High Resolution Radiometer (AVHRR) to derive the Normalized Difference Vegetation Index (NDVI), is a way to quantify the biomass of actively photosynthesizing vegetation (Eidenshink, 1992). The relationship between NDVI and vegetation is well documented (Birkey, 2001; Rahman, 2003). NDVI has been used to predict the vineyard leaf area index (Johnson et al., 2003), to monitor vegetation response, and to determine the change in vegetation cover over time. Species richness of vascular plants and mammals was related to a standard deviation and coefficient of variability of NDVI in Kenya (Oindo and Skidmore, 2002). NDVI maps were used to locate urbanization, forest, and other areas (Jones et al., 1997).

Ecoregion Mapping

Ecoregions of the Continents characterize global potential natural vegetation at approximately 1/2-degree resolution. The dataset is based on a Russian vegetation map prepared by Gerasimov in 1964 which was updated by the US Fish and Wildlife Service (Bailey and Hogg, 1986 and Bailey 1989). Projected to geodetic coordinates at the World Conservation Monitoring Center, England.

Code	Description
1	Rock and ice
2	Andaman Islands rain forests
3	Brahmaputra Valley semi-evergreen forests
4	Chin Hills-Arakan Yoma montane forests
5	Eastern highlands moist deciduous forests
6	Himalayan subtropical broadleaf forests
7	Lower Gangetic Plains moist deciduous forests
8	Malabar Coast moist forests
9	Maldives-Lakshadweep-Chagos Archipelago Tropical Moist Forest

10	Meghalaya subtropical forests
11	Mizoram-Manipur-Kachin rain forests
12	Nicobar Islands rain forests
13	North Western Ghats moist deciduous forests
14	North Western Ghats montane rain forests
15	Orissa semi-evergreen forests
16	South Western Ghats moist deciduous forests
17	South Western Ghats montane rain forests
18	Sundarbans freshwater swamp forests
19	Upper Gangetic Plains moist deciduous forests
20	Central Deccan Plateau dry deciduous forests
21	Chhota-Nagpur dry deciduous forests
22	East Deccan dry-evergreen forests
23	Khathiar-Gir dry deciduous forests
24	Narmada Valley dry deciduous forests
25	Northern dry deciduous forests
26	South Deccan Plateau dry deciduous forests
27	Himalayan subtropical pine forests
28	Northeast India-Myanmar pine forests
29	Eastern Himalayan broadleaf forests
30	Northern Triangle temperate forests
31	Western Himalayan broadleaf forests
32	Eastern Himalayan subalpine conifer forests
33	Western Himalayan subalpine conifer forests
34	Terai-Duar savanna and grasslands
35	Rann of Kutch seasonal salt marsh
36	Deccan thorn scrub forests
37	Northwestern thorn scrub forests
38	Thar desert
39	Goadavari-Krishna mangroves
40	Indus River Delta-Arabian Sea mangroves
41	Sundarbans mangroves
42	Northeastern Himalayan subalpine conifer forests
43	Central Tibetan Plateau alpine steppe
44	Eastern Himalayan alpine shrub and meadows
45	Karakoram-West Tibetan Plateau alpine steppe
46	North Tibetan Plateau-Kunlun Mountains alpine desert
47	Northwestern Himalayan alpine shrub and meadows
48	Pamir alpine desert and tundra
49	Western Himalayan alpine shrub and Meadows
50	Yarlun Tsangpo arid steppe
51	Baluchistan xeric woodlands

Forested areas in each ecoregion that currently harbour tigers or have potential tiger habitat were estimated.

Climatological Data

The precipitation data (New et al., 2002) was generated from a 10' latitude/longitude data set of mean monthly surface climate over global land areas. The climatology includes 8 climate elements —precipitation, wet-day frequency, temperature, diurnal temperature range, relative humidity, sunshine duration, ground frost frequency and windspeed—which

was interpolated from a data set of station means for the period between 1961 to 1990. This data was used to understand the influence of meteorological factors of tiger distribution and for evaluating potential tiger habitat.

Census data :

Human population data was obtained from the office of Registrar General, India for the year 1991, under the section Primary Census Abstract (PCA). The PCA gives the data on number of houses and households, total population, Scheduled Castes and Scheduled Tribes, population in the age group 0-6 years, number of literates, number of workers classified by industrial categories, marginal workers and non workers. These data are available at the resolution of the village level for rural areas, and at ward level for cities and towns. We summarised this data at the Tehsil level to model tiger distribution.

Forest Cover Map

Forest Cover map was obtained from Forest Survey of India (FSI 2003). The assessment is based on digital interpretation of satellite data for the entire country. LISS-III sensor data of IRS-1C satellite with a resolution of 23.5 m has been used. This was one of the main layers in the GIS that was used for deriving landscape characteristics.

Roads & Drainage

The roads and drainage maps of digital chart of the world (ESRI 1992) for the country at a scale of 1: 1000,000 was used. Euclidean distances and densities were generated using ArcGIS (ESRI) software.

Protected Areas

The locations of the Protected Areas, National Parks, Wildlife Sanctuaries, and Tiger Reserves were obtained from the Wildlife Database cell, Wildlife Institute of India and Project Tiger Directorate.

Core Areas

Forested habitats are like islands in a sea of human dominated landscapes. People living on the edges (and within forests) utilize these forests to varying degrees, depending on their life styles, legal status of the forests, and implementation of protection measures. These anthropogenic pressures penetrate inwards from the edges. To model these effects and to assess the amount of forest that likely remains free of such disturbances we buffered each forest patch with an inward buffer of 3 km. These buffered “disturbance free” patches are referred to as cores.

Landscape Characterisation

For the Landscape characterization and evaluation, fragmentation metrics like forest patch size, distribution and density, patch shape complexity and core area metrics were calculated using Fragstat (McGarigal and Marks 1995).

We derived Euclidian distance from protected areas, night light, drainage, roads and density of roads and drainage in 10 x 10 km grids to asses the human influence and habitat suitability (**Appendix 3**).

APPENDIX 3 Modeling Tiger Occupancy and Conservation Priority Tiger Occupancy

We used a questionnaire survey addressed to the Chief Wildlife Wardens of all tiger states. The questionnaire was directed to obtain data on the spatial distribution of tigers and its prey species at the administrative resolution of tehsils for the past five years based on the supervised knowledge of the forest department.

Though we obtained a crude estimate of tiger numbers at the tehsil resolution, we reduced this data to mere tiger presence or absence. A tehsil was considered to have tiger presence if tigers were reported from its forests at least once during the past 5 years (1999-2004). Tiger occupied tehsils were further classified into areas having reported tigers for (a) more than three years, (b) 3 years and (c) only 1-2 in the 5-6 year period. Since tiger presence in a forest patch is easy to detect due to its predatory habits on large ungulates and cattle, we believe that tehsils where tigers were not reported during the past 5 years were areas where tigers (established population) were truly absent. Tehsils that had contiguous forests with tiger bearing tehsils were likely to have occasionally dispersing tigers occupying these forests on a temporary basis. Such areas were unlikely to support a breeding tiger population but would serve as corridors between source populations. The nature of the data on tiger occupancy was at a coarse resolution (tehsils), since our main objective was to understand broad landscape patterns that make a habitat conducive for tiger occupancy. We use logistic regression (Augustin et al. 1996) instead of other multivariable techniques like Ecological Niche Factor analysis (Hirzel et al. 2002, Brotons et al. 2004), which considers only presence data for modeling spatial distribution. Once high resolution data on tiger presence/absence has been obtained at the forest beat level through Phase I of the ongoing population monitoring exercise (Jhala, Qureshi, and Gopal 2005), there will be greater possibilities of having false negatives (missing out on tiger presence). We would then use appropriate statistical models to address these issues (Boyce and McDonald 1999, Guisan and Zimmermann 2000).

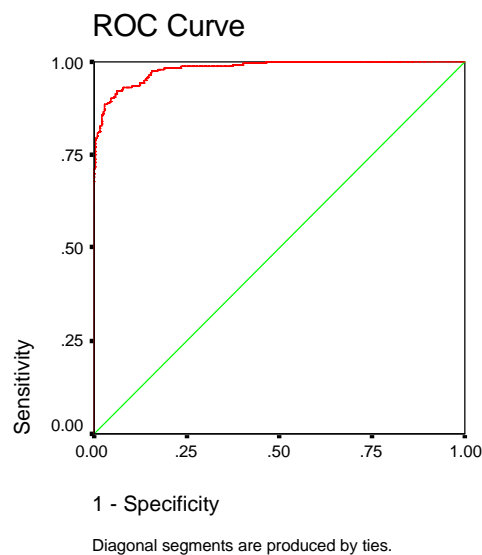
Each landscape complex was modeled separately. Forest cover was superimposed on the tehsil maps of each of the 17 tiger occupied states and those forest patches ≥ 15 km² that occurred in tehsils where tigers were reported were scored as "tigers present". The remaining forest patches were scored as "tigers absent".

A 10 x 10 km grid was then superimposed on this data and information on independent variables averaged for each grid. The matrix of values for "Tiger Present" and "Tiger Absent" grids (response/dependent variable) were then analysed using stepwise logistic regression. With a binomial dependent variable (presence/absence of tigers), logistic regression is often chosen when the predictor variables are a mix of continuous and

categorical variables. Logistic regression makes no assumptions about the distributions of the independent variables. Receiver Operator Characteristic (ROC) Curves were used to test model fit.

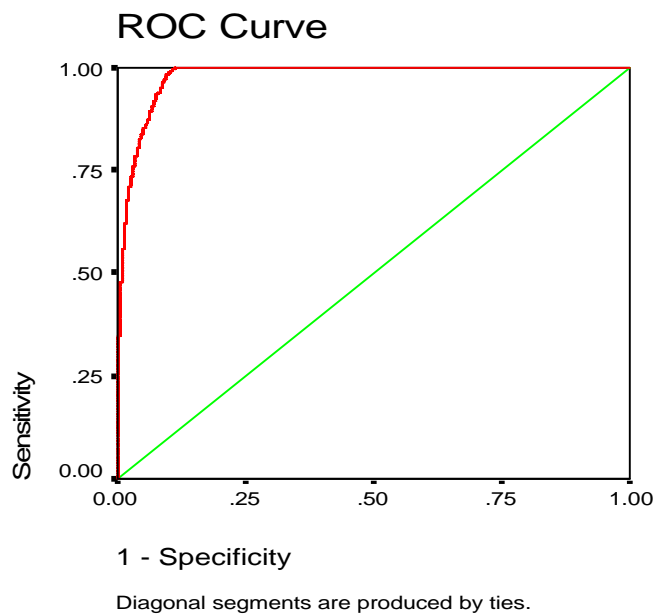
The significant predictor variables used by the logistic regression to predict tiger occupancy of the 10 x 10 km grids were mean and variation in Normalized Difference Vegetation Index (NDVI), area of forest cores, forest patch size, human density, mean and variation in annual precipitation, drainage density, road density, distance to and area of night light (human settlements), human population dependent on forest resources, tiger prey presence, and forest patch shape index. The potential tiger habitat was mapped using probability of prediction by the logistic regression greater than 50 percent.

ROC curve for evaluating logistic regression results for Shivalik and the Gangetic Plain Landscape Complex



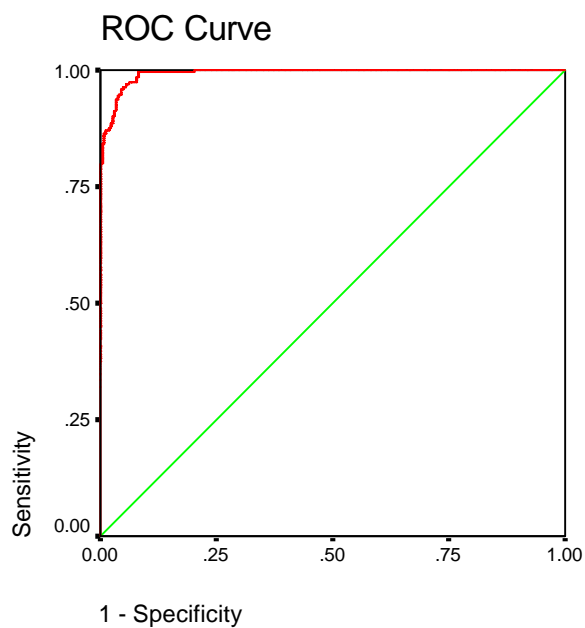
ROC area = 0.982 (P= 0.001)

ROC curve for evaluating logistic regression results for Central India Landscape Complex



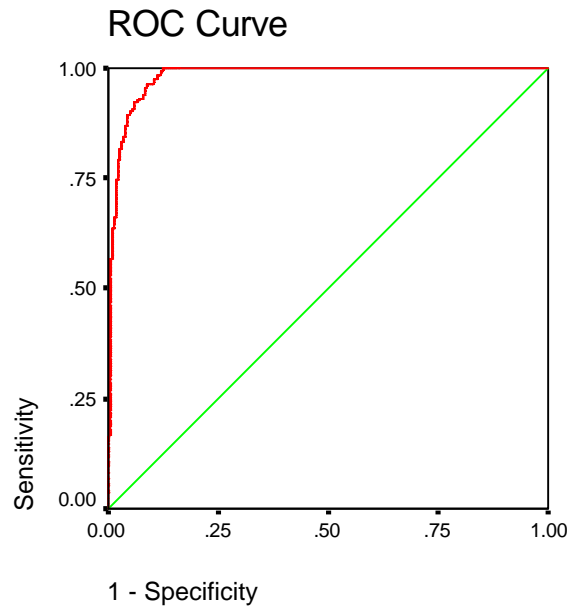
ROC area = 0.980 (P= 0.001)

ROC curve for evaluating logistic regression results for North East Landscape Complex



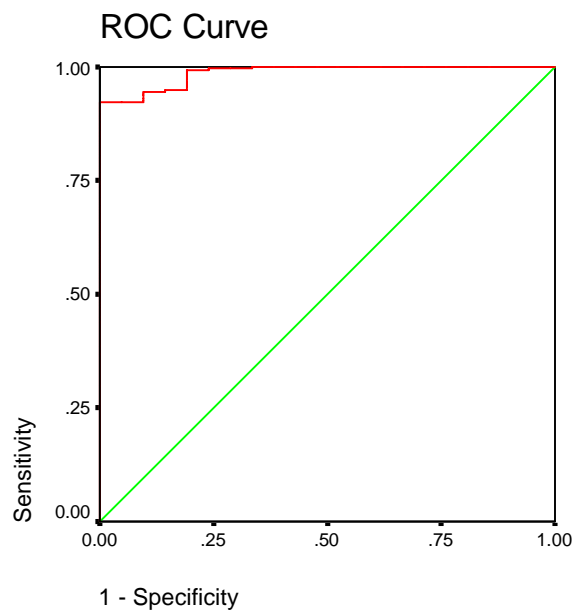
ROC area = 0.994 (P= 0.001)

ROC curve for evaluating logistic regression results for Western Ghats Landscape Complex



ROC area = 0.983 (P= 0.001)

ROC curve for evaluating logistic regression results for Eastern Ghats Landscape Complex



ROC area = 0.987 (P= 0.001)

Conservation Priority

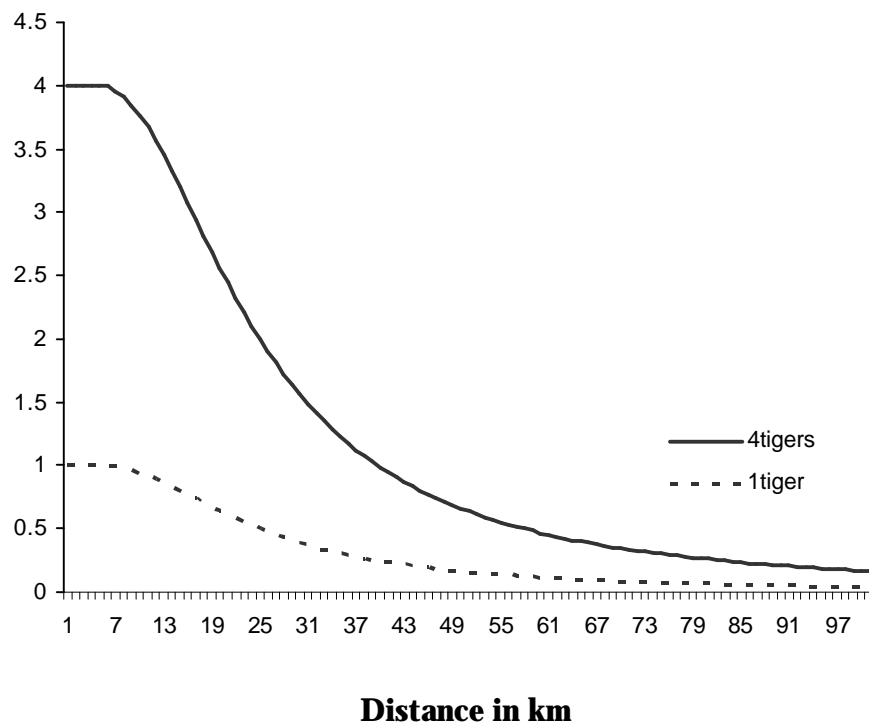
We considered tiger reserves and National Parks covering tiger occupied forests as having source populations of tigers. We further made a conservative assumption that tigers exist at a density of 4 per 100 km² in these tiger reserves and National Parks. Our objective for assuming this density was for modeling tiger dispersal on a relative scale and not to arrive at any absolute number. We further assumed that tigers could disperse from these source populations for a maximum distance of 100 km through forested habitat (Smith 1993). With higher number of dispersing individuals closer to the source and the density exponentially decreases to 1 tiger per 1000 km² at a distance of 100 km and beyond from the source in forested habitats (**Figure 70**).

We further assumed that if dispersing tigers from tiger reserves and National Parks encountered favourable habitats (as modeled by the logistic model) which was greater than 200 km², they established a low density population of 1 tiger per 100 km². Tigers could disperse from this low density population as well, but at a lower density gradient (**Figure 70**). A relative tiger density map that connected source populations through potential tiger habitat was created to prioritize the relative importance of habitats as source and connectivities between sources to target conservation efforts. The steps used for the GIS model were as follows :

- a) The probability rating of the habitat for tigers by the logistic model was used to generate a cost surface (higher the probability lower the cost) as an impediment to dispersal.
- b) An exponential decay function (**Figure 70**) was then generated which decreased hypothetical tiger densities from the source populations within a radius of 100 km in contiguous forested habitats.
- c) The cost surface map generated in (a) was then multiplied with the exponential decay function of tiger density from source populations (b). The resultant tiger density gradient was used as a relative scale to prioritize areas as high priority (Priority-I), medium priority (Priority II) and low priority (Priority III) areas for tiger conservation.
- d) Forest patches were then vectorised from the raster data, categorised into various size classes and boundaries superimposed on the tiger conservation priority map (c) to assess contiguity between source population of tigers and potential for existing in a metapopulation framework.

These combined maps were used for priority rating and for relative conservation importance of areas within landscapes.

Figure 70: The decay function for dispersing tigers from source (4 tigers/100 Km²) and nonsource areas (1 tiger/100 Km²) estimated by equation $\mu = 1/(1+((x-c)/(c-d))^2)$ where c and d are the inflection points.



APPENDIX 4 Characteristics of Landscape Complexes

	Landscape Complexes					
	Central	Eastern-ghats	Shiwalik-Gangetic Plain	North-East-Hills and Brahmaputra valley	Western-ghats	Sunderbans
Geographic Area	1170220	120764	422675	271129	281726	2585
Forest	369987.80	24580.92	93094.82	142775.36	92334.97	1473.65
Past Tiger Area	796128	28673	80197	167117	151284	
Tiger Forest	178998.00	21034.00	22326.00	104053.00	36316.00	1473.65
Probability Tiger Forest	156548.00	15837.00	20807.00	64295.00	51808.00	
NP-E	7683.43	352.62	2166.89	3253.23	1842.74	2585.00
NP-P	125.00	1500.00	0.00	1200.00	500.00	
WS-E	15263.98	363.74	1874.83	4587.33	6458.97	
WS-P	2667.00	200.00	450.00	3486.00	1208.21	
Total Protected Area Existing	22947.41	716.36	4041.72	7840.56	8301.71	2585.00
Total Protected Area Proposed	2792.00	1700.00	450.00	4686.00	1708.21	
Number of patches	19405	2062	5660	3824	4983	737
Patch density per 1000 km²	9.4	8.6	3.5	4.5	6.1	12.27
Largest patch index	1.45	2.69	1.3	3.497	4.56	5.9146
Patch area: Mean (km²)	13.63	7.58	11.48	18.05	13.68	3.05
Patch area: Coefficient of Variation	2483.55	2010.29	2526.8	2935.123	3939.535	0
Perimeter area ratio: Mean	34.22	36.11	33.8	34.239	34.578	16.6383
Perimeter area ratio: Standard Deviation	8.3	6.79	8.2	7.976	7.586	47.0095
Total core area (km²)	30272	4371	3337	15588	11123	534.42
Number of disjunct core areas	1013	33	233	241	242	0
Disjunct core area density/1000 sq. km.	0.5	0.1	0.1	0.3	0.3	128
Core: Mean (km²)	1.04	1.15	0.59	3.03	2.03	0.72
Landscape shape index	1.0077	1.0100	1.0004	1.0033	1.0033	1.2395

APPENDIX 5 Details of Bioregions of India

Bio-regions	Bio- Province	Geographic Area	Forest Area	Historically tiger occupied district area	Forest areas occupied by tigers	Potential tiger habitat
1A	Ladakh Mtns	109223	4879			
1B	Tibetan Plateau	74534	831			
2A	North-West Himalaya	68794	25739	311		21
2B	West Himalaya	50455	14865	17487	3758	4137
2C	Central Himalaya	5275	1752	1534	152	348
2D	East Himalaya	79229	14514	43126	14499	4852
3A	Thar	171799	6662	26		
3B	Katchchh	18421	1750	441		
4A	Punjab Plains	119523	20750	6279	56	105
4B	Gujarat Rajputana	389869	47811	196033	10071	8264
5A	Malabar Plains	65426	21143	36418	5683	6336
5B	Western Ghats Mtns	64915	26088	54948	10483	15569
6A	Central Highlands	232349	60830	161198	34885	30826
6B	Chotta-Nagpur	171498	48544	101650	7196	4388
6C	Eastern Highlands	201096	59516	173360	32212	28682
6D	Central Plateau	398443	51438	202435	19979	13222
6E	Deccan South	339468	49977	106914	16016	13009
7A	Upper Gangetic Plain	199662	19236	71649	7034	4906
7B	Lower Gangetic Plain	142480	7692	50932	1675	1353
8A	West Coast	56149	3969	4946	245	180
8B	East Coast	59964	4650	8516	1101	101
9A	Brahmaputra Valley	63832	15140	45042	13479	10757
9B	North-East Hills	100904	34405	59201	3983	5888

APPENDIX 6 Details of ecoregions and their potential to support tiger populations

Ecoregion name	Geographic area	Forest area	Forest area of tehsils with tiger	Potential tiger habitat
Brahmaputra Valley semi-evergreen forests	54205	12021	10118	7801
Central Deccan Plateau dry deciduous forests	232259	34288	12528	12698
Chhota-Nagpur dry deciduous forests	117429	30770	4155	3
Deccan thorn scrub forests	330152	31308	7280	4534
East Deccan dry-evergreen forests	25367	2820	651	236
Eastern highlands moist deciduous forests	328470	95446	54768	42219
Eastern Himalayan alpine shrub and meadows	12039	3442	3056	2
Eastern Himalayan broadleaf forests	49552	6584	6030	3867
Eastern Himalayan subalpine conifer forests	12217	3312	2916	6
Goadavari-Krishna mangroves	6471	703		7
Himalayan subtropical broadleaf forests	5496	939	777	629
Himalayan subtropical pine forests	42964	19164	3841	4437
Khathiawar-Gir dry deciduous forests	256205	34274	8217	5879
Lower Gangetic Plains moist deciduous forests	140079	10961	551	425
Malabar Coast moist forests	34606	8839	2616	2612
Meghalaya subtropical forests	39950	8457	5911	6108
Mizoram-Manipur-Kachin rain forests	55738	18817	2491	3623
Narmada Valley dry deciduous forests	163120	42319	21928	18175
North Western Ghats moist deciduous forests	46885	14442	1615	2265
North Western Ghats montane rain forests	30350	14716	4386	7581
Northeastern Himalayan subalpine conifer forests	5054	1448	1430	43
Northern dry deciduous forests	56127	14536	4921	5071
Orissa semi-evergreen forests	21412	3850	1862	1011
South Deccan Plateau dry deciduous forests	82397	14457	1582	2801
South Western Ghats moist deciduous forests	23978	6880	4372	5058
South Western Ghats montane rain forests	22808	8391	4972	6636
Sundarbans freshwater swamp forests	6626	947	148	0
Sundarbans mangroves	4423	813	703	0
Terai-Duar savanna and grasslands	11406	1879	1269	1176
Upper Gangetic Plains moist deciduous forests	253300	26084	6809	4337
Western Himalayan alpine shrub and Meadows	13322	1512	17	24
Western Himalayan broadleaf forests	47683	18278	499	327
Western Himalayan subalpine conifer forests	11128	26356	14	55

APPENDIX 7 Landscape characteristics and potential tiger habitat of tiger occupied states

State	Geographic area	Total forest Area	Historically tiger occupied district area	Forested areas of tehsils with tiger presence	Area of potential tiger habitat km ²	Area under National Park km ²	%ge of area under National Park	Area under Wildlife Sanctuary km ²	% of area under Wildlife Sanctuary	Total Protected Area km ²	% of area under Protected Area	Area under Tiger Reserve km ²	Human Population density No./km ²	Priority-I	Priority-II	Priority-III
Andhra Pradesh	275069	54544	120898	53423	18578	373.2	0.1	12599.2	4.6	12972.4	4.7	3568	275	4409	11933	14798
Arunachal Pradesh	83743	68186	43077	68063	29476	2290.8	2.7	7606.4	9.1	9897.2	11.8	2795	13	12320	47507	4879
Assam	78438	27938	54330	25635	23375	1977.8	2.5	1932.0	2.5	3909.8	5.0	3211	340	4352	16007	6345
Bihar	94163	5842	33702	965	869	335.7	0.4	2949.12	3.1	3284.8	3.5	840	880	604	227	35
Chhattisgarh	135191	56648	130359	27967	34757	2929.5	2.2	3409.1	2.5	6338.6	4.7	2799	154	6016	20650	21505
Jharkhand	79714	23613	44829	8150	384	231.7	0.3	1862.7	2.3	2094.4	2.6	1026	338	2623	4487	5143
Karnataka	191791	40236	96287	15539	25769	2472.2	1.3	3888.1	2.0	6360.3	3.3	2000	275	6587	17595	4955
Kerala	38863	15631	16348	14298	14857	558.2	1.4	1859.1	4.8	2417.2	6.2	777	819	5330	8037	1305
Madhya Pradesh	308245	80717	203573	70010	62768	3656.4	1.2	7158.4	2.3	10814.8	3.5	5893	196	9627	30346	25292
Maharashtra	307713	53619	170478	13702	26483	955.9	0.3	14461.7	4.7	15417.6	5.0	2554	314	9349	14435	8342
Mizoram	21081	17961	15895	256	90	150.0	0.7	840.8	4.0	990.8	4.7	500	42	538	8546	9010
Orissa	155707	54620	96675	27424	30672	990.7	0.6	6969.2	4.5	7959.9	5.1	2750	236	2818	6553	29553
Rajasthan	342239	21292	113593	1835	529	4122.3	1.2	5447.0	1.6	9569.4	2.8	2200	165	593	1430	1603
Tamilnadu	130058	24662	23791	5129	8674	307.8	0.2	2539.8	2.0	2847.7	2.2	800	478	3785	4619	3480
Uttar Pradesh	240928	14424	72569	8615	5506	490.0	0.2	5222.5	2.2	5712.5	2.4	1362	689	1264	1911	4984
Uttaranchal	53483	24536	22528	13954	15303	4725.0	8.8	2413.8	4.5	7138.8	13.4	1316	159	3358	9690	8252
West Bengal	88752	10842	16600	2649	2204	1693.2	1.9	1203.3	1.4	2896.5	3.3	3344	904	2977	2539	1228

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