

Chapter 2

Ecological Biodiversity of Panchet Forest Division and Dalma Wildlife Sanctuary



Abstract This chapter starts with a detailed characterisation of the human–elephant conflict zone. We describe both the source and destination regions, providing information on their location, physiographic, climatic natural vegetation and administrative characteristics. We applied a variety of landscape ecological techniques to determine the ecological character of the studied area. A spatial analysis of heterogeneity was calculated through different patch metrics, including edge density, forest core, patch shape and Euclidean nearest-neighbour metrics, using FRAGSTATS and ArcGIS software. Moreover, detailed field survey–based information on the composition, pattern and association of plant species was collected through randomly selected microhabitats covering all forest beats (forest administrative units) of both the Dalma Forest area and the Panchet Forest Division. The nature of forests as elephant habitats was measured through patch arrangement and fractal dimension techniques. We identified different factors behind forest fragmentation, for example, temporal change in forest cover, shrinkage of forest cover because of agriculture and settlement expansion, construction of railways and roads, mining and quarrying activities. Patterns of temporal change in land use/land cover in general and forest cover in particular were identified by analysing Landsat TM images of 1970, 1980, 1990, 2000 and 2014. Finally, the effects of factors such as the construction of roadways and railways, mining and quarrying activities and forest encroachment in both the source and destination regions were examined through cartographic diagrams and geographical information systems.

Keywords Spatial analysis • Patch metrics • Temporal change of habitat

2.1 Introduction

The theory of ecological biogeography entails the relationship between species and their environment (de Candolle 1820) over geographical space and time. Here ‘environment’ refers to latitudinal factor or gradients, competition among species, geology of that area, climate, soil and other factors (de Candolle 1820). The association of plants and animals depending on these factors is variously known as a ‘biome’, ‘life zone’ or ‘ecoregion’ (Wagner and Sydow 1888, cited in Cox and Moore, 1931). The adaptations of both plants and animals within a specific environment are studied in ecophysiology. Both ecological biogeography and ecophysiology consider the importance of environmental factors for the distribution of plants and animals. In this chapter we give a detailed description of the ecological biogeography of both the source and destination regions of elephant migration in our study area. The original habitat of the migratory elephants is the Dalma Wildlife Sanctuary (DWS) and the destination ecoregion is the Panchet Forest Division (PFD). Actually, a paradigm shift has taken place, as Dalma elephants are no longer treated as migratory

elephants in West Bengal. Previously, fewer elephants used to come from the Dalma hills to southern West Bengal (where the PFD is situated) and stayed only for a very short period. Thus, they had originally been called 'Dalma elephants'. Now that large numbers of these elephants stay in southern West Bengal throughout the year, they should be called 'South Bengal elephants' (Kulandaivel 2010). This fact raises the issue of the habitat preference of elephants. Why do they prefer the newly formed habitat? To answer this question, it is necessary to identify the ecological biogeography of both regions, especially the destination region.

2.2 Destination Area

2.2.1 *Panchet Forest Division*

The PFD was previously known as the Panchet Soil Conservation Division. It was established on 1 April 1966. The objective behind the formation of this department was mainly to do soil conservation projects in upper Damodar catchments. The name was derived from the base name 'Panchet', a place where the Damodar River originates. It is located in Dhanbad district now in the state of Jharkhand. Initially, the headquarters were situated in Purulia district. In 1982, it was shifted to Bishnupur of Bankura district to control the flood and soil erosion of the Rupnarayan–Ajay catchment area, which comes under Bankura, Bardhaman and Birbhum districts. Several afforestation projects, including water harvesting schemes and the construction of check dams, were undertaken to control soil erosion. In 1995, this division was reorganised and converted into a territorial division incorporating the eastern portion of Bankura district. As of 1 November 1995, the Panchet Soil Conservation Division was excluded from the soil conservation circle and included under the central circle of forest, West Bengal, and newly known as Panchet Forest Division (Map 1.1).

2.2.2 *Geographical Boundaries*

PFD is one of the three forest divisions of Bankura district; the other two are Bankura North and Bankura South. Geographically, PFD extends between 22°53'N to 23°12'N latitude and 87°03'E to 87°42'E longitude, covering an area of 355.62 km². It is distributed among 5 community development blocks and 236 forest-bearing mouzas, or administrative districts, of Bankura district, West Bengal. The study area, PFD, is bounded by Patrasayer Police Station and Indus Police Station in the north, Hoogly district, Paschim Medinipur district and Simlapal Police Station of Bankura district in the south, Hoogly district in the east and Bankura Police Station in the west.

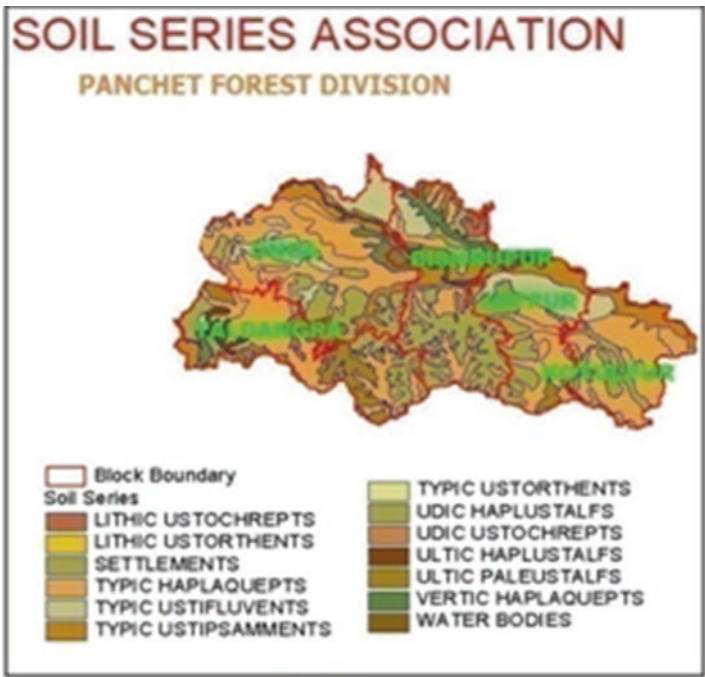
2.2.3 *Administrative Setup*

The PFD area is divided into five territorial forest ranges and 21 forest beats. The administrative structure is as follows:

Division	Name of the range	Name of the beat
Panchet Forest Division	Bishnupur	1. Bishnupur I
		2. Bishnupur II
		3. Basudevpur
		4. Chaugan
		5. Hereparvat
	Joypur	6. Adhkata
		7. Joypur
		8. Machantala
		9. Kuchiakole
	Taldangra	10. Taldangra
		11. Asna
		12. Panchmura
	Bankadaha	13. Bankadaha
		14. Amdangra
		15. Peardoba
		16. Uparsole
		17. Amdahara
	Onda	18. Chhagulia
		19. Krishnanagar
		20. Onda
		21. Chingani

2.2.4 *Geology and Physiography*

This area is an extended part of the Chota Nagpur Plateau. Geomorphologically, the study area is located where the margin of the Chota Nagpur Plateau descends to the alluvial flats of Damodar basin. Hence, the slope and relative relief gradually decrease towards the east. Some residual hills can be seen in the west. The continuity of the lateritic upland tracts has been broken by agricultural fields, which have replaced early river valleys. Thus, the area is clearly segregated into three distinct geomorphological units: lateritic upland with residual hills, upland margins and river valleys. The soil of the study area is mainly red and brown lateritic soil. The eastern part is covered by alluvial soil.



Map 2.1 Soil series association of Panchet Forest Division

2.2.5 Climate

The average annual rainfall of the study area is 1320 mm. The highest rainfall is seen from June to August, while the lowest rainfall is found from November to January. The average temperature is highest during April and May, at 38 °C, and lowest in December and January, at 15 °C (Figs. 2.1 and 2.2).

2.2.6 Natural Vegetation

Natural vegetation follows climatic and edaphic factors. According to the *Bengal Gazetteer*, this area was previously known as *Jangalmahal* (Bayley 1813), a Hindi term that means ‘dense, forest-covered area’. The entire area was covered by a deep jungle of sal trees (*Shorea robusta*) (O’Malley 1908). The forest composition includes associated species of sal and various tropical deciduous species (Table 2.1).

The legal status of ‘forest’ in this division is generally classified as reserved forest, protected forest, unclassified forest and non-forest land. Table 2.2 lists data from the division forest report about the size of each of these different forest areas.

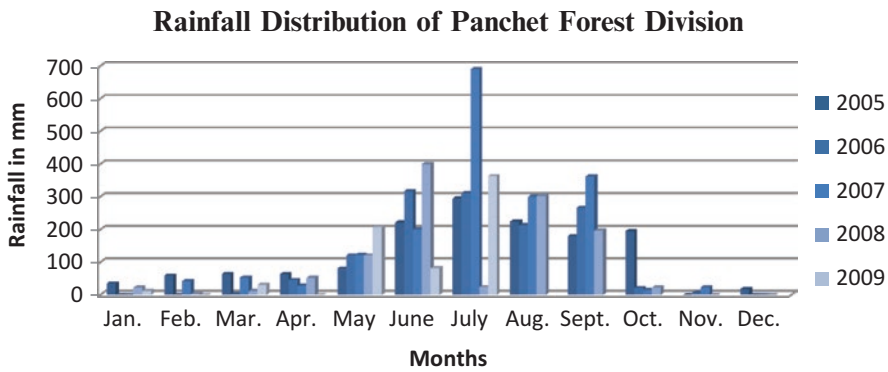


Fig. 2.1 Rainfall distribution of the Panchet Forest Division from 2005 to 2009

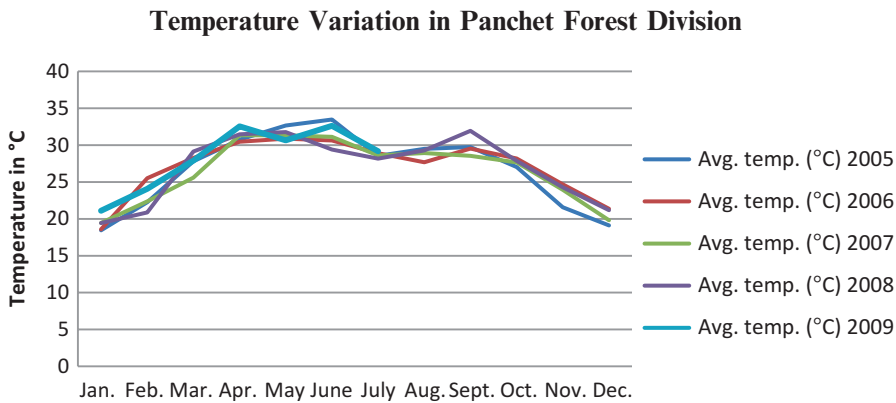


Fig. 2.2 Temperature distribution of the Panchet Forest Division in 2005–2009

2.3 Source Region

2.3.1 Dalma Wildlife Sanctuary

Dalma Wildlife Sanctuary (DWS) is situated in Purbi Singhbhum district of Jharkhand state. DWS encompasses a wonderworld of forest and has nearly unmatched natural beauty. The name of this sanctuary came from the Hindi word *Dalma*, meaning ‘the deity of forest,’ reflecting the belief that this forest is home to

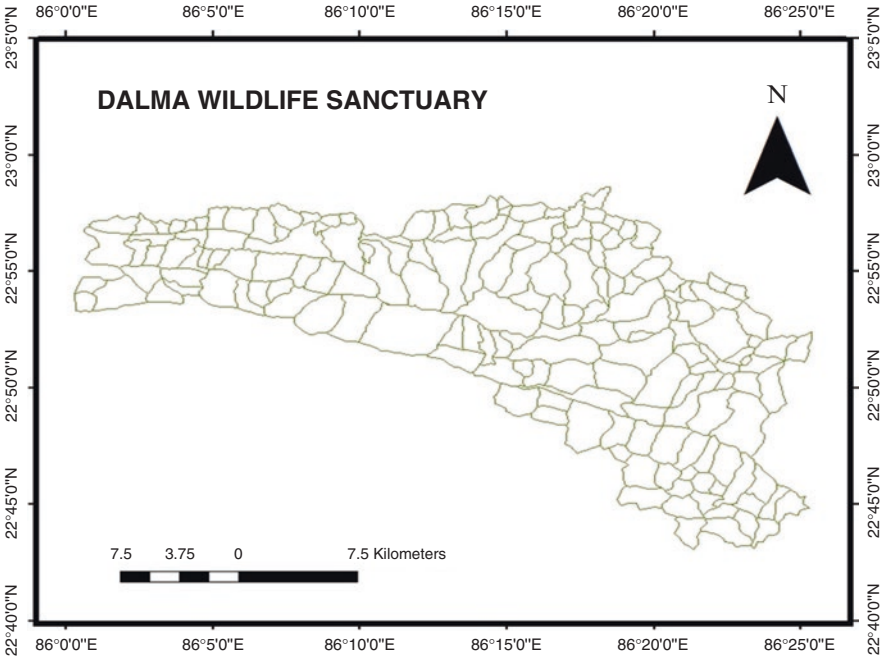
Table 2.1 Natural vegetation at Panchet Forest Division

SI no.	Local name (Trees)	Scientific name
1	Akashmoni	<i>Acacia auriculiformis</i> , syn <i>A. Moniliformis</i> , Linn.
2	Am	<i>Mangifera indica</i> Linn.
3	Amla	<i>Phyllanthus emblica</i> Linn.
4	Amra	<i>Spondias mangifera</i> Linn.
5	Anjan	<i>Hardwickia binata</i> Roxb.
6	Ankura	<i>Alangium lamarckii</i> Lamk.
7	Arjun	<i>Terminalia arjuna</i> Linn.
8	Asan	<i>Terminalia tomentosa</i> Linn.
9	Aswatha	<i>Ficus religiosa</i> Linn.
10	Bahera	<i>Terminalia belerica</i> Linn.
11	Bangab	<i>Diospyros montana</i> Linn.
12	Barmalla	<i>Callicarpa arborea</i> Linn.
13	Bat	<i>Ficus bengalensis</i> , Linn.
14	Bel	<i>Aegle marmelos</i> , corr.
15	Bhela	<i>Semecarpus anacardium</i> Linn.
16	Cashew	<i>Anacardium occidentale</i> Rottb.
17	Challa or papri	<i>Holoptelea integrifolia</i> Planch.
18	Chanlal	<i>Wendlandia exserta</i> Bartt.
19	Chapot siris	<i>Dalbergia lanceolaria</i> , krowce.
20	Chhatim or chhatiwan	<i>Alstonia scholaris</i> R. Br.
21	Dhaw	<i>Anogeissus latifolia</i> Wall.
22	Dumur	<i>Ficus hispida</i> Linn.
23	Gabdi	<i>Cochlospermum gossypium</i> , kunth.
24	Gamar	<i>Gmelina arborea</i> Linn.
25	Gokul	<i>Ailanthus excelsa</i> Des
26	Gular	<i>Ficus glomerata</i> Linn.
27	Haldu or karam	<i>Adina cordifolia</i> Salisb.
28	Haritaki	<i>Terminalia chebula</i> Linn.
29	Jak or Jacj	<i>Artocarpus integrifolia</i> Forst.
30	Jarul	<i>Lagerstroemia flos-reginae</i> Linn.
31	Jhau	<i>Casuarina equisetifolia</i> Linn.

Table 2.2 Legal status of Panchet Forest Division and Dalma Wildlife Sanctuary

Legal status of forest	Area (km ²)
Reserved forest	0.9290
Protected forest	335.1100
Unclassed forest	7.6170
Non-forest land	0.0016

the forest deity. For the protection of wildlife, the whole Dalma range was declared a wildlife sanctuary on in 1976. The main aims were to bring fresh life to the forest and its inhabitants by giving full protection to wildlife as well as to make it an important centre of attraction for nature lovers (Ministry of Environment and Forest Report, Government of Jharkhand). DWS spreads over the districts of East Singhbhum and Sairaikella–Kharbwan of Jharkhand. The Mango and Chandil forest ranges have been transferred to the wildlife division of Ranchi for ease of administrative control over the area. It is bounded by the Dalbhum and Saraikella forest divisions of Jharkhand and the Kangsabati forest division of West Bengal, Jamshedpur Township and Chandil subdivisional town.



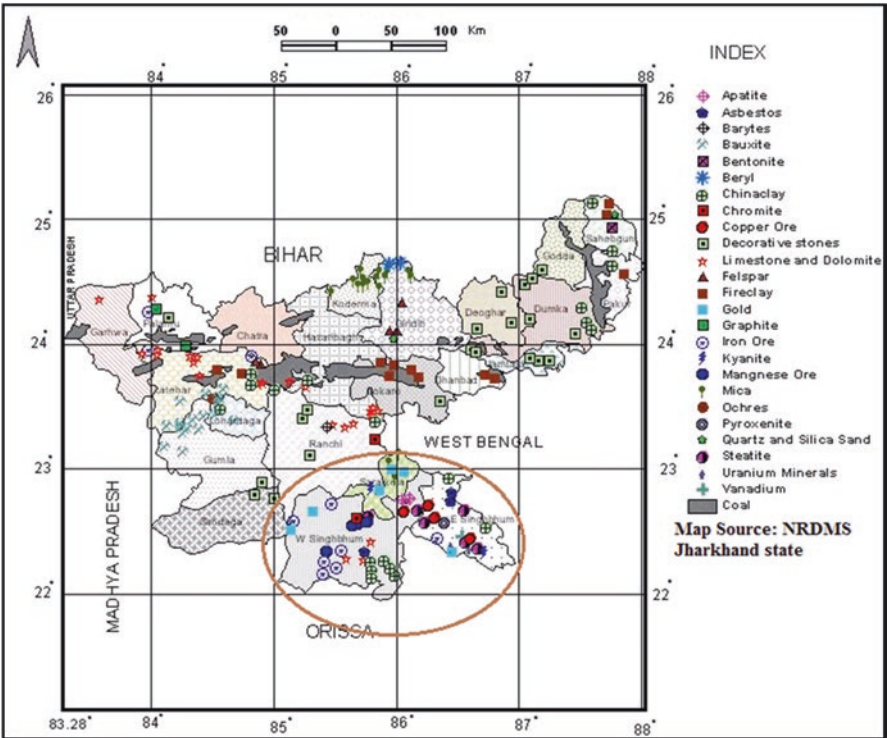
Map 2.2 Map of Dalma Wildlife Sanctuary

2.3.2 Location

DWS, Jamshedpur, lies between 22°46'30" N and 22°057'N latitude and 86°03'15" E and 86°26'30" E longitude. It covers an area of 193.5077 km² (*Gazette of India* 2012). The sanctuary includes more than 85 villages.

2.3.3 Physiography

Jharkhand, where the DWS is situated, literally means ‘the land of forest’. It is an extended part of Chota Nagpur Plateau. The area is characterised by undulating terrain with high hillocks (the highest elevation above mean sea level is 984 m), plateaus, deep valleys and open fields between hillocks. It provides diverse habitats of flora and fauna. The major part of the area is covered by an Archaean group of rocks. The rocks bear iron ore series, mica schist, hornblendes, phyllites and more. This region has huge reserves of coal, iron ore, mica, bauxite and limestone as well as considerable reserves of copper chromite, asbestos, kyanite, china clay, manganese, dolomite and uranium. Most of the mining areas are situated in the Purbi Singhbhum district (Map 2.3).



Map 2.3 Mineral distribution map of East Singhbhum district

2.3.4 Climate

The climate of DWS is of tropical monsoon type. The average annual rainfall is 1447 mm. The summer temperature ranges from 22 to 38 °C, while the winter temperature ranges from 5 to 28 °C. The mean rainfall and temperature of the nearest meteorological centre, Ranchi, are given here to show the climatic characteristics.

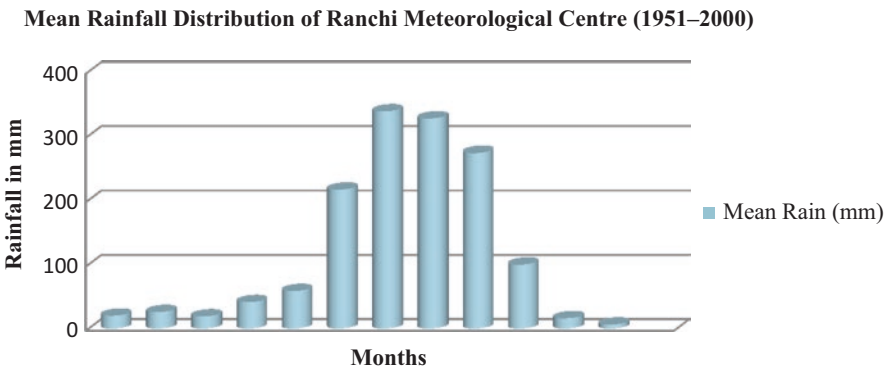


Chart 2.1

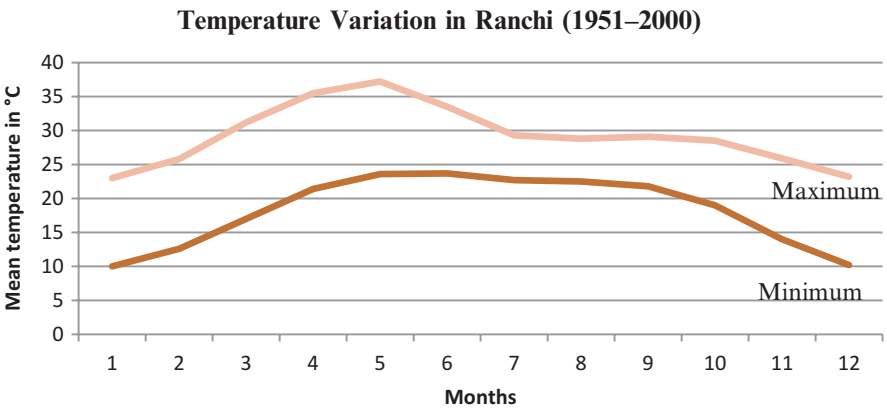


Chart 2.2

2.3.5 Administrative Arrangement

In the 2012 notification published by the Ministry of Environment and Forest, DWS was declared a notified area under the Wildlife Protection Act. It is part of the eco-sensitive zone of Jharkhand state, which covers an area of 522.98 km² in Jharkhand and consists of the following elements:

1. Enclave villages:

Total number of villages—85	
Area to be included in the eco-sensitive zone:	
Non-forest area	200.28 km ²
Forest area	198.30 km ²
Total	398.58 km ²

2. Villages situated outside the boundary of protected area:

Total number of villages—51	
Area to be included in the eco-sensitive zone:	
Non-forest area	80.45 km ²
Forest area	43.95 km ²
Total	124.40 km ²

The legal status of the forest in Jharkhand appears in Table 2.3.

The type of forest cover found in Jharkhand state consists of the district categories, namely tropical moist deciduous, tropical dry deciduous and subtropical broad-leaved hill forest. The Dalma region is mainly covered by tropical moist deciduous forest. The forest cover is dominated by sal (*S. robusta*) species (<http://www.Jharkhandforest.com>. Accessed 01 Aug 2014). The other common species found here are shimul (*Bombax ceiba*), jamun (*Eugenia jambolana*), kendu (*Diospyros melanoxylon*), gamhar (*Gmelina arborea*), karam (*Adina cordifolia*), mahua (*Madhuca Latifolia*) and dhautha (*Anogeissus latifolia*). They are deciduous in character (Table 2.4). Because of favourable resources like water, fodder and shelter, this is called the heaven of the elephants, but other species, including the giant

Table 2.3 Legal status of Panchet Forest Division and Dalma Wildlife Sanctuary

Legal status	% of total forest cover	Total forest (area in km ²)
Reserve forest	18.59	36.860
Protected forest	81.27	161.158
Unclassed forest	0.14	0.277
Total forest	198.30	

Table 2.4 Natural vegetation in Dalma Wildlife Sanctuary

Sl. no.	Latin name	Local name
<i>A. Trees</i>		
1	<i>Acacia arabica</i>	Babul
2	<i>Acacia catechu</i>	Khair
3	<i>Adina cordifolia</i>	Karam
4	<i>Aegle marmelos</i>	Bel
5	<i>Ailanthus excelsa</i>	Ghorkaranj/Ghorkaram
6	<i>Alangium lamarckii</i>	Dhela
7	<i>Albizzia lebbek</i>	Siris
8	<i>Albizzia odoratissima</i>	Jang siris
9	<i>Albizzia procera</i>	Safed siris
10	<i>Alstonia scholaris</i>	Chatni
11	<i>Anogeissus latifolia</i>	Dhautha
12	<i>Antidesma ghaesembilla</i>	Bhabiranj
13	<i>Artocarpus integrifolia</i>	Kathal
14	<i>Artocarpus lakoocha</i>	Barhar
15	<i>Azadirachta indica</i>	Neem
16	<i>Bauhinia retusa</i>	Kathul
17	<i>Bauhinia purpurea</i>	Koenar
18	<i>Bauhinia racemosa</i>	Katmauli
19	<i>Bauhinia variegata</i>	Kachnar
20	<i>Bombax ceiba</i>	Semal
21	<i>Boswellia serrata</i>	Salia
22	<i>Bridelia retusa</i>	Kajhi
23	<i>Buchanania lanzan</i>	Piar
24	<i>Butea frondosa</i>	Palas
25	<i>Careya arborea</i>	Kumbhi
26	<i>Casearia tomentosa</i>	Beri
27	<i>Cassia fistula</i>	Dhanraj/Amaltas
28	<i>Chloroxylon swietenia</i>	Bharhul
29	<i>Cordia Macleodii</i>	Belwanjan
30	<i>Cordia myxa</i>	Bahuar
31	<i>Cochlospermum gossypium</i>	Galgal
32	<i>Dalbergia lanceolaria</i>	Hardi
33	<i>Dalbergia latifolia</i>	Kala shisham
34	<i>Dalbergia sissoo</i>	Shisham
35	<i>Diospyros embryopteris</i>	Madartendu
36	<i>Diospyros melanoxylon</i>	Tend/Kend/Tiril
37	<i>Dillenia pentagyna</i>	Rai
38	<i>Elaeodendron Mukorossi</i>	Ratangur
39	<i>Ehretia laevis</i>	Bhaire
40	<i>Emblica officinalis</i>	Amla
41	<i>Eugenia heyneana</i>	Katjamun

(continued)

Table 2.4 (continued)

Sl. no.	Latin name	Local name
42	<i>Eugenia jamb</i>	Jamun
43	<i>Eugenia operculata</i>	Paiman
44	<i>Ficus benghalensis</i>	Bar
45	<i>Ficus cunia</i>	Parho
46	<i>Ficus histida</i>	Dimar
47	<i>Ficus religiosa</i>	Pipal
48	<i>Ficus tomentosa</i>	Barun
49	<i>Gardenia latifolia</i>	Papra
50	<i>Gmelina arborea</i>	Gamhar
<i>B. Shrubs and herbs</i>		
1	<i>Achyranthus aspara</i>	Chirchiri
2	<i>Andrographis paniculata</i>	Kalmegh
3	<i>Antidesma diandrum</i>	Amti
4	<i>Asparagus racemosa</i>	Satawar
5	<i>Berberis aristata</i>	Kashmoi
6	<i>Calotropis gigantea</i>	Akaon
7	<i>Carisa carandas</i>	Kanwar
8	<i>Carisa spinarum</i>	Jangli karonda
9	<i>Cassia tora</i>	Chakor
10	<i>Cleistanthus collinus</i>	Kargali
11	<i>Clerodendron infortunatum</i>	Bhant
12	<i>Colebrookia oppositifolia</i>	Binda/Bindhu
13	<i>Croton oblongifolius</i>	Putri
14	<i>Emblica robusta</i>	Baborang
15	<i>Euphorbia hirta</i>	Dudhi
16	<i>Flacourtia ramontchi</i>	Katai
17	<i>Flemingia chappar</i>	Galphuli
18	<i>Flemingia stricta</i>	Salpani
19	<i>Flueggia obovata</i>	Sika
20	<i>Gardenia turgida</i>	Karhar/Dhanuk
21	<i>Gardenia gummifera</i>	Dekamali
22	<i>Glochidion lanceolarium</i>	Kalchu/Chiku
23	<i>Helicteres isora</i>	Aitha/Atham
<i>C. Climbers, parasites, semiparasites, orchids</i>		
1	<i>Abrus precatorius</i>	Karjani
2	<i>Acacia pennata</i>	Arar
3	<i>Bauhinia vahlii</i>	Maholan
4	<i>Butea parviflora</i>	Cihut
5	<i>Butea superba</i>	Dorang
6	<i>Casytha spp.</i>	—
7	<i>Combretum decandrum</i>	Rateng/Phalandur
8	<i>Cryptolepis buechanani</i>	Dudhia lar

(continued)

Table 2.4 (continued)

Sl. no.	Latin name	Local name
9	<i>Cuscuta reflexa</i>	Alaj-jori/Parasite
10	<i>Habenaria susannae</i>	Orchid
11	<i>Ichnocarpus frutescens</i>	Saon lar
12	<i>Loranthus spp.</i>	Banda
13	<i>Milletia auriculata</i>	Gurnar
14	<i>Momordica dioica</i>	Keksa
15	<i>Mucuna prurita</i>	Alkosi
16	<i>Mukia maderaspatana</i>	Bilari
17	<i>Pogonia spp.</i>	Orchid
18	<i>Porana paniculata</i>	Bhidia lar
19	<i>Pueraria tuberosa</i>	Patal konhra
20	<i>Smilax macrophylla</i>	Ram datwan
<i>D. Grasses, bamboo, agave</i>		
1	<i>Agave spp.</i>	Moraba
2	<i>Apluda varia</i>	Dudhia sauri
3	<i>Arundinella setosa</i>	Jharu/Motaminijhar
4	<i>Bambusa arundinacea</i>	Bara bans
5	<i>Chrysopogon aciculatus</i>	Chor kanta
6	<i>Chrysopogon mountanus</i>	–
7	<i>Cymbopogon martini</i>	Nanha dudhe grass
8	<i>Cynodon dactylon</i>	Doob
9	<i>Dendro calamus strictus</i>	Bans/Bamboo
10	<i>Eulaliopsis binata</i>	Sabai
11	<i>Imperata arundinacea</i>	Cherogress
12	<i>Imperata cylindrica</i>	Ulu
13	<i>Heteropogon contortus</i>	Kher/Sauri grass
14	<i>Panicum montana</i>	Khrj
15	<i>Saccharum munja</i>	Munj
16	<i>Thysanolaena agrostis</i>	Jharu/Broom grass
17	<i>Vetiveria zizanioides</i>	Khus-khus

squirrel (*Ratufa indica*), sloth bear (*Melursus ursinus*), striped hyena (*hyaena hyaena*), Indian porcupine (*Hystrix indica*), barking bear, mouse deer (*Tragulus meminna*), macaque (*Macaca mulatta*), langur monkey (*Presbytis entellus*), wild boar (*Sus scrofa*), civet (*Viverricula indica*), mongoose (*Herpestes edwardsii*) and wolf (*Canis lupus*) are also found.

2.4 Landscape Ecology and Analysis

Alexander von Humboldt (1807) defined landscape as the total character of a region. In that sense, landscape deals with the totality of physical, ecological and geographical entities, integrating all natural and human-induced patterns and processes (Naveh 1987). According to Forman and Godron (1986), landscape is a heterogeneous land area composed of a cluster of interacting ecosystems that repeat in similar form throughout. So a particular landscape represents a specific topography, vegetation cover, land use and settlement pattern that delimits some coherence of natural and cultural processes and activities (Green et al. 1996). These views give a clear idea about the concept of landscape: Landscape is an entity perceived by all other organisms (plant and animal) on the one hand and humans on the other (Farina 2006). It supports the functioning of organisms and finally gives a spatial pattern of arrangement. Landscape consists of four material (or physical) and non-material (or cognitive) components. Thus, landscape can be described as an ecological or cognitive unit. In this chapter, we emphasise the ecological characterisation to understand the mosaics of the landscape. Landscape ecology is concerned with the ecological functioning of the entire landscape over space and time. It examines the spatial diversity and its effect on ecological processes (Risser et al. 1984). While assessing the characteristics, one should consider a diverse array of fields and disciplines, including physical and human geography, biology, forestry, wildlife management, architecture and planning (Kupfer 1995). This chapter focusses on characterising different components of landscape, their complexity as well as their variability (Li and Reynolds 1995a). Spatial patterns and their change over time form a geobotanical perspective. Emphasis has also been given to the human-made environment or noospheric factors, which alter or modify the natural landscape. Thus, we take human-made factors into consideration. Finally, we try to correlate these landscape characteristics to an organism's preference.

2.4.1 *Landscape Composition and Configuration*

A landscape under consideration consists of heterogeneous components that give a typical pattern to the landscape. To analyse the pattern of an area, it is necessary to quantify the components of the spatial pattern, that is, the composition and configuration of the landscape mosaic (Li and Reynolds 1995a, b). Composition is the non-spatial characteristic; it includes the number and proportion of patch types. Configuration, on the other hand, is the spatial characteristic of landscape and includes the spatial arrangement of patches, that is, patch shape, patch size, contrast between neighbouring patches, connectivity among patches of the same type or the similarity of patches, anisotropy or the variation of other attributes in different directions. Seven attributes have been recognised to demonstrate a spatial pattern (Pielou 1977; Romme 1982; Forman and Godron 1986; Renolds 1988; O'Neill et al. 1988; Wines et al. 1993; Li and Reynolds 1995a). This type of analysis proves very helpful not only in preparing a habitat map for a species but also in evaluating the

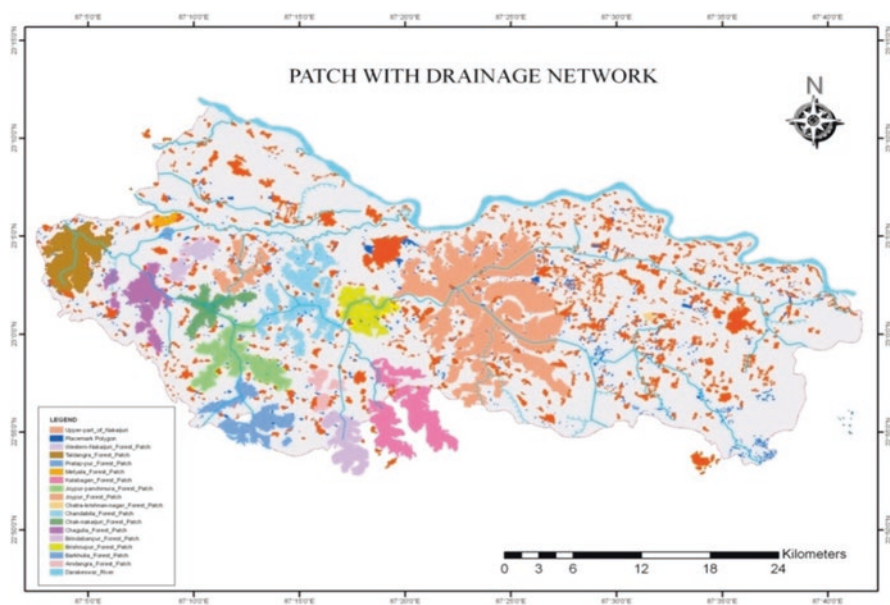
behavioural pattern of the species. The number and proportion of a specific patch indicate the dominance of that patch in a given landscape. Therefore, that information indicates the availability and diversity of resources. The spatial distribution and concentration of a resource are a driving force for species dispersal and to determine foraging behaviour. The patch shape and size indicate the irregularity of patches, or whether patches are affected by edge effects. For example, settlement expansion near the forest fringe areas causes fragmentation of the habitat patch. The magnitude of the edge effect can be measured through the neighbouring contrast in relation to the background matrix. Connectivity among the same patches indicates the ease of dispersal of species from one patch to another. In such a situation, the movement of species is followed by a similar fragment of patches as a 'stepping stone'. Anisotropy is related to the influence of topographical or edaphic factors (Landscape Ecology 2007). But all these factors are not equally quantifiable and in some cases are difficult to measure. Hence, the attributes and indices are selected according to the aims and feasibility of the current research work.

2.4.2 Heterogeneity: Patch, Corridor and Background Metrics

The important aspect of landscape ecology is to focus on the patterns of biological diversity (MacArthur 1972; Wiens 1976). Biogeographical studies examine the regional abundance and distribution pattern of species. The spatial pattern or structure is further wielded by the heterogeneity of the landscape. Landscape heterogeneity refers to the complexity or variability in a system property of interest in space and time (Li and Reynolds 1995a). Patch, corridor and background matrix are the three elements of a landscape structure. They contribute to the nature of landscape heterogeneity.

2.4.2.1 Patches

A patch may be described as a wide, relatively homogenous area that differs from its surroundings (Forman 1995a, b). The size of a patch is scale-dependent and relative to the habitat requirements of an organism. For more mobile animals, the recognition of a patch takes place at a broader scale than it does for animals requiring a precise habitat. The size of the patch is important, as it increases the probability of resource availability though the patch size in all cases does not support habitat diversity. In randomly distributed small patches, habitat diversity is usually high, but this can support a lower population because of the scarcity of space. Thus, fragmented patchy habitats regulate the movement behaviour of animals. The same is happening with elephant migration in PFD. The entire area is characterised by a fragmented patchy landscape. The patch type includes both natural and manmade patches in the form of forest, water bodies, settlements, agricultural lands and so forth. Twenty-three forest patches in PFD have been identified or digitised from Google Maps to analyse the patch size, edge effect, boundary characteristics and other attributes (Map 2.4).



Map 2.4 Patch distribution map of Panchet Forest Division

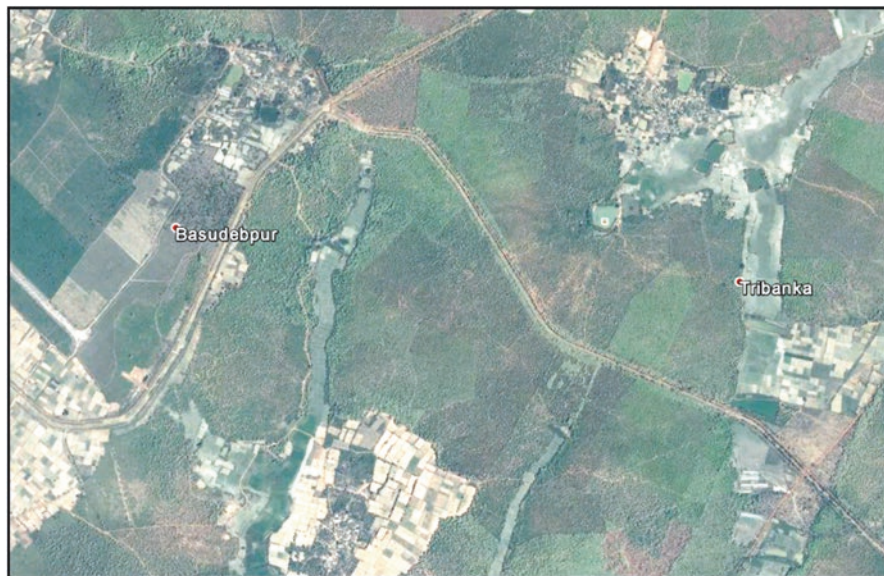


2.4.2.2 Corridor

Corridors are the linear features such as roads, rail lines, roadside verges, rivers, canals and power lines in a given landscape (Bell 2003). Essentially, these permanent lines should be termed 'linear habitats', but 'a wildlife corridor' is used to refer to those linear features that are used for migration and dispersal or otherwise link habitats in ways that reduce population isolation (Spellerberg and Gaywood 1993). On the basis of the structure, these corridors are classified into line, strip and riparian or stream corridor (Forman and Godron 1986). The corridors are used by the species for movement. For wide-ranging species like elephants, these corridors are very helpful, allowing them to migrate from one habitat to another. In this way, Dalma elephants migrate to southern West Bengal following the remnant forest patches in between. But these lined corridors sometimes dissect or interrupt the habitat and create disturbances in the free movement of species. For example, constructing railway lines through forest patches hampers the movement of wildlife (Map 2.5).

2.4.2.3 Mosaic

In a dynamic landscape, the structure, function and spatial patterns experience continuous change, resulting in a highly varied mosaic of different habitat types (Forman 1995b). A mosaic in a specific landscape thus refers to varying habitat types and their arrangement. Landscape mosaics simply mirror landscape patterns. This patterning is a dynamic process. The landform is characterised by geomorphology, climate, soil (Plate 2.1), vegetation, and other factors, but at the same time



Map 2.5 Aerial view of forest patches

it is patterned by human activities on landforms (Forman 1995a). Agriculture, expansion of settlement, deforestation and development activities are the major causes that shape the landscape mosaic (Plate 2.1). The landscape mosaic of Dalma and that of Panchet differ in nature. Components of the landscape mosaic in Dalma mainly consist of forest patches, mining and quarrying areas within or at the margin of the forested tracts, agricultural lands and scattered settlement areas with industrial growth centres. The mosaic pattern of Panchet includes agricultural land, fragmented forest and scattered villages with Bishnupur urban centre. Thus, the landscape mosaic of Panchet is less disturbed than that of the Dalma area.

2.4.2.4 Metrics

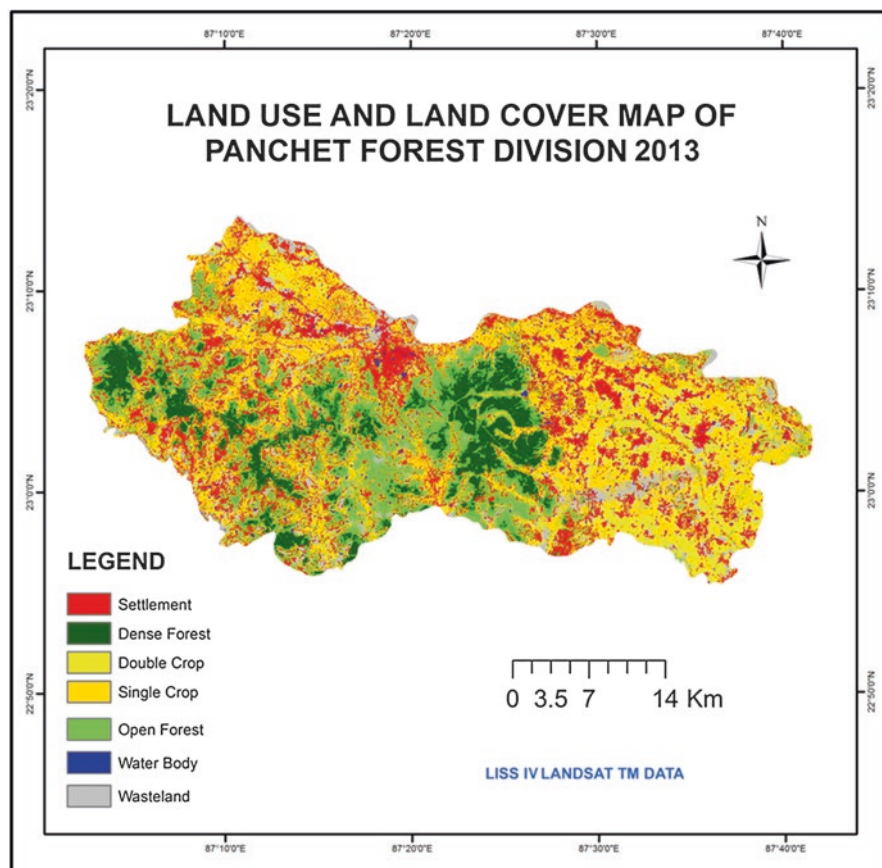
The metrics of a landscape are the background, the enclosing and affecting patches as well as the corridors. They normally cover an extensive area and form a highly connected and controlled landscape (Forman 1995a). The bulk of an area in a given landscape constitutes its matrix. It may be forested land, agricultural land or settled area or may be another land use type. If one element type covers more than 50 % of the land area contiguously or is much more extensive than the second land use type, it should be considered the matrix. If the total area of each of the two most extensive element types is similar, connectivity may be used to differentiate them. The landscape matrix is important in determining resistance to species percolation across boundaries and between patches (Bell 2003). The background matrix influences the distance an individual will move and thereby the colonisation probabilities of different patches within a habitat (Stamps et al. 1987).



Plate 2.1 Patches on open source image

The background matrix of the study area is dominated by agricultural land, then forested land, followed by settled area (Map 2.6). Agricultural land is found extensively over the entire study area, but a more continuous patch is seen in the eastern part of the study area. The western part is characterised by several fragmented forest patches. This fragmentation occurs because of the extension of communication lines through the patches or the extension of settlement. Forest patches are further fragmented as a result of deforestation along the forest edges.

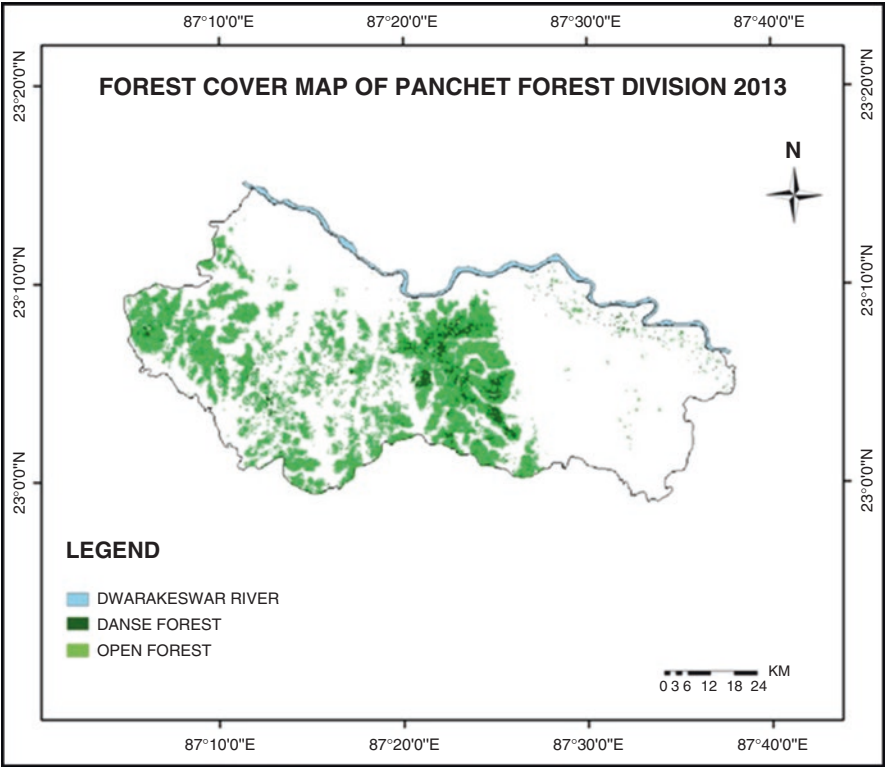
Elephant movement in the study area is strongly related to the composition and configuration of forests. In previous decades, the movement of elephants was restricted within the fragmented forests surrounded by agricultural lands in the western parts. However, it has recently been observed that elephants are extending their forage ground to the eastern part of the study area, which is predominantly occupied by agricultural land and settled area. This is a significant cause of rising human–elephant conflict in the study area.



Map 2.6 Land use and land cover map of Panchet Forest Division in 2013 to show the background metrics

2.4.3 Forest Types and Composition

Our study mainly concentrated on characterising PFD. The study area is situated in the extended Chota Nagpur Plateau in the east, covering the districts of Bankura, Purulia, and Paschim Medinipur. The vegetation type is tropical dry deciduous forest. The forest belongs to category 5B of group 5 and is represented by types C₁/1C, C2, DS1, E5, E7 and 2S1 (Singh 2006) on the basis of the composition of species found in the forest. It can be divided into four categories, namely, coppice sal, open shrub forest with scattered sal forest, bushes and plantations. The other common species of trees, shrubs, herbs and climbers found here are listed in Table 2.1.



Map 2.7 Forest cover map of Panchet Forest Division in 2013



Plate 2.2 Typical features of forest in the study area

2.4.4 Changing Species Association

A habitat is characterised by its species composition as well as phytocoenosis. Phytocoenosis, or species association, is a collection of plant species within a designated geographical unit that form a relatively uniform patch distinguishable from neighbouring patches of different vegetation types influenced by soil type, topography, climate and human disturbance.

Plant species association strongly influences the occurrence of animal species in a particular area, but plant species association may be modified by natural and human disturbances. Over-exploitation of forest resources sometimes alters and modifies the existing natural assemblage of plant species. Hence, it affects or forces animals to adjust to or leave their original habitat. Once the study area was known as *Jangalmahal* and was covered by natural sal forest. The major associates were mahua (*Bassia latifolia*, syn. *Madhuka Litifilis*, Linn), karam (*Adina cordifolia* Salisb.), sidha (*Lagerstroemia parviflora* Linn.), shegun (*Tectona grandis*, Linn.F.), palash (*Butea frondosa* syn. *B. monosperma* Roxb.), arjun (*Hardwickia binata* Roxb.), haritaki (*Terminalia chebula* Linn.), bahera (*Terminalia belerica* Linn.) and asan (*T. tomentosa* Linn.). But after the Permanent Settlement Act in 1793, the local tribes (Santhal) were displaced by the hill agronomist tribe Mal Paharias, migrating from the Chhotonagpur and Palamau regions of Bihar to convert forest lands into agricultural fields (Palit 1991).

The reckless forest destruction took place during the expansion of the Bengal Nagpur railway line in 1889 followed by the railway tracks through Midnapur district in 1903 (Palit 1991; Malhotra 1995). This huge destruction of forest prompted the government to establish a committee in 1938. The committee recommended

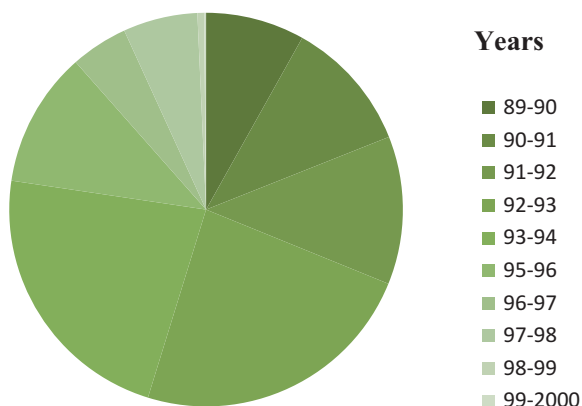
mandating that landowners plant forests on an approved working plan. This policy was passed as the Bengal Private Forest Act of 1945. The act also made provisions for voluntary or compulsory vesting of forest lands (Palit 1991).

During the 1970s, a new initiative was taken by the forest department to protect and restore forest through community participation. In 1981, the Social Forestry Project was launched under a joint forest management (JFM) programme. The objective of the JFM was the plantation of fast-growing species on public and private lands to meet the fuel demands of the local people (Malhotra and Poffenberger 1989). Species selected for this purpose included eucalyptus, akas hmoni, casuria, gamhar, kadam, bamboo, khair, semul, sissoo, tendu, mahua, champ, sal, mahogoni and teak (<http://moef.nic.in>. Accessed 02 Aug 2014).

Thus, sal-dominated forest degenerated into coppice sal forest in southern West Bengal. Malhotra and colleagues (1991) carried out a rapid appraisal of natural forest regeneration in West Midnapur district in West Bengal, where he observed the changes in regenerated coppice sal forest (Martin 2008).

Though the regenerated forests of coppice sal and other monospecies have replaced the indigenous species of lateritic tracts, it has increased the total forest cover of the district (21.27%). The district report of the Bankura Forest Division shows an extensive area brought under social forestry. The following table depicts this scenario. The canopy cover increased by 26.5 % in 1994. This process ultimately increased the number and size of forest patches in the study area.

Generated Forest under social forestry(forest in ha.)



A total of 541 forest protection committees in the whole district looked after 43,522.942 ha of land in the district.

2.4.5 Spatial Analysis of Heterogeneity

Background metrics of PFD show that the landscape is covered by patches of agricultural land, fragmented forest area, intruded settled area in the forest fringes, communication lines through the forest patches and so forth. Agricultural land, which is the dominant matrix, covers the largest area in PFD. Agricultural crops are given to single-crop, double-crop, orchard or kitchen gardens. Forest patches are very fragmented in nature and are spatially distributed among 21 forest beats. Forest lands may be classified as dense forest, open forest, degraded forest, regenerated forest and so on. Analysis of spatial heterogeneity is necessary to elucidate the relationship between the ecological process and the spatial pattern (Turner 2005) in general and the interaction of humans and animals in specific. Several metrics were developed to analyse the landscape heterogeneity. In our work we used FRAGSTATS and ARC Map 10.2.1 (patch Analyst in Arc-view). Numerous metrics were used for landscape analysis, but some of the relevant metrics are selected here. In FRAGSTATS, the landscape can be analysed at the patch, class or landscape level. We adopted patch-level metrics for our study. Landscape composition and configuration metrics are transacted here at the patch level.

2.4.5.1 Landscape Composition Metrics and Percentage of Landscape

Landscape composition metrics form an area matrix. Hence, they quantify an area both in terms of landscape percentage and in absolute terms, that is, in hectares. The landscape composition represents the proportion of land occupied by a particular land cover patch. This is an important measure to estimate the status of a targeted patch. In our study this status helps to assess the intensity of habitat loss because of fragmentation and anthropogenic causes. Each organism inhabits a specific niche and requires a minimum area as its home range. There are many measures of landscape composition involving proportion or percentage of each land type, patch richness, patch evenness and patch diversity. All the analyses are applied to the forest patch only because this is the most important matrix in the context of wildlife.

2.4.5.2 Forest Patch Metrics

The number of patches (NP), patch density (PD), mean shape index (MSI), mean patch size (MPS), and largest patch index (LPI) represent the landscape's composition and configuration. Patch number (NP) refers to the total number of patches in a targeted landscape. It represents the heterogeneity in terms of number and types of patches in a given landscape. PD and MPS differ with the heterogeneity of the landscape. Both metrics represent the landscape's composition and configuration. PD refers to the number of patches per unit of land (e.g., NP within 100 ha) and MPS represents the average size of patches in a given landscape. An increase in NP and in PD in a forest landscape or a reduction in MPS generally indicates landscape fragmentation (FRAGSTATS).

The LPI at the class level quantifies the percentage of the total landscape area comprised by the largest patch. As such, it is a simple measure of patch dominance (McGarigal and Marks 1995). Thus, if a landscape contains one large patch occupying a large amount of the total landscape area, that patch may have a dominant and important role in the functioning of the entire landscape (Couvillion 2005).

Patch density calculation methodology (<i>source</i> : McGarigal and Marks 1995)	
$PLAND = P_i = \frac{\sum_{j=1}^n a_{ij}}{A} (100)$	P_i = proportion of the landscape occupied by patch type (class) i
	a_{ij} = area (m^2) of patch ij
	A = total landscape area (m^2)
<i>Description</i>	PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by the total landscape area (m^2), multiplied by 100; in other words, PLAND equals the percentage of the landscape comprised of the corresponding patch type. Note that the total landscape area (A) includes any internal background present
<i>Units</i>	Percent
<i>Range</i>	$0 < PLAND \leq 100$
	PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire image is composed of a single patch

Patch density calculation methodology (*source*: McGarigal and Marks 1995)

$PD = \frac{n_i}{A} (10,000) (100)$	n_i = number of patches in the landscape of patch type (class) i
	A = total landscape area (m^2)
<i>Description</i>	PD equals the number of patches of the corresponding patch type divided by the total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 ha). Note that the total landscape area (A) includes any internal background present
<i>Units</i>	Number per 100 ha
<i>Range</i>	$PD > 0$, constrained by cell size

Mean patch area calculation methodology (*source*: McGarigal and Marks 1995)

$MN = \frac{\sum_{j=1}^n a_{ij} \left(\frac{1}{10,000} \right)}{n_i}$	n_i = number of patches in the landscape of type (class) i
	a_{ij} = area (m^2) of patch ij
<i>Description</i>	MN area equals the area (m^2) of the patch, divided by 10,000 (to convert to hectares), summed across all patches of the corresponding patch type, divided by the number of patches of the same size
<i>Units</i>	Hectares
<i>Range</i>	$MN \text{ area} > 0$, without limit

Largest patch index calculation methodology (*source*: McGarigal and Marks 1995)

$LPI = \frac{\max_{j=1}^n (a_{ji})}{A} (100)$	a_{ji} = area (m^2) of patch ij
	A = total landscape area (m^2)
<i>Description</i>	LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by the landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the total landscape composed of the largest path. Note that the total landscape of any area includes any internal background present
<i>Unit</i>	Percent
<i>Range</i>	$0 < LPI \leq 100$ LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small; LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type, that is, when the largest patch comprises 100 %

Edge density calculation methodology (*source*: McGarigal and Marks 1995)

$ED = \frac{\sum_{k=1}^m e_{ik}}{A} (10,000)$	e_{ik} = total length (m) of edge segments in landscape involving patch types (class) i ; includes landscape boundary and background segments involving patch type i
	A = total landscape area (m^2)
<i>Description</i>	ED equals the sum of the lengths (m) of all edge segments involving the corresponding patch type, divided by the total landscape area (m^2), multiplied by 10,000 (to convert to hectares). If a landscape border is present, ED includes landscape boundary segments involving the corresponding patch type and representing the 'true' edge only (i.e., abutting patches of different classes)
<i>Unit</i>	Meters per hectare
<i>Range</i>	$ED \geq 0$, without limit

Mean core area calculation methodology (*source*: McGarigal and Marks 1995)

$MN = \frac{\sum_{j=1}^n X_i a_{ij}^c \left(\frac{1}{10,000} \right)}{n_i}$	a_{ij}^c = core area (m^2) of patch ij based on specified edge depths (m)
	n_i = number of patches in the landscape of patch type (class) i
<i>Description</i>	Core MN equals the area (m^2) within the patch that is farther than the specified edge distance depth from the patch perimeter, divided by 10,000 (to convert to hectares), summed across all patches of the corresponding patch type, divided by the number
<i>Units</i>	Hectares
<i>Range</i>	Core MN > 0, without limit

Core area percent of landscape calculation methodology (*source*: McGarigal and Marks 1995)

$CPLAND = \frac{\sum_{j=1}^n a_{ij}^c}{A} (100)$	a_{ij}^c = core area (m^2) of patch ij based on specific edge depths (m)
	A = total landscape area (m^2)
<i>Description</i>	CPLAND equals the sum of the core areas of each patch (m^2) of the corresponding patch type. Note that the total landscape area (A) includes any internal background present
<i>Units</i>	Percent
<i>Range</i>	$0 \leq CPLAND < 100$ CPLAND approaches 0 when the core area of the corresponding patch type (class) becomes increasingly rare in the landscape, because of increasing smaller patches and/or more convoluted patch shapes. CPLAND approaches 100 when the entire landscape consists of a single patch type

Fractal dimension calculation methodology (source: McGarigal and Marks 1995)	
$PAFRAC = \frac{2 - \frac{\left[n_i \sum_{j=1}^n (\ln p_{ij} - \ln a_{ij}) \right] - \left[\left(\sum_{j=1}^a \ln p_{ij} \right) \left(\sum_{j=1}^n \ln a_{ij} \right) \right]}{\left(n_i \sum_{j=1}^n \ln p_{ij}^2 \right) - \left(\sum_{j=1}^n \ln p_{ij} \right)^2}}{1}$	a_{ij} = area (m ²) of patch ij p_{ij}^2 = perimeter (m) of patch ij n_i = number of patches in the landscape of patch type (class) i
Description	PAFRAC equals 2 divided by the slope of regression line obtained by regressing the logarithm of the patch area (m ²) against the logarithm of the patch perimeter (m). That is, 2 divided by coefficient b_1 divided from a least-squares regression fit to the following equation: $\ln(\text{area}) = b_0 + b_1(\text{perim})$. Note that PAFRAC excludes any background patches
Units	None
Range	$1 \leq PAFRAC \leq 2$

2.4.5.3 Forest Edge Metrics: Edge Density

Edge metrics are generally used to represent the landscape configuration. The total amount of edge in a landscape is important for many ecological phenomena (McGarigal and Marks 1995). Specifically, it is a very important metric to assess wildlife edge relation (Thomas et al. 1978 and 1979; Strelke and Dickson 1980; Morgan and Gates 1982; Logan et al. 1985). Energy in the landscape edge differs from that in the core areas. For example, along the forest edge, the velocity of wind, intensity of light, level of soil moisture and so forth differ from these values in core areas; these individual values create a distinct microclimatic condition and disturbance rate. The variable microclimatic condition and disturbance rate influence the vegetation composition and structure and ultimately regulate the behaviour of the herbivory (Ranney et al. 1981, cited in FRAGSTATS manual). The forest edge is affected by patch shape, size and adjacent land covers. The edge density (ED or percentage of edge in a given landscape is very useful for the study of fragmentation. The total amount of edge in a landscape is related to the degree of spatial heterogeneity.

2.4.5.4 Forest Core Metrics

The average core area per patch and percentage of core area are forest core metrics. The core area is defined as the area within a patch beyond some specified edge distance or buffer width. It reflects both landscape composition and configuration. It is inversely related to the edge effect: the greater the edge effect, the lesser the core area. Generally, the core area has been considered to be a much better predictor of habitat quality than the patch area (Temple and Cary 1986). In other words, the forest core is protected by a buffer of forest edge. Hence, it is less influenced by external forces.

(L30) Total Core Area Index

Vector/Raster

$$TCAI = \frac{\sum_{i=1}^m \sum_{j=1}^n a_{ij}^c}{A} (100)$$

Units: Percent.

Range: $0 \leq TCAI < 100$.

TCAI = 0 when none of the patches in the landscape contain any core area (CORE = 0 for every patch); that is, when the landscape contains no core area. TCAI approaches 100 when the patches, because of size, shape, and edge width, contain mostly core area.

Description: TCAI equals the sum of the core areas of each patch (m^2), divided by the total landscape area (m^2), multiplied by 100 (to convert to a percentage); that is, TCAI equals the percentage of the landscape that is core area.

The average core area of forest patches represents the mean area of the core portion of all forest patches in the landscape. If the landscape is fragmented, then the mean area of the core portion will be less than a more contiguous landscape (Couvillion 2005). The percentage of the core area quantifies the proportional abundance of the core area in the landscape. In a fragmented and patchy landscape, the percentage of the core area will be lower than that in a more contiguous landscape.

2.4.5.5 Patch Shape Metric: Fractal Dimension

Patch shape metrics is an important measure to detect forest fragmentation. The patch shape is uneven and complex where the edge effect is high and core area is less. To measure this irregularity of shape perimeter we use the Area Fractal Dimension index. It quantifies the degree of complexity of the patch shape.

$$1 \leq \text{FRAC} \leq 2$$

A fractal dimension greater than 1 for a two-dimensional patch indicates a departure from Euclidean geometry (i.e., an increase in shape complexity). FRAC approaches 1 for shapes with very simple perimeters such as squares and approaches 2 for shapes with highly convoluted, plane-filling perimeters.

2.4.5.6 Patch Arrangement/Connectivity Metrics: Euclidean Nearest Neighbour Matrix

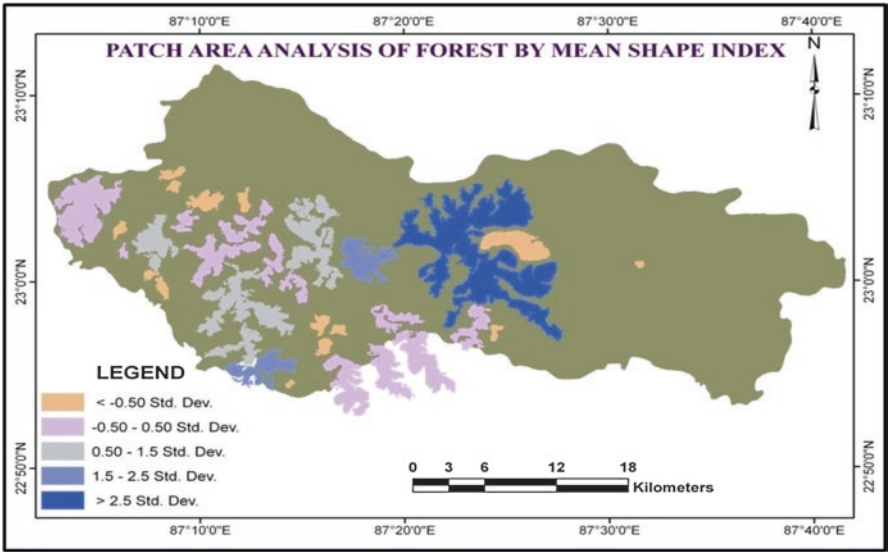
It examines the distance between the fragmented patches. A more fragmented landscape is expected to have more patches and consequently the distance between these patches may be less than a more contagious landscape with a few large forest patches. Thus, if the patch density increases and landscape composition decreases and the distance between patches increase, which is indicative of more fragmentation.

Result of Patch Analysis

In our study, we identified a total of 23 patches. They are situated all across the beats under PFD. The selected forest patches appear in Table 2.5.

All the patch metrics are applied to this selected vector layer of patches. The main objective behind this analysis is to assess landscape heterogeneity in general and habitat heterogeneity in specific. Habitat is a species- or organism-centric term that refers to a particular environmental condition or gradient with reference to one species while it can be considered a barrier for another (Anderson et al. 2006). Hence, through patch analysis, habitat status has been assessed in terms of forest PN, PD, mean patch area, LPI, forest Edge metrics (ED), core area index, fractal dimension and Euclidean nearest-neighbour metrics.

The MSI represents the mean shape of an individual patch. It signifies the average shape of the patch whether it is affected by fragmentation, disturbance or edge effect. The value ranges from ≥ 1 to infinity. As the patch shape becomes more irregular, the MSI value increases, and vice versa. The MSI of PFD is more than 2.5, which signifies a considerable fragmentation of the forest patch. The MSI value has been calculated from the standard deviation value, as it signifies the level of deviation more clearly.

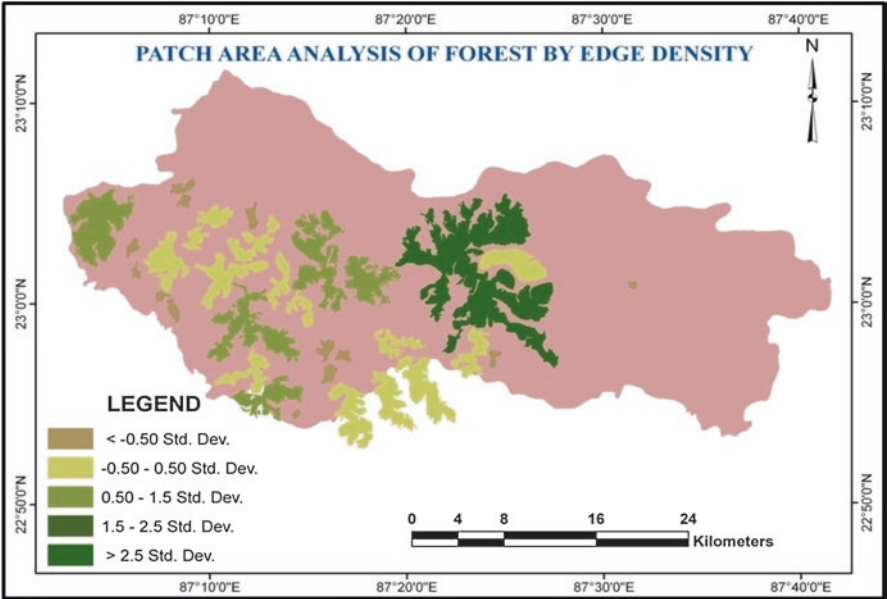


Map 2.8 Patch area analysis of forest by the mean shape index

Table 2.5 Patch IDs for forest patch analysis

ID no.	Name of forest patch	Name of forest beat
14	Asna 3	Asna
11	Asna 1	
12	Asna 2	
13	Asna 4	
1	Below Chagulia area	Chagulia
3	Bishnupur 2	Bishnupur
2	Bishnupur forest patch	
5	Chagulia 1	Chagulia
6	Chagulia 2	
23	East Pratappur	Bankadaha
4	Joypur 1	Joypur
8	Joypur 2	
9	Joypur 3	
10	Kalabagan	
7	Patch near Dwarkeswar River	Bishnupur
15	Peardoba 1	Peardoba
16	Peardoba 2	
17	Taldangra 1	Taldangra
18	Taldangra 2	
20	Upper Nakaijuri	Nakaijuri
19	Upper part of Adhkata	Adhkata
21	Upper Peardoba	Peardoba
22	Western part of Nakaijuri	Nakaijuri

The ED value of Panchet signifies that a considerable number of edge patches are present in the landscape. As the forest landscape is fragmented in nature, the ED value is high; in maximum cases, core areas are surrounded by edge.



Map 2.9 Patch area analysis of forest by edge density

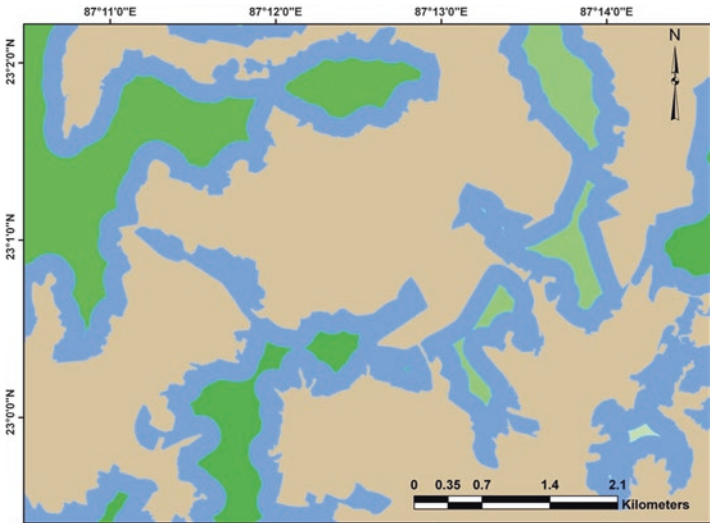
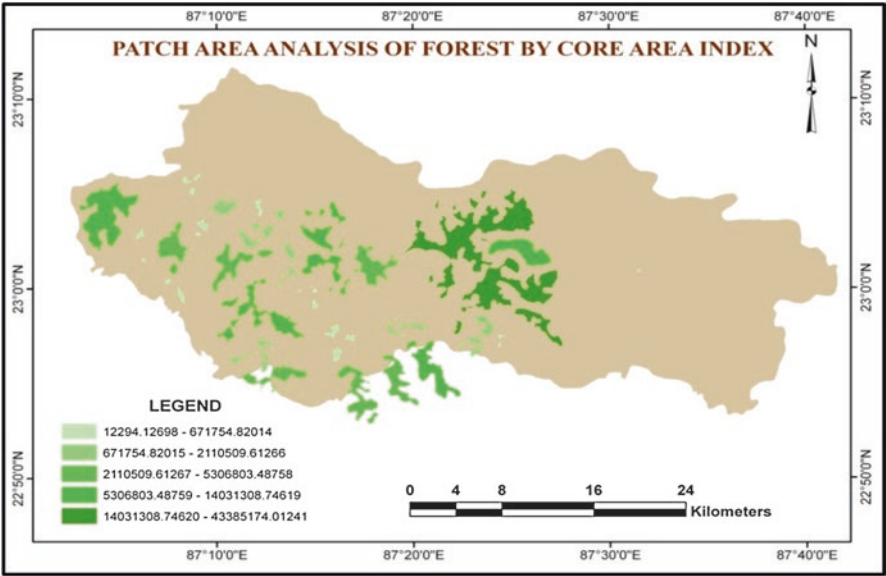


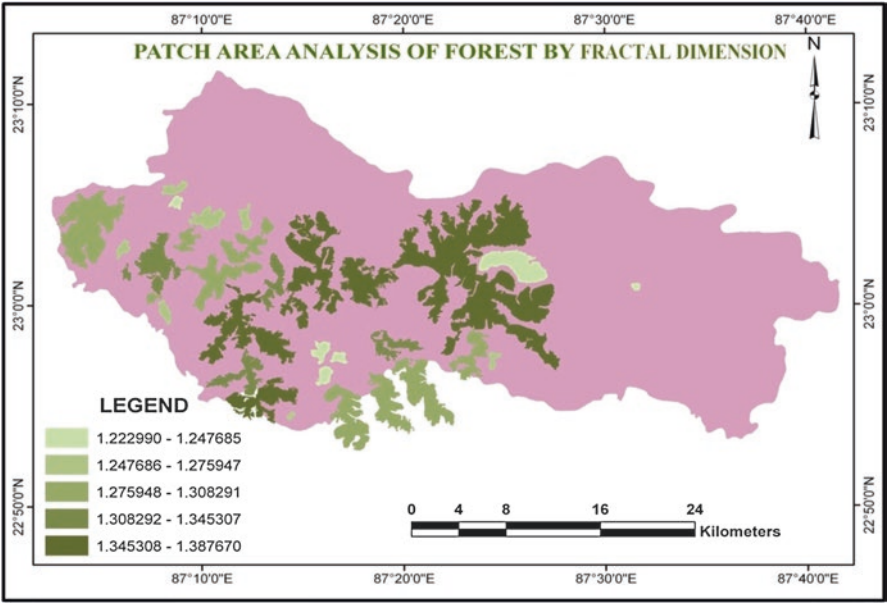
Plate 2.3 Core at 200 m buffer

The CA index represents the amount of core area within a landscape. It is used to assess patterns of and trends in forest fragmentation in the landscape throughout the region. After taking a 200-m buffer from the edge for each forest patch, we observed that the core area is good in the Bankadaha and Joypur forest beat areas. Thus, the area will be preferred for habitat selection by big herbivores like the elephant.



Map 2.10 Patch area analysis of forest by core area index

A fractal dimension value indicates the complexity of the shape. It is further related to whether the patch is affected by fragmentation or edge effect. The value for fractal dimension for most of the patches ranges from 1.22 to 1.38. It signifies that the forest patches are affected by fragmentation.



Map 2.11 Patch area analysis of forest by fractal dimension

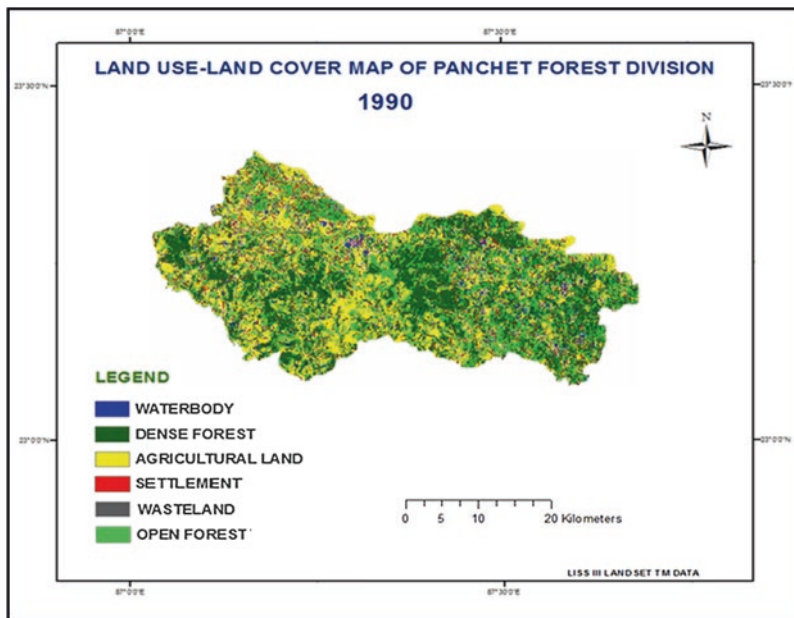
2.5 Factors of Forest Fragmentation

The patch analysis of the PFD landscape depicts that fragmentation of the forest landscape is prominent. Forest fragmentation has multitudes of direct and indirect impacts on those who depend on forest ecosystems. It not only regulates the micro-climatic condition, forest productivity and habitat suitability, but it has also been found to affect the abundance, movement and depredation caused by wild animals. The effects of forest fragmentation on wildlife population are some of the most well-known results of fragmentation. During our literature survey on human–elephant conflict, we observed that fragmentation of habitat is one of the most important causes of elephant migration and depredation to the nearby villages and agricultural lands.

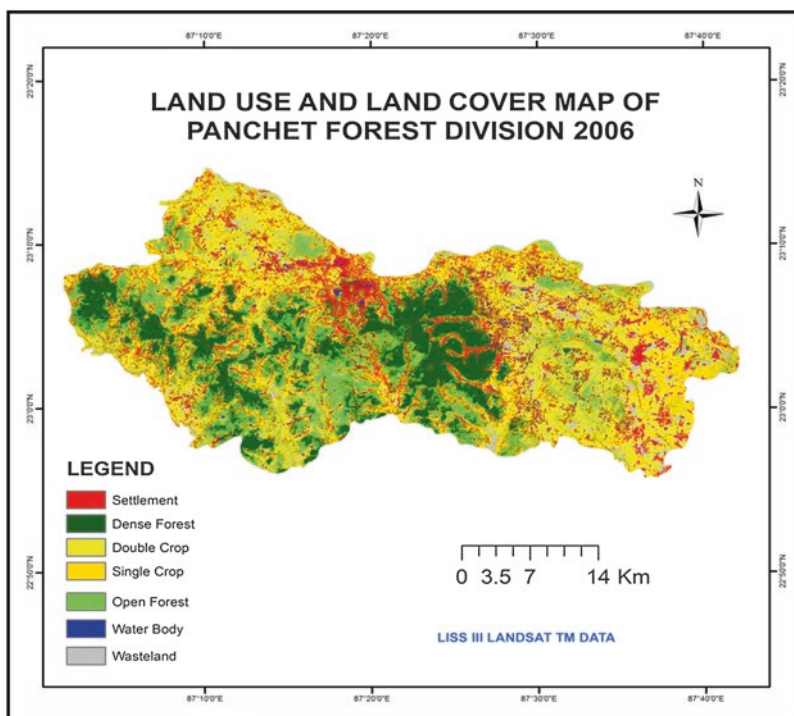
There are so many causes of forest fragmentation. Some are ecological, whereas some are anthropological in nature. In the study area, the main causes of fragmentation are land use and land cover change, shrinkage of forest cover and habitat fragmentation, reduction of forest covers for agriculture, construction of roads and railways and mining and quarrying activities.

2.5.1 *Land Use and Land Cover Change*

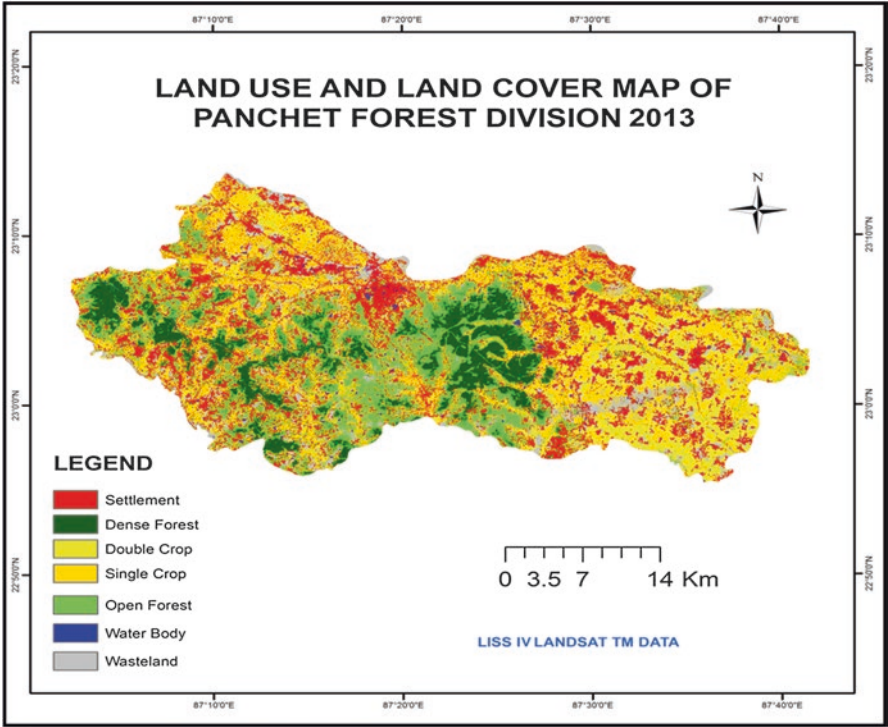
To detect the land use and land cover change in the study area, three satellite images (1990, 2006 and 2013) were taken. For 1990 and 2006, LISS III images were used, and for 2013, LISS IV data have been used. The land use map of the study area shows land under various uses. The south-western part is dominated by forest cover, fragmented patches of forest and degraded or regenerated forest patches, whereas the northern and eastern parts are dominated by agricultural land use. The maximum forest cover is found in the Machantala, Bishnupur I, Heraparvat, Chougan, Bishnupur II, Taldangra, Asna and Krishnanagar areas. The maximum portion is covered by agricultural land as the dominant land use. The main river, the Dwarakeswar, flows along the entire northern boundary, from west to east. The mode of connectivity is moderate; the main rail line is the south-eastern railway, which runs in a south to north-western direction. NH 60 is the major road along with other metalled, unmetalled, cart track, pack track and dispersed rural road networks. The land use and land cover maps of three different years show that there is a change in natural forest cover and settlement expansion.



Map 2.12 Land use and land cover map of Panchet Forest Division in 1990



Map 2.13 Land use and land cover map of Panchet Forest Division in 2006



Map 2.14 Land use and land cover map of Panchet Forest Division in 2013

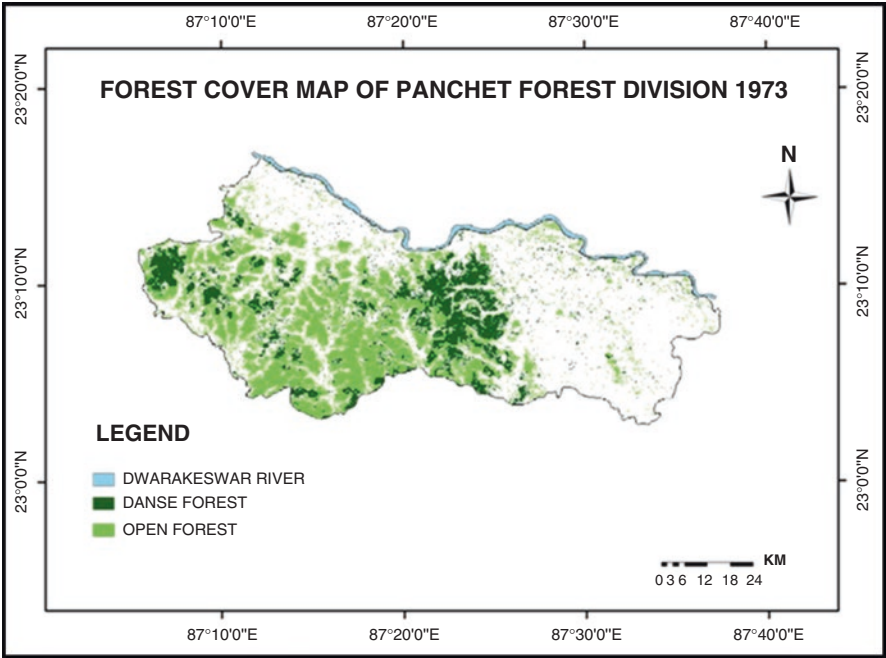
2.5.2 Shrinkage of Forest Cover and Habitat Fragmentation

To detect forest cover change in the study area, we used five satellite images of different years and seasons, from 1973, 1990, 2001, 2006 and 2013. The 1973 and 2013 images are pre-monsoon images, whereas the 1990, 2001 and 2006 images are post-monsoon images. From these images temporal changes in vegetation can be clearly identified. Forest patches become more fragmented and isolated in 1973 and 2013 mainly caused by the expansion of agriculture and settlement. According to the forest report of West Bengal in 2007–2008, the total forest cover of the district increased from 1988 to 2006, but at the same time continuous forest cover has been fragmented due to encroachment and other development activities. As the report of the West Bengal Forest Department reveals, a massive area of forest land has been encroached each year (Table 2.6).

Table 2.6 Land enclosed during 2007–2012 in Panchet Forest Division

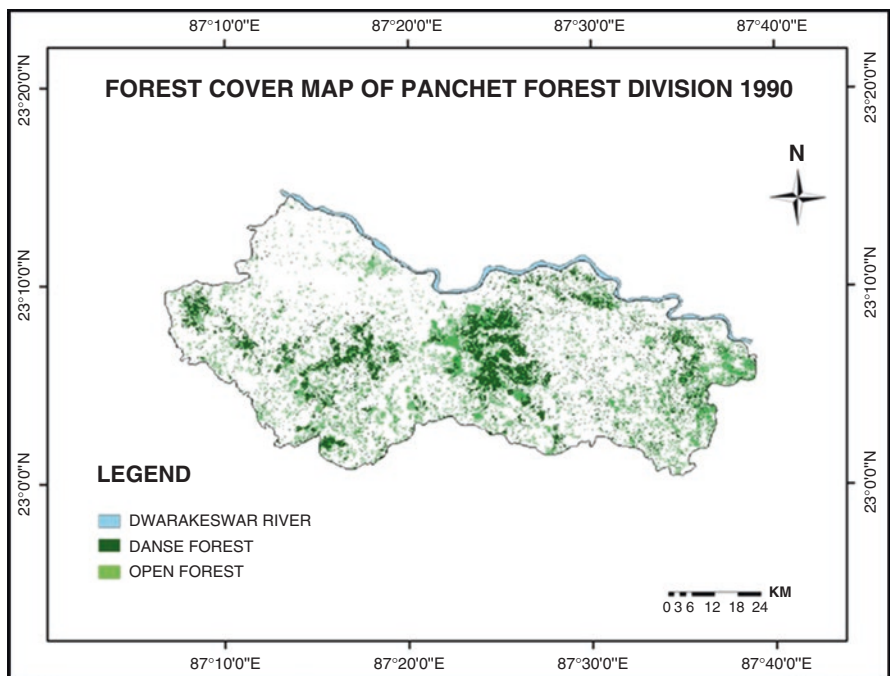
Year	Land encroached (in ha)
2007	1191.00
2008	780.97
2009	1022.55
2010	951.55
2011	708.37
2012	708.37

Source: State Forest Report 2007–2012

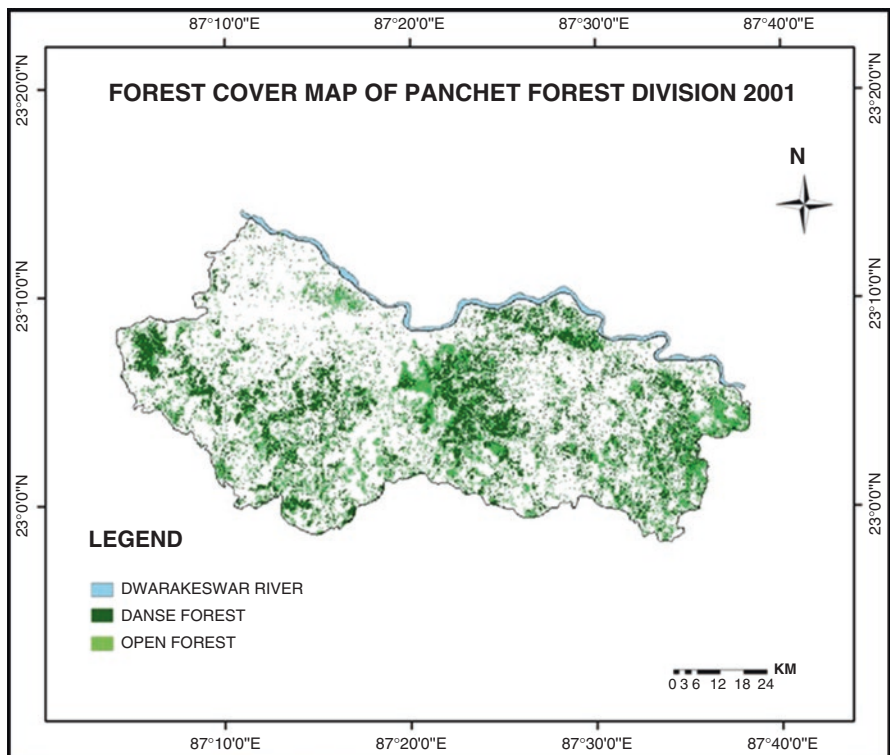


Map 2.15 Forest cover map of Panchet Forest Division in 1973

To recover the encroached and degraded forest areas, the forest department launched joint forest management (JFM) programmes in 1980. Raman Sukumar pointed out that the event of elephant migration from the Dalma Forest of Jharkhand was ironically supported by the success of the Social Forestry Project in West Bengal, under which large patches of denuded forest were regenerated (Sukumar 2003).



Map 2.16 Forest cover map of Panchet Forest Division in 1990



Map 2.17 Forest cover map of Panchet Forest Division in 2001

2.5.3 Reduction of Forest Covers for Agriculture

The main land use in our study area is agriculture. Agricultural land has been developed at the cost of forest, which has a great impact on the primary productivity of the habitat. The land use map shows that natural tree cover is present all over the area, at a considerably higher rate than in Bankadaha and Joypur range. Forest degradation occurs at a medium level over the whole study area. Settlement encroachment is very high in the Adkata, Chingani, Chagulia and Bishnupur beats. This natural and planted forest is mainly degraded by agricultural activities in the forest fringe areas. The field observation reveals that forests are encroached by forest fringe dwellers and roadside settlements that cross through the forest patches.

2.5.4 Construction of Roads and Railways

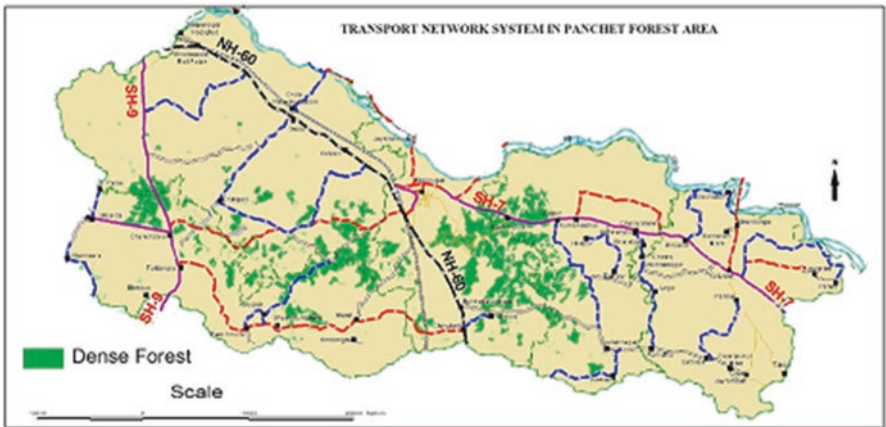
The construction of railways in the study area added another anthropogenic element that breaks the natural continuity of forest. In addition, road networks in the study area cover more area than railway lines. Both railways and roads pass through the forested tracts and elephant corridor, hampering the natural movement of elephants. Sometime wild animals are involved in vehicle accidents, and they are directly exposed to people, triggering the issue of human–animal conflict.



Plate 2.4 Road passes through the forest: elephant habitat



Plate 2.5 Herd of elephants crossing newly established Bishnupur–Tarakeswar railway line (Photo source: Panchet Forest Division)



Map 2.18 Transport network system in Panchet Forest Division

2.5.5 Mining and Quarrying Activities

Within the forest areas, quarrying of semi-precious minerals like sand, China clay, laterite, gravels and so on causes deforested patches within the forest. It degrades the quality of the natural habitat too.

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