SPRINGER BRIEFS IN ENVIRONMENTAL SCIENCE

Nilanjana Das Chatterjee

Man-Elephant Conflict

A Case Study from Forests in West Bengal, India

Springer

SpringerBriefs in Environmental Science

More information about this series at http://www.springer.com/series/8868

Nilanjana Das Chatterjee

Man–Elephant Conflict

A Case Study from Forests in West Bengal, India

Springer

Nilanjana Das Chatterjee
Department of Geography and Environment Management
Vidyasagar University
Midnapore, West Bengal, India

ISSN 2191-5547 ISSN 2191-5555 (electronic)
SpringerBriefs in Environmental Science
ISBN 978-3-319-31161-6 ISBN 978-3-319-31162-3 (eBook)
DOI 10.1007/978-3-319-31162-3

Library of Congress Control Number: 2016933858

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Dedicated to my teacher Manjusri Basu

Foreword

Human–elephant conflict issues have become crucial in the fragmented landscapes not only in West Bengal state but all over India. Urbanisation, expansion of settlements and increasing agricultural encroachment in the forest fringes have interrupted the movement of elephants in their own habitat. As a result, human–elephant conflict is evident. This book explores the issues and management options for the affected areas.

The contents of the book are the result of academic research carried out by the author with financial support provided by the Indian Council of Social Science Research (ICSSR). The book analyses different dimensions of human–elephant conflict with the help of empirical observations and information. A number of models and techniques are applied to assess habitat quality.

This book's intended audience includes researchers and scholars working on conservation issues, forest department personnel, and local government officials charged with environmental impact assessments, strategic planning and management at the local level. Thus, this book is a reference to study human–elephant conflict issues from a multidisciplinary perspective.

Preface

Elephants are known as a ‘keystone species’ in an ecosystem. A keystone species is a species that has a very large effect on the community through both direct and indirect pathways (Pain 1966; Power et al. 1996). Being a mega herbivore, an elephant has a tremendous impact on the habitat through its feeding and other activities (Sukumar 2003). Habitat selection of the elephant depends on its behavioural characteristics and the ecological carrying capacity of the habitat it inhabits. The unprecedented growth of the human population is responsible for the degradation and decline of the forest cover. It has been decimated from 40% (a century ago) to 19% in 1997 (MoEF). Anthropogenic perturbation in the form of agricultural and settlement expansion results in depletion or loss of natural habitat, loss of biodiversity, fragmentation of habitat and loss of corridors. The disproportionate sharing of forest resources and shrinkage of the sojourn area creates a food scarcity for the elephant, which ultimately forces animals to change their original habitat and migrate to a new one. During this migration, human–elephant conflict is a common issue in the corridors and edges in between habitats.

Human–elephant conflict is recognized as one of the main threats for survival of Asian elephants (Choudhury et al. 2008). Habitat destruction, human encroachment in the elephant habitat, fragmentation of natural habitat due to a rise in population pressure, settlement expansion and developmental activities within or near the forest areas ultimately squeeze the animals into narrower areas of remaining habitats. In most cases, these remnants of habitats are surrounded by crops or agricultural fields that elephants like to feed upon. As a result, elephants frequently raid and destroy crop fields (Living Planet Report 2006).

Human–elephant conflict has become a serious socioeconomic and political issue today. There were 900 human deaths from elephant attack in India from 1998 to 2001. Every year 250–300 people lose their life due to elephant attacks. This number increased to over 400 in 2010 (Baskaran et al. 2011). In 2011, 67 people were killed by wild elephants in West Bengal alone (State Forest Report 2011–2012). Elephants annually damage 0.8–1 million hectares of land in India (Bist 2002a) and affect at least 500,000 families (Gajah 2010). The marginal small landholders and individual cultivators suffer tremendously. Our religious beliefs, taboos, and cultures in many cases prevent us from either protecting or harming them, but continuous suffering eventually changes the attitudes of local people, and the conflict increases in many villages on forest fringes.

Man–elephant conflicts do have ecological consequences too. Farmers are forced to change both their cultivation patterns and their selection of species for cultivation. Resistance efforts employed to prohibit elephants lead to unusually aggressive behaviour, which actually multiplies problems.

The selected study area, Panchet Forest Division (PFD) of Bankura district, West Bengal, has experienced human–elephant conflict since 1987. Herds of elephants from the Dalma Wildlife Sanctuary (DWS) of Jharkhand generally migrate eastward into the adjoining districts of Bankura, Purulia, and Midnapore in the state of West Bengal after the rainy season. The study area is largely covered by agricultural land along with moist and dry deciduous forests. Elephants utilise small patches of regenerated sal (S*horea robusta*), a species selected for community development and conservation programmes (Gajah 2010), for shelter. This monoculture of sal is not a food source so the elephants raid crops found in the forest fringe agricultural lands as well as those along their migration route. As a result, man–elephant conflict has developed and has led to a huge loss to agricultural production, damage to property, human injury and even death.

A literature search revealed that man–elephant conflict not only led to socioeconomic loss, but also had detrimental impacts on elephants. In order to understand this problem better, an in-depth description of the land use, land cover characteristics and landscape ecology is provided. One of the primary objectives of the research presented in this book is to assess the ecological deterioration in both the source region (DWS, Jharkhand) from which the elephants are forced to migrate and the destination region (PFD) that lures the elephants to immigrate. This study assesses habitat quality by evaluating the forest density, structural pattern, plant species composition and association. Emphasis has also been given to identifying the characteristics of the man–elephant conflict zone in terms of land use, cropping patterns, elephant migration trends, patterns of migration, suffering of local population due to elephant attacks, livelihood patterns of villagers and probable causes of elephant migration. Moreover, we also focus on community attitudes towards elephants, level of awareness of the locals and methods they have adopt to resist elephant crop-raiding. Particular importance is also given to the crop selection behaviour of elephants.

The content of this book is divided into eight chapters.

Chapter 1 provides detailed information regarding the distribution of elephants throughout Asia and the Indian subcontinent. It clearly depicts elephant habitat characteristics in different parts of India including the vegetation and climatic characteristics. The objectives and methodology of our study are described in this chapter.

Chapter 2 deals with the ecological biogeography of PFD and DWS. This chapter is important because it gives the background matrix of the study. The theory of ecological biogeography entails the relationship between animal species and their environment over space and time (de Candolle). For instance, ecological biogeography analyses the type of environment where a specific plant is found. In this context 'environment' refers to the latitudinal factor or gradients, competition between species, geology of that area, climate, soil and so on (de Candolle 1820). The associations of plants depending on these factors are known as 'biomes', 'life zones' or 'ecoregions' (Wagner and Sydow 1888, cited in Cox and Moore, 1931). Similarly, the associations of both plants and animals within a specific environment are studied in ecophysiology. Both of these branches of study—ecological biogeography and ecophysiology—express the importance of environmental factors for the distribution of plants and animals. In this chapter we give a detailed ecological biogeography of both the source and destination regions of elephant migration.

Chapter 3 provides information on habitat requirements of elephants. Throughout India, elephant habitats represent diversified characteristics. In this chapter, we attempt to establish their habitat preference in terms of shelter, source of water or food, disturbed or undisturbed environments, seasonality of crop production and so forth.

Chapter 4 describes the migration and movement behaviour of elephants with the help of different models. We apply various statistical models, including regression, correlation, multivariate analysis, habitat suitability index and gap analysis models to understand the habitat–wildlife relationship.

In Chapter 6 we discuss various aspects of the local human population. Demographic characteristics such as density, composition, education level, economic status and occupation characteristics are considered because they are related to the man–elephant conflict issue.

Chapter 7 focuses on the behavioural study of migratory elephants and the changing behaviour of people in the affected area. We applied a perception survey technique that was supported by a pre-structured questionnaire to gauge people's attitudes towards elephants.

Chapter 8, the concluding chapter, is segregated into two parts: mitigation measures and various ways of managing human–elephant conflict. Mitigation measures adopted by the local people as well as by the forest department and those on the national level are examined. Finally, we propose some rational management measures that could be applied to address the issue of human–elephant conflict based on the major findings of this research work.

Nilanjana Das Chatterjee

Acknowledgements

I am indebted to the Indian Council of Social Science Research (ICSSR), New Delhi, for extending financial support for this project. The project would not have been completed without the help of this project's research assistants, Mr Mrinmoy Mondal and Mr Jayanta Hazra; and research scholars Mr Gour Dolui, Mr Murari Mohan Bera, Mr Rajkumar Bhattacharya and Mr Arabinda Maity. I am thankful to them. I would like to thank the students of third semester 2013 of our department for their help during the field survey. My sincere thanks to the vice-chancellor and the registrar of Vidyasagar University, for their administrative support to carry on this project. I would like to thank Dr Soumendu Chatterjee, Head, Department of Geography, Presidency University, for precious suggestions and guidance. I am grateful to all the forest officers of forest beats and ranges in Panchet Forest Division for providing sufficient information. I am grateful to Saini Sherestha (Springer) and Dhayanidhi Karunanidhi (Project Coordinator, Books, Springer) for their constant guidance to complete the work. Last, but certainly not least, I would like to thank my family and my daughter for all of their love and support, without which the present work could not have been completed.

Contents

1 Introduction 1
1.1 Introduction 2
1.2 Background of the Study 3
1.3 Similar Works on the Topic 6
1.3.1 Causes of Conflict 6
1.3.2 Consequences of Human–Elephant Conflict 8
1.4 Introducing the Study Area 13
1.5 Research Questions 13
1.5.1 Objective 1 13
1.5.2 Objective 2 14
1.5.3 Objective 3 14
1.5.4 Objective 4 14
1.6 Data and Methods 14
1.6.1 Data Collection Procedure 17

2 Ecological Biodiversity of Panchet Forest Division and Dalma Wildlife Sanctuary 19
2.1 Introduction 20
2.2 Destination Area 21
2.2.1 Panchet Forest Division 21
2.2.2 Geographical Boundaries 21
2.2.3 Administrative Setup 22
2.2.4 Geology and Physiography 22
2.2.5 Climate 23
2.2.6 Natural Vegetation 23
2.3 Source Region 24
2.3.1 Dalma Wildlife Sanctuary 24
2.3.2 Location 27
2.3.3 Physiography 27
2.3.4 Climate 28
2.3.5 Administrative Arrangement 29

2.4 Landscape Ecology and Analysis 33
2.4.1 Landscape Composition and Configuration 33
2.4.2 Heterogeneity: Patch, Corridor and Background Metrics 34
2.4.3 Forest Types and Composition 39
2.4.4 Changing Species Association 40
2.4.5 Spatial Analysis of Heterogeneity 42
2.5 Factors of Forest Fragmentation 53
2.5.1 Land Use and Land Cover Change 53
2.5.2 Shrinkage of Forest Cover and Habitat Fragmentation 55
2.5.3 Reduction of Forest Covers for Agriculture 58
2.5.4 Construction of Roads and Railways 58
2.5.5 Mining and Quarrying Activities 59

3 Habitat Requirements of the Elephant 61
3.1 Introduction 62
3.2 Home Range of Elephants 63
3.3 Habitat Analysis 64
3.3.1 Food, Nutrition and Changing Food Habits 65
3.3.2 Shelter 66
3.3.3 Water Source 79

4 Habitat–Wildlife Relationship and Different Models 83
4.1 Introduction 84
4.2 Habitat Heterogeneity and Disturbance 85
4.2.1 Vegetation Composition and Structure Model 86
4.2.2 Disturbance Model 89
4.2.3 Gap Analysis Model 90
4.2.4 Habitat Suitability Index Model 93

5 Elephant Migration and Dispersal: A Biogeographic Process 97
5.1 Introduction 98
5.1.1 Habitat Requirements for Elephants 99
5.2 Historical Perspective of Elephant Migration in the Study Area 99
5.3 Elephant Migration Trend: Volume and Duration of Stay 101
5.4 Elephant Migration Routes and Their Temporal Shifts 104
5.4.1 The Common Return Route 109
5.5 Seasonal Dependence on Migration Events 115
5.6 Crop Calendar and Appearance of Elephants 117
5.7 Conversion of Migrated Elephant to Residential Elephant 118

6 Characterising the Human–Elephant Conflict Zone 119
6.1 Introduction 120
6.2 Demographic Characteristics 121
6.3 Livelihood Pattern of Forest Fringe Dwellers 122
6.4 Land Use Pattern 122
6.4.1 Agriculture 123
6.4.2 Settlement 125

6.5 Human Appropriation of Forest Ecosystem Resources 126
6.5.1 Joint Forest Management and Forest Protection Committees in Panchet Forest Division 126
6.5.2 Use of NTFPs 128
6.6 Elephant Attacks on Humans 130
6.7 Damage to Life and Assets 131
6.8 Human Resistance Towards Elephants 132

7 Behavioural Study 135
7.1 Introduction 136
7.2 Local People's Attitude Towards Elephants 137
7.3 Community Perception Survey 138
7.4 Anthropogenic Causes of Damage by and Sufferings of Elephants 143
7.5 Views of Local People in Settling Human–Elephant Conflict 144
7.6 Locals' Evaluation of the Forest Department's Role and Response from the Forest Department 145
7.7 Changing Behaviour of Elephants 147

8 Conclusion 149
8.1 Introduction 150
8.2 Mitigation Measures 151
8.2.1 Scaring and Driving the Herd Away 152
8.2.2 Crop Guarding 153
8.2.3 Throwing Stones or Arrows 154
8.2.4 Wild Elephant Capture 155
8.2.5 Chemical Immobilisation 155
8.2.6 Habitat Development 155
8.3 Managing Human–Elephant Conflict at the National Level 156
8.3.1 Project Elephant 156
8.3.2 Community Involvement 158
8.3.3 Land Use Planning 158
8.4 Major Findings 161
8.5 Conclusion 162

Appendix A 163

References 167

Index 177

List of Maps

Map 1.1 Administrative setup of Panchet Forest Division 12
Map 1.2 Location of Panchet Forest Division 12

Map 2.1 Soil series association of Panchet Forest Division 23
Map 2.2 Map of Dalma Wildlife Sanctuary 26
Map 2.3 Mineral distribution map of East Singbhum district 27
Map 2.4 Patch distribution map of Panchet Forest Division 35
Map 2.5 Aerial view of forest patches 36
Map 2.6 Land use and land cover map of Panchet Forest Division in 2013 to show the background metrics 38
Map 2.7 Forest cover map of Panchet Forest Division in 2013 39
Map 2.8 Patch area analysis of forest by the mean shape index 49
Map 2.9 Patch area analysis of forest by edge density 50
Map 2.10 Patch area analysis of forest by core area index 51
Map 2.11 Patch area analysis of forest by fractal dimension 52
Map 2.12 Land use and land cover map of Panchet Forest Division in 1990 54
Map 2.13 Land use and land cover map of Panchet Forest Division in 2006 54
Map 2.14 Land use and land cover map of Panchet Forest Division in 2013 55
Map 2.15 Forest cover map of Panchet Forest Division in 1973 56
Map 2.16 Forest cover map of Panchet Forest Division in 1990 57
Map 2.17 Forest cover map of Panchet Forest Division in 2001 57
Map 2.18 Transport network system in Panchet Forest Division 59

Map 3.1 Elephant distribution map of South East Asia 63
Map 3.2 Elephant migration route from Dalma Wildlife Sanctuary to Panchet Forest Division on open source image 64

Map 3.3	Sample sites for ecological surveying at Panchet Forest Division	67
Map 3.4	Sample sites for ecological surveying at Dalma Wildlife Survey	68
Map 4.1	Ecological component of Panchet Forest Division	86
Map 4.2	Major land use/land cover types of Panchet Forest Division in 1990	92
Map 4.3	Major land use/land cover types of Panchet Forest Division in 2013	93
Map 4.4	Habitat suitability map for Panchet Forest Division	94
Map 5.1	Elephant migration entry route at Panchet Forest Division, 2010	105
Map 5.2	Elephant migration entry route at Panchet Forest Division, 2011	106
Map 5.3	Elephant migration entry route at Panchet Forest Division, 2012	107
Map 5.4	Normalised differential vegetation index and entry route at Panchet Forest Division, 1990	108
Map 5.5	Shifting entry route in the years 2010–2012	109
Map 5.6	Elephant migration return route from Panchet Forest Division to Dalma, 2010	110
Map 5.7	Elephant migration return route from Panchet Forest Division to Dalma, 2011	111
Map 5.8	Elephant migration return route from Panchet Forest Division to Dalma, 2012	112
Map 5.9	Elephant migration return route in relation to the normalised difference vegetation index, 2005–2009	113
Map 5.10	Normalised difference water index for Panchet Forest Division, 2013	114
Map 5.11	Soil adjusted vegetation index for Panchet Forest Division, 2013	115
Map 5.12	Seasonal variation and migration patterns	116
Map 6.1	Beat-wise population density in Panchet Forest Division	121
Map 6.2	Beat-wise education profile in Panchet Forest Division	122
Map 7.1	Respondents’ opinions regarding agricultural expansion as a factor for elephant migration	139
Map 7.2	Respondents’ opinions regarding changed cropping pattern as a factor for elephant migration	139
Map 7.3	Respondents’ opinions regarding decreased forest resources as a factor for elephant migration	140

Map 7.4 Respondents' opinions regarding forest fire as a factor for elephant migration.. 140
Map 7.5 Respondents' opinions regarding human intrusion as a factor for elephant migration.. 141

Map 8.1 Trend of elephant migration route, 2005–2009............................... 159
Map 8.2 Damage map of Panchet Forest Division, 2011.............................. 160
Map 8.3 Damage map of Panchet Forest Division, 2012.............................. 160

List of Plates

Plate 2.1 Patches on open source image 37
Plate 2.2 Typical features of forest in the study area 40
Plate 2.3 Core at 200 m buffer 50
Plate 2.4 Road passes through the forest: elephant habitat 58
Plate 2.5 Herd of elephants crossing newly established Bishnupur–Tarakeswar railway line 59

Plate 3.1 Ecological surveying at Adkhatha forest range 71
Plate 3.2 Elephant venturing the crop field 77
Plate 3.3 Agricultural fields on the vicinity of forest 77
Plate 3.4 Elephant are crossing motorable road 78
Plate 3.5 Elephant are across railway track 79
Plate 3.6 Kangsabati canal, as source of water in PFD 80
Plate 3.7 Elephant herd near Dwarakeswar River 80
Plate 3.8 Metalled road through the forest 81

Plate 5.1 Solitary bulls raiding in agricultural field 103
Plate 5.2 People throwing stone at elephant 103

Plate 6.1 Agricultural diversity's in study area 124
Plate 6.2 Hut damage due to elephant attack 125
Plate 6.3 Plantations at Bakhadaha, Amdangra, and Joypur Range 127
Plate 6.4 Forest as a resource base 128
Plate 6.5 Herd elephant raiding crops 133

Plate 7.1 People throwing stone to drive away elephant herd 142
Plate 7.2 Minutes of district forest office Bankura 146
Plate 7.3 Aggressive behaviour of elephant as a reaction of people attack 147

Plate 8.1 Elephant calf trapped in man made tank 151
Plate 8.2 Hullah pati chasing elephant to drive elephant 152
Plate 8.3 Crop guarding at night by the villagers... 153
Plate 8.4 People scaring elephant part to drive them
back to the forest 154
Plate 8.5 Plantations by the forest department
for habitat improvement... 156

List of Figures

Fig. 2.1 Rainfall distribution of the Panchet Forest Division from 2005 to 2009 24
Fig. 2.2 Temperature distribution of the Panchet Forest Division in 2005–2009 24

Fig. 3.1 Ecological survey at Bishnupur—transect A 69
Fig. 3.2 Ecological survey at Bishnupur—transect E 69
Fig. 3.3 Ecological survey at Dalma—foothill 70
Fig. 3.4 Ecological survey at Dalma—middle hill 70
Fig. 3.5 Ecological survey at Bankadaha—transect A 71
Fig. 3.6 (a) Temperature variation in Panchet Forest Division (PFD). (b) Rainfall distribution in PFD 72
Fig. 3.7 Duration of elephant stay at different stations in Belsulia village 73
Fig. 3.8 Duration of elephant stay at different stations in Basudevpur village 73
Fig. 3.9 Duration of elephant stay at different stations in Kharikasuli village 74
Fig. 3.10 Duration of elephant stay at different stations in Chougan village 74
Fig. 3.11 Duration of elephant stay at different stations in Siromonipur village 75
Fig. 3.12 Duration of elephant stay at different stations in Dhangapathar village 75
Fig. 3.13 Duration of elephant stay at different stations in Herapabat village 76
Fig. 3.14 Duration of elephant stay at different stations in Dhangasole village 76

Fig. 4.1 Ecological transect of different station, Bishnupur—F 87
Fig. 4.2 Ecological transect of different station, Bankadaha—A................. 88
Fig. 4.3 Ecological transect of different station, Taldangra—H................... 88
Fig. 4.4 Percentages of canopy and ground cover....................................... 89
Fig. 4.5 Relationships between population density and forest cover 90
Fig. 4.6 Distances from forest edge and diameter at breast height (DBH)... 90
Fig. 4.7 Relation between forest edge and abundance of plant species 91
Fig. 4.8 Concentration of pond in forest core 91
Fig. 4.9 Motorable road ratio and abundance of plant species..................... 91

Fig. 5.1 Preferences for habitat selection 100
Fig. 5.2 Trend of elephant migration in Panchet Forest Division in 1995–2012 101
Fig. 5.3 Duration of stay at Panchet Forest Division in 1995–2012 102
Fig. 5.4 Beat-wise elephant migration in Panchet Forest Division in 2008–2009 117
Fig. 5.5 Volumes of migration and duration of stay of residential and migratory elephants, 2001–2012... 118

Fig. 6.1 Landholding characteristics in Panchet Forest Division................. 123
Fig. 6.2 Land use category under different classes 123
Fig. 6.3 Human–elephant conflict and its consequences, 2003–2012.......... 130
Fig. 6.4 Loss of property due to elephant depredation, 2003–2012............. 131
Fig. 6.5 Diurnal behaviour of elephant attack... 132

Fig. 7.1 People's attitude towards elephants 138
Fig. 7.2 Awareness notice issued by the forest department......................... 143
Fig. 7.3 Elephant deaths in southern West Bengal since 1991..................... 144
Fig. 7.4 Different methods adopted by villagers to resist elephant attack 145

Fig. 8.1 Schematic representations of elephant landscape reserves............. 157

List of Tables

Table 2.1 Natural vegetation at Panchet Forest Division 25
Table 2.2 Legal status of Panchet Forest Division and Dalma Wildlife Sanctuary 25
Table 2.3 Legal status of Panchet Forest Division and Dalma Wildlife Sanctuary 29
Table 2.4 Natural vegetation in Dalma Wildlife Sanctuary 30
Table 2.5 Patch IDs for forest patch analysis 49
Table 2.6 Land enclosed during 2007–2012 in Panchet Forest Division 56

Table 4.1 Table for habitat suitability index 94

Table 5.1 Crop calendar and appearance of elephants 117

Table 6.1 Number of forest protection committees in the study area (2006–2012) 126
Table 6.2 Collection of non-timber forest products in Panchet Forest Division 128
Table 6.3 Utilisation of forest and forest products in different forms 129

Abbreviations

CAI	Core area index
DWS	Dalma Wildlife Sanctuary
ED	Edge density
FD	Fractal dimension
FPC	Forest protection committee
HSI	Habitat suitability index
JFM	Joint forest management
MSI	Mean shape index
NDVI	Normalized differential vegetation index
NTFPs	Non-timber forest products
PFD	Panchet Forest Division
PM	Patch metrics
SAVI	Soil adjusted vegetation index

Chapter 1
Introduction

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_1

Abstract Chapter 1 is an introductory chapter. This chapter initially focusses on the issue of human–elephant conflict worldwide, with special emphasis on the countries of South East Asia and Africa because in these areas the problem is severe. A large body of literature was critically reviewed to understand the severity of the problem. It is also helpful to become familiar with previous research, including the methodology and perspective of work done in this field. This chapter also suggests the causes and consequences of human–elephant conflict throughout the elephant habitats of the world. Next, it focusses on the typical characteristics of human–elephant conflict in the author's study area, West Bengal state. A detailed introduction of the study area is given, and a location map, administrative units, forest units, ecological background and more information are provided. Research questions are delineated and objectives (both general and specific objectives) are set accordingly. The objectives cover different dimensions to the issue, such as characterising elephant habitats, analysing elephant migration behaviour, assessing habitat intervention and its consequences, modelling the habitat–elephant relationship and studying the nature of human–elephant conflict. The text describes data collection procedures as well as the methodologies adopted here.

Keywords Problem of human–elephant conflict • Elephant habitats • Methodology

1.1 Introduction

The Asian elephant (*Elephas maximus*) once ranged over a vast area extending from the Tigris and Euphrates rivers in West Asia over to South East Asia (Olivier 1978). The distribution of elephants today is limited to Nepal, Bhutan, Bangladesh, India, Sri Lanka, Myanmar, China, Thailand, Malaysia, Indonesia, Cambodia, Laos and Vietnam (Santiapillai 1987). The total number of Asian elephants is estimated to be about 44,000–56,000 (Doyle et al. 2010). India has by far the largest number of Asian elephants, with an estimated population of about 26,000–28,000, or nearly 60 % of the species population (Bist 2002a, b, data from Project Elephant Report 2009). The Asiatic elephant is able to utilise a wide variety of habitats that have the basic requirements of water, shade and forage. Elephant habitats range from savanna, forest scrub, and secondary forest to forest–grassland mosaic (Eisenberg 1981). Its preference varies from a closed canopy forest to open degraded forests with the availability of basic forage; elephants can survive even in small, isolated, fragmented forest areas. Today the wild elephant distribution zone in India is confined to the following five major zones:

1. the foothills of the Himalayas in the north;
2. the north-eastern states;
3. the forests of eastern and central India;
4. the forested hilly tracks of the Western and Eastern Ghats in southern India;
5. Andaman Island.

1. *The foothills of the Himalayas in the north*: The Himalayan foothill region spreads from west to east and covers Uttarakhand and Uttar Pradesh states and the adjoining part of Nepal. This zone is characterised by large-scale development projects such as power generation, irrigation and cultivation; the introduction of monoculture and commercial plantations have fragmented the landscape (Johnsingh et al. 1990).
2. *The north-eastern states*: The elephant zone of north-eastern India extends along the Himalayan foothills from northern West Bengal to the eastern states of Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. Some part of this zone extends to Bhutan and Myanmar. The habitat of this region has experienced deforestation caused by illegal logging, shifting cultivation or *Jhum*, monoculture and encroachment. Habitat degradation is a major threat here. Three thousand square kilometres of land (out of 32,600 km^2) was lost between 1991–1999 because of human encroachment; the area is seriously affected by habitat loss, fragmentation and human–elephant conflict (Bist 2002a, b).
3. *The forests of eastern and central India*: The elephant habitat of eastern and central India extends over Chota Nagpur Plateau to parts of Orissa and Jharkhand (Shahi and Chowdhury 1986; Sar and Varma 2004). A typical feature of elephant migration from the neighbouring states, especially southern West Bengal and Chhattisgarh to north-eastern Andhra Pradesh, is creating a problem of human–elephant conflict in this region. The elephant habitat in this region is characterised by natural forest, often degraded or fragmented, village forest, agricultural land, mining sites and more. The large-scale mining of iron ore, manganese and chromate is the largest threat for elephants of southern Jharkhand and northern Orissa (Baskaran et al. 2011).
4. *The forested hilly tracks of the Western and Eastern Ghats in southern India*: The elephant habitat of southern India ranges over the hilly tracts of the Western Ghats and adjacent Eastern Ghats, covering the states of Karnataka, Kerala, Tamil Nadu and some parts of Andhra Pradesh, Maharashtra and Goa. Elephants living here are threatened by high populations, expansion of agricultural land, commercial plantations, hydroelectric power generation and irrigation dams (Sukumar 1989a, b).
5. *Andaman Island*: This habitat is situated in the Andaman and Nicobar Islands, but most of these elephants were taken from the mainland for timber extraction and were abandoned by the East India Company in 1962 (Sivaganesan 1993; Sivaganesan and Kumar 1995).

1.2 Background of the Study

The elephant habitats distributed throughout India have some common characteristics. Most of the habitats are located on the fringe of settled areas and are encroached by increasing human population, settlement extensions and development activities such as the construction of dams, hydropower projects, power line installation and the building of canals, roads and railway lines through the habitats. In a true sense, no elephant habitat is free from human encroachment. Thus, habitat loss and human intervention are the most important threats to elephants in India. Moreover, human-caused fragmentation, degradation and alteration of habitat are the major factors that lead to issues of human–elephant conflict.

Elephants are known as “keystone species” in an ecosystem. A keystone species is a species that has a very large effect on the community through both direct and indirect pathways (Paine 1966; Power et al. 1996). Being mega herbivores, elephants have a tremendous impact on their habitat through their feeding and other activities (Sukumar 2003). They alter the ecosystem, affect the physiognomy of plant species and promote the growth of herbaceous plants by creating gaps in the forest ecosystem that provide forage for other herbivores, create soil erosion through their “geophagy” habits and help dispose of seeds (Sukumar 2003). At the same time, however, elephants need large areas to forage. The size of their ground and home range depends on the habitat type. Generally, it ranges from 250 to 600 km^2 (Doyle et al. 2010). The home range depends on the landscape characteristics of an area. It is strongly influenced by the elephants’ need for water and forage. Elephants can adjust to living within a fragmented patchy forest. The home range also varies seasonally. One study on male elephants in Zambia’s Luangwa Valley revealed that during the dry season the forage behaviour is sedentary, whereas elephants move longer distances with the coming of rain (Sukumar 2003). This trend results from the scarcity of water or green biomass. Elephants confine themselves to small areas where these sources are available. They can quickly move from one resource patch to another (Sukumar 2003). The nature of their movement is also governed by the presence of agricultural land surrounding the habitat or regenerated fragmented forest patches that are used as corridors during their movement. A similar case has been observed for a subpopulation of elephants in Dalma Sanctuary, Jharkhand, and its surroundings when a herd of elephants began to make deep forays eastward into southern West Bengal and thus created problems of human–elephant conflict.

But the most abundant cause of human–elephant conflict is habitat manipulation by people. This manipulation process is present in almost all elephant ranges in India. Different ways the manipulation occurs include timber extraction, shifting agriculture, grazing activity and the cultivation of bamboo and grasses in the forest fringe areas, which attracts elephants as a secondary feeding source along with the primary natural forest (Sukumar 2003). Extracting extensive non-timber forest products (NTFPs) from the forest (e.g., fruit, flowers, roots, bark, leaves and medicinal plants) can hamper the nutrient potentiality as well as the natural productivity of the forest and reduces the available forage biomass for elephants. Human penetration in the forest increases the probability of conflict issues.

The conversion of the natural forest into monoculture plantations, croplands and developed areas has drastically reduced available habitats (Santiapillai and Jackson 1990; Sukumar 2003; Nyhus et al. 2000; Hedges 2006). Habitat loss, degradation, fragmentation conversion and resource exploitation by humans thus result in spatial shrinkage and reconfiguration of the original habitat (Gascon et al. 1999). Large-scale fragmentation leads to isolation of the habitat, which restricts the movement of wild animals (Laurance et al. 1997). Land use configuration in a habitat creates patches and corridors, which ultimately impact the movement pattern of elephants. Mega herbivores like the elephant are compelled to move within the restricted fragmented habitat, causing human–elephant conflicts. Sometimes elephants disperse and wander well outside their habitat, causing severe problems of human–elephant conflict (Fernando et al. 2008a). Erosion of the habitat forces elephants into agricultural areas, where they destroy crops and inevitably enter into conflict with humans. Thus, forest degradation and habitat loss are major factors of human–elephant conflict (Dawson and Blackburn 1991). Human–elephant conflict is not a new phenomenon. Humans and elephants have been utilising the same space for thousands of years (Sukumar 1989a, b, 2003; Fernando et al. 2005). The rock paintings of India depict the history of elephants in domesticity (Lahiri-Choudhury 1988). The hymns, prayers, poems and rituals of the Vedic period (1500 B.C.E.) provide the earliest sources of information on the human–elephant relationship (Sukumar 2003). Owning an elephant was a status symbol (Lahiri-Choudhury 1988). In the Hindu religion, worship of the elephant in the form of the elephant-headed god *Ganesha* is very popular. Their tusks were used for carvings. Elephants were used for logging the forest and in warfare too. Hence, Indians have a benevolent attitude towards elephants. But the increasing population demand for land has created a competition between humans and elephants, resulting in a conflict that now borders a threshold where the benevolent attitude has begun to erode (Fernando et al. 2008a, b, c).

Human–elephant conflict has become a serious socio-economic and political issue today. From 1998–2001, there were 900 human deaths due to elephant attack in India, with 250–300 deaths each of those years. This number increased in 2010, when it exceeded 400 (Baskaran et al. 2011). In 2011, 67 persons were killed by wild elephants in West Bengal state alone (State Forest Report 2011–2012). Elephants annually damage 0.8–1.0 million hectares of land in India (Bist 2002a, b) and affect at least 500,000 families (Rangarajan et al. 2010). The marginal small landholders and individual cultivators suffer immensely. The local religious beliefs, taboos and culture in many cases prevent Indians from either protecting or harming elephants, but continuous problems eventually change the local attitudes and the conflict increases in many forest fringe villages. On the other hand, human–elephant conflicts have ecological consequences. Farmers are forced to change their cultivation patterns and species selection. Efforts to prohibit elephants lead to unusually aggressive elephant behaviour, which actually multiplies the problem.

The selected study area, Panchet Forest Division of Bankura district, West Bengal, has experienced such a typical situation of human–elephant conflict since 1987. A herd of elephants from Dalma Wildlife Sanctuary of Jharkhand make deep forays eastward into the adjoining districts of Bankura, Purulia and West Midnapore of West Bengal state. The elephants have migrated each year from Dalma to the study area after the rainy season. The area is predominated by moist deciduous forests interspersed with dry deciduous forests and largely covered by agricultural land. The elephants utilise small patches of regenerated sal (S*horea robusta*), a species selected for community development and conservation programmes (Chowdhury et al. 1997). This monoculture of sal provides shelter for elephants but not food, and so the elephants raid crops both in the forest fringe agricultural lands and along their migration route. This has become a regular phenomenon in the study area and has resulted in human–elephant conflict. Huge losses to agricultural production, damage to houses, human injuries and even death have become regular features in the Panchet Forest Division.

1.3 Similar Works on the Topic

The consequences of human–elephant conflict are not only of key conservation concerns but are also major socio-economic and political issues (Fernando et al. 2008a, b, c). In recent years, increasing human–elephant conflict has been a major issue in managing the wild elephant population in India (Sukumar 1990; Dey 1991; Johnsingh and Panwar 1992; Daniel et al. 1995; Nath and Sukumar 1998). The literature on human–elephant conflicts depicts two clear-cut classifications, one addressing the causal factors behind migration and another dealing with the consequences and management of the issues (*Gajah* articles from 1986 to 2012). Much of the literature also relates to damage caused by this mega herbivore, damage to the ecosystem as well as injury to or death of the elephants.

1.3.1 Causes of Conflict

Agricultural expansion in the forest fringe areas is one the main causes of human–elephant conflict. In West Africa, cultivation of maize and the number of crops grown on farms attract elephants in both savannas and forests (Barnes et al. 2008; Danquah et al. 2006). Sumatran elephants are threatened by various development programmes such as the large-scale establishment of human settlements in plantation estates, oil exploration, mining, irrigation and agriculture. The conversion of primary forest into agricultural holdings seriously affects the elephant population (Blair and Noor 1981). Phanthavong and Santiapillai (1992) stated that throughout Asia the root causes of elephant depredation are deforestation and conversion of forests to agricultural land. The alteration of habitat to agriculture, plantation forestry, wholesale clearing of forest, competition from domestic livestock and direct human predation for food, ivory or crop protection have steadily eroded the limited remaining habitat and are causing human–elephant conflict in Asia (Dudley 1993). In Laos, shifting cultivation at higher elevation is one of the causes of forest degradation. As of 1989 in Laos, 253,000 families were engaged in shifting cultivation and about 300,000 ha of land were being used for that purpose each year (Salter 1989). This may be detrimental for elephant habitats in Laos. Along with shifting cultivation, timber extraction and hydroelectric power generation are the other major factors affecting the habitats of wild elephants (Poole 1991). Moreover, population and settlement growth in the riverine grasslands, which are among the most preferred elephant habitats, have led to those grasslands' conversion into agriculture, which affects elephants' source of food (Phanthavong and Santiapillai 1992). Massive shrinkage and fragmentation of natural habitats caused by illegal human settlement and opening of the tea industry are major anthropogenic disturbances that have contributed enormously towards the total destruction of the elephant habitat in the Golaghat district of Assam (Sarma et al. 2008). Forest cover loss in Assam is one of the main causes of human–elephant conflict.

In Asia, natural forest clearance for agriculture is the main cause of elephant depredation (Andau and Payne 1992). Elephants' preference for selected plant species may also enhance the conflict. In Africa, early European travellers observed that elephants prefer plants like acacias, and it indeed is their favourite target (Sukumar 2003). As a result, they have flattened entire forests dominated by such species. The famous Serengeti National Park in Tanzania also had an elephant problem. In 1967, Hugh Lamprey and his associates reported damage to acacia and commiphora woodland in the Northern Serengeti and destruction of the favoured tree *Acacia xanthopholea* by bull elephants in the Seronera area to the south. In Africa, other favoured species include the gum arabic *A. senegal*, the umbrella thorn acacia *A. tortillis*, the baobab or Adansonia digitata tree, and *Delonix elata*. On the other hand, the number of species that elephants do not prefer (e.g., *Melia volkensii*) has increased (Sukumar 2003). Reports of human–elephant conflict are frequent in areas with preferred food plants. In the moist tropics of Asia, the staple cereal paddy (*Oryza sativa*) is a favourite target of elephants. Cultivated grasses, particularly cereals and millets, are the most common targets of elephant depredation. According to Sivaganesan, as reported in Daniel (2009), it is not the overexploitation of food species that leads to destruction of the forest community as a whole, but the selective disappearance of the most favoured species of trees fed on by elephants in different habitat types. In drier regions of both Asia and Africa, elephants consume a variety of agricultural products, chiefly corn, sorghum, wheat, finger millet and sugarcane. These crops attract elephants and increase the probability of conflict in these areas. Elephants often attack the garden and plantation areas in tropical and subtropical countries. In southern India, elephants attack coffee garden or coconut plantation areas. Moreover, elephants also raid vegetables and fruits usually grown in homestead gardens (Anandabazar Patrika 2014g). In the forested areas of North Bengal, elephant depredation has become a severe problem. In Assam, a growing human population, demands for cultivable lands and the conversion of forest habitation to human habitation and cropland have resulted in serious human–elephant conflict (Talukdar and Barman 2003). In North-east India, more than 1000 km^2 of forest are destroyed annually (Choudhury 1991).

In the early 1900s, elephants were abundant in the dense sal (*Shorea robusta*) forests of the Medinipur district and its adjoining areas of southern West Bengal, where the study area sits (O'Malley 1911a, b). However, they became rare until the 1980s because of forest losses and poor quality of coppice sal forests (Palit 1991; Malhotra 1995; Panda 1996). The reappearance of elephants in southern West Bengal started in the late 1980s with the revival of forest cover under participatory forest protection initiatives (Palit 1991; Malhotra 1995). Thus, regeneration of forest cover is the principal cause responsible for attracting elephants to this area. Since 1987, elephants have migrated from the Dalma Forest to the Panchet Forest each year following the newly generated forest corridors (Sukumar 2006).

Climate change at the micro or macro level can also be a factor for elephant migration; this is especially true of the decline in annual rainfall. In many cases, it is observed that there is a direct relationship between rainfall variation and elephant migration. During the years 1993–1995 in the northern Sebungwe region of Zimbabwe, Hoare and Du Toit (1999) observed that annual rainfall, human density and area under settlement are correlated to crop raiding. Climate change in India is also the main reason for habitat destruction, which causes human–elephant conflict (Daniel 1993). The dispersal of elephant herds from Tamil Nadu and Karnataka to Andhra Pradesh, where they reside for a long time, may be attributed to a combination of habitat and climate factors (Sukumar 2003). Another observation by Sukumar (2003) involves the initial migration that occurred in 1987, which was a drought year on the subcontinent. Migration takes place because elephants decide to expand their winter range and forage ground in wet season. The easy availability of food attracted them, and subsequently it became a routine migration each year after the rainy season. According to the Forest Report (2011) of the Purbi Singhbhum district (where the Dalma Wildlife Sanctuary is situated), it had a forest cover of 31.51 % of its total geographical area. During 1997–1999, 32,000 ha of dense forest were cleared; during 2001–2003, this number was 7,900 ha. The responsible factor behind this large-scale forest destruction is expansion of mining of iron ore, copper, chromite, asbestos, kyanite, china clay, manganese, dolomite and uranium deposited in the forested tracts. The rapid industrialisation in Purbi Singhbhum district has caused the large-scale destruction of the forest, which was once the abode of many wildlife species, including the elephant. Thus, the quality and quantity of forest cover deterioration in Dalma Wildlife Sanctuary forced elephants to migrate.

According to the State Forest Report for West Bengal, the forest cover in Bankura district has increased from 24.66 % of its geographical area in 1998 to 32.17 % in 2006. It depicts a natural increase in forest cover, but the density decreased (State Forest Report, 2007–2008). This regeneration of forest provides a natural forest corridor between and within the study area. At the same time, the 2007 West Bengal State Report on encroachment of forest land states that 1191 ha of land in the Panchet Division had been encroached that year. This tradition of encroachment has continued although the Forest Department is trying to tackle it. In 2012, the encroachment totalled 708.37 ha. This type of encroachment for the collection of fodder, small timber and NTFPs enhances the probability of human–elephant conflict in the study area. Thus, human–elephant conflict is a result of improvement in the forest quality in Panchet Forest Division and degradation of the habitat in the Dalma Wildlife Sanctuary.

1.3.2 Consequences of Human–Elephant Conflict

Human–elephant conflict is recognised as one of the main threats for the survival of Asian elephants (Choudhury et al. 2008). It describes occurrences of crop raiding, infrastructural damage, injury to and death of humans and elephants (Hoare, 2000).

Habitat destruction, human encroachment in the elephant habitat, fragmentation of natural habitat caused by huge population pressure, settlement expansion and developmental activities within or near the forest areas have ultimately squeezed the animals into smaller remaining habitats. These remnants of habitats are in most cases surrounded by crops or agricultural fields that elephants like to eat. As a result, elephants frequently raid and destroy crop fields (Living Planet Report 2006).

In Sri Lanka, around 50 people and 120 elephants die each year as a result of human–elephant conflict (Jayawardene, 2003). In Sumatra, elephants have been forced to migrate to the forested slopes of mountain ranges, where they frequently enter gardens and raid crops (Nyhus et al. 2005; Nyhus and Tilson 2004; Linkie et al. 2007) and the incidence of human–elephant conflict has increased. Fragmented forests increase the tendency for human–elephant conflict to occur (Hoare 1999; Sitati et al. 2005; Rood 2006). Conversion or encroachment of habitat by cultivation of crops ultimately increases crop raiding (Linkie et al. 2004; Sitati et al. 2005). Another report of crop raiding by elephants from South East Asia stated that elephants have raided crops in the transmigration zones surrounded by settled areas in Padang Sugihan Game Reserve, Sumatra. In Sumatra, 10–15 human deaths occur annually because of elephants (Santiapillai and Ramono 1993). Human–elephant conflict in Sri Lanka is mainly the result of shrinkage of forage ground (Olivier 1978; Santiapillai et al. 1984). As a result, elephants cause serious damage in villages and inflict significant human mortalities, at an estimated rate of 50 villager deaths each year. Habitat erosion forces elephants into agricultural areas, where they destroy crops and inevitably cause human fatalities.

About 150–200 people are killed each year by elephants in India. With a continuous loss of habitat, herds of wild elephants frequently intrude into human habitations and cause massive property damage and human deaths in the state of Assam in India (Fernando et al. 2008a). In the Nilgiri Biosphere Reserve, elephants cause crop depredation and their attacks on humans lead to injuries, severe wounds and sometimes death. In addition, elephants also cause damage to human property (Arivazhagan and Ramakrishnan 2010). Every year more than 100 humans and 40–50 elephants are killed during crop raiding in India (Johnsingh and Panwar 1992; Menon et al. 2005). Baskaran et al. (2007a, b) reported that in the year 2005, 10 human causalities took place in Southern Tamil Nadu state.

Crop depredation by elephants occurs sporadically throughout the year in India. But the intensity varies from season to season based on the availability of crops in the field (Thouless 1994; Sukumar 1989a; Chowdhury et al. 1997). In Kenya, the intensity of depredation increases close to harvesting time, usually in August and September (Thouless 1994). Hoare (1995) reported a seasonal peak depredation when crops mature in late wet season. Martin Tchamba's (cited in Sukumar 2003) 1993 study in northern Cameroon clearly brought out the influence of the movement pattern of elephants as opposed to merely rainfall pattern or crop availability.

In India, the intensity of crop raiding increases between September and December during the major crop season (Sukumar 1989a; Datye and Bhagawat 1993; Chowdhury et al. 1997). In Karnataka, two peak crop raiding seasons have been observed: one during July–September and the other during November–January

(Nath and Sukumar 1998). During the years 2002–2013, 10,200 cases of crop raiding by elephants were recorded (Prachi and Jayant 2013). In northern West Bengal, the depredation frequency has been reported as 57 % for paddy between August–January, 21 % for maize between March–June and 22 % for other minor crops between February–July (Chowdhury et al. 1997). In southern West Bengal, the elephants start to migrate from Dalma Wildlife Sanctuary just after the rainy season towards the districts of Bankura, Purulia, and Midnapore following the crop calendar of West Bengal (Sukumar 2003). The total amount of crop damage in southern West Bengal has also increased since 2002–2003 at an alarming rate. In 2002–2003, the total area of crop land damaged by elephants was 709.13 ha, which increased to 3488.36 ha by 2010–2011 (Annual Report 2011–2012, Forest Directorate, Govt. of West Bengal).

Human–elephant conflict often ends with loss of human life and property. Records from Africa and Asia indicate that the largest numbers of human death occur in India, followed possibly by Nepal and Sri Lanka (Doyle et al. 2010). In northern Kenya, 21 people were killed and 18 people were injured by elephants from 1989 to 1992 (Thouless 1994).

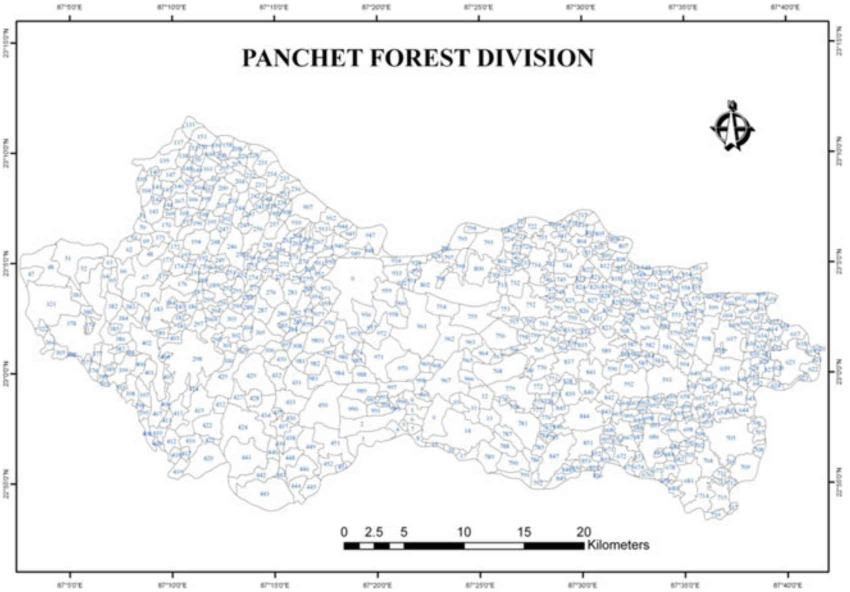
In India, the deaths of 30–50 people were reported from South India. In Maharashtra, 10 people died and 21 were injured in 2002–2003 (Prachi and Jayant 2013). The highest numbers of human deaths and injuries occurred in October (43.75 %) during the festive season in this area. In 1998, a bull killed dozens of people during crop raids in Nilgiri (Sukumar 2003). Another bull in Jharkhand has killed 40 people over the past few years. West Bengal ranks second in India for the number of human deaths by elephant depredation (Bist 2006). The State Forest Department of West Bengal has reported that in the years 2008–2009, 94 were killed and 273 injured by animal depredation, of which 15 were killed and 33 injured in southern West Bengal alone (State Forest Report 2008–2009). Seventy-four people were killed by elephants in West Bengal and 134 in Bihar during the years 1980–1991 (Datye and Bhagawat 1993). The causes of manslaughter by elephants may be area-specific. They may be the result of human attempts to defend crop raiding, enter the forest to collect firewood or NTFPs, encroach elephant corridors or complete other activities in the proximity of elephant habitats, but the ultimate result is tragic.

It is estimated that elephants annually damage 10,000–15,000 houses in India (Bist 2006). In West Bengal, 2,975, 4,091, 4,259 and 3,491 huts were damaged in 2006–2007, 2007–2008, 2008–2009 and 2009–2010 respectively (West Bengal State Forest reports). In northern West Bengal, there is an average damage of 800 huts per year (Dey 1991). In 1985, an unusually high destruction of more than 2000 huts was reported by Dey. The elephant habitat in southern West Bengal exhibits a more devastating picture than that in northern West Bengal. It is the result of higher population pressure and the more fragmented nature of the forest, which increase the chance for conflict.

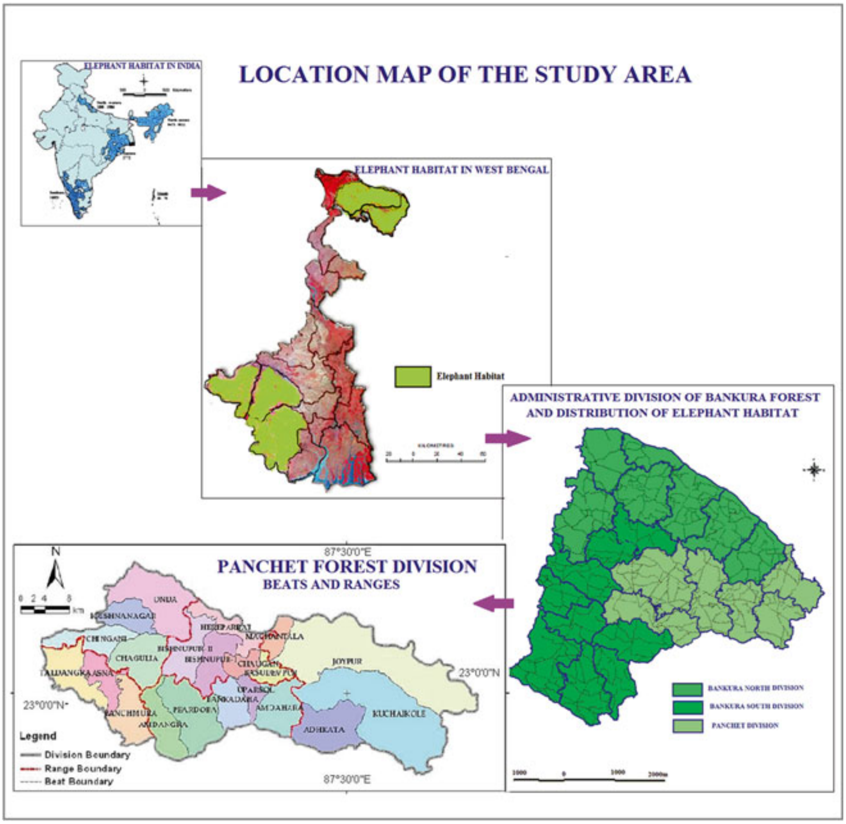
However, it is not only humans who suffer from the conflict with elephants. These phenomena also have a very negative impact on the elephant population. Continuous conflict events change the behaviour of elephants. In Bannerghatta National Park, in Nilgiri, on average two elephants are killed each year from conflict with humans (Sarma et al. 2008). In the Golaghat district of Assam, a huge number of elephants die each year due to human–elephant conflict (Sarma et al. 2008). The traditional techniques of elephant catching, for example, *Mela shikar* and *Phand* (Sarma et al. 2008), lead to a number of wild elephants unavoidably being strangled and killed (Milroy 1923). In the years 1990–2000, human–elephant conflict resulted in 86 deaths and 35 injuries in Keonjhar, Orissa (Sar and Lahiri-Choudhury 2006). In West Bengal, elephant deaths result from two major causes: accidental deaths and deaths due to anthropogenic causes. In northern West Bengal, each year a large number of elephants are injured or die after being run over by trains or road vehicles (Anandabazar Patrika 2014a, b, c, d, e, f, g, h, i, j). Seven elephants were killed in just one month (5–29 May 2006) due to train accidents and four elephants died due to road accidents in northern West Bengal (West Bengal Forest Report 2006–2007). In West Bengal, the total number of elephant deaths was 39 in the year 2007–2008, which decreased to 25 in 2009–2010. Though the number continues to decline according to forest reports, the deaths still occur each year, which is alarming.

Although myriad research has addressed the issue of human–elephant conflict, the paucity of data in many research reports increases the importance of further research on human–elephant conflict resolution (Mavatur et al. 2010). A multitude of traditional techniques have been developed through the ages to reduce and prevent crop raiding in the conflict zones. Increasing incidence of human–elephant conflict during the past few decades and technological advances have encouraged the development of additional methods to address the problem (Fernando et al. 2008a, b). Traditional methods such as chasing elephants by *hullah party*, dram beating, noise making, and use of crackers, trained elephant or *coonkie* are also attempted. Along with these, constructing barriers along the forest area, building biological and electrical fences, developing communication system translocation, culling, telemetry, and providing compensation and insurance payments are all widely used methods to address the problem (Fernando et al. 2008a, b, c).

No one method alone can work for conflict management. The methods selected should be decided according to the nature of the conflict in the area of concern. Hence, we need research to generate a sufficient database on the nature and cause of human–elephant conflict with respect to the study area in order to fill the gaps in the past research. Thus, this research tries to address the issue of human–elephant conflict in a holistic approach through characterising the landscape, pursuing the causes of conflict, assessing the present situation, and developing proposals of practical solution to this long-term problem.



Map 1.1 Administrative setup of Panchet Forest Division



Map 1.2 Location of Panchet Forest Division

1.4 Introducing the Study Area

The area selected for study is Panchet Forest Division of Bankura district, West Bengal. Panchet Forest Division covers an area of 355.62 km^2 distributed among 236 forest-bearing mouzas. The division consists of 5 ranges and 21 beats.

1.5 Research Questions

The objective of this research is to assess the ecological deterioration in both the source region (Dalma Wildlife Sanctuary, Jharkhand) from where the elephants are forced to migrate and the destination region (Panchet Forest Division) into which the elephants immigrate. This study tries to assess the quality of habitats by evaluating forest density, structural pattern, plant species composition and association. Emphasis has also been given to identify the characteristics of human–elephant conflict zones in terms of land use, cropping pattern, trend of elephant migration, pattern of migration, suffering of the locals from elephant attack, livelihood pattern of villagers and their dependence on forest and probable causes of elephant migration. Moreover, weight has been placed on community attitude towards elephants, level of awareness of the local people and methods they adopt to resist elephant crop raiding. The study also takes the behaviour of elephants into consideration, especially their crop selection behaviour.

Hence, the objectives are set in a way that could address all the problems associated with elephant migration in Panchet Forest Division. Major objectives are categorised as four broad objectives; other objectives that are associated with the main objectives are treated as subobjectives.

1.5.1 Objective 1

Identify the changes in the structural characteristics of forests and increasing trends.

1. Trace the major change in the forest structure of both the source region and destination areas in terms of the composition density and coverage since 1990.
2. Find out the reasons for habitat loss, degradation and fragmentation that have caused the elephants to migrate since 1987.

1.5.2 Objective 2

Find out the temporal pattern of elephant migration.

3. Sketch the temporal shift in the migration routes.
4. Characterise the nature of sojourn grounds where elephants prefer to stay for a few days during their journey.

1.5.3 Objective 3

Outline the important characteristics of human–elephant conflict zones.

5. Examine changing land use practice in the study area.
6. Correlate the changing land use pattern and volume of migration and route of migration under study.
7. Trace the types and volume of damage done by elephants and the trends in such damage.
8. Find out how local people and forest departments address the problems.
9. Identify the changing perception, attitudes and responses of local people.

1.5.4 Objective 4

Suggest appropriate management options to combat human–elephant conflict.

10. Develop awareness about elephant behaviour, causes and nature of human–elephant conflict and desired response among the local people.

1.6 Data and Methods

This research work was a field-based empirical study. Both quantitative and qualitative data and methods were adopted for the study. The first part of the work sought to verify the ecological causes of elephant migration. The methods adapted to find out the causes were mainly observation and analysis of migration records received from the concerned forest beat, range or divisional offices. In the second part of the study, emphasis was given to explore the trend or temporal pattern of elephant migration and its relation to the changing forest habitat. The third part was associated with characterisation of human–elephant conflict zones, that is, the forest margin villages or the destination areas of the migration elements that exert pulling forces to attract elephants. These are the areas where human–elephant conflicting situations find expression in the form of damage and losses of human life and property. Land use pattern and its changes, damage as the outcome of conflict, methods adopted to resist elephant attacks and perception of the local people in regard to the problem were the prime considerations in defining the character of the conflict zone. Lastly, various non-lethal management options were assessed for their applicability in the context of people's subjective experience and interpretation of the root causes.

A change detection study was carried out to assess the changing vegetation cover in the study area. LISS-III TM images of 1973, 1991 and 2001 and LISS-IV TM images of 2013 were used for this purpose. Vector layers were created on Google maps to get a clear-cut picture of the size, arrangement and pattern of patches. In total, 716 patches were drawn for these purposes. Those patches were then analysed on a GIS platform. ERDAS Iimagine, FRAGSTATS and ArcGIS software were used for patch analysis. Ecological characteristics like association and density of plant species (trees, shrubs and herbs), forest density, canopy cover and pattern of fragmentation of each of the forest types in the study area were identified from image analysis. Ecological survey techniques were applied for ground truth verification. Data were collected through vivid field survey. Quadrat, transect and gradsect surveys were conducted at randomly plotted sites in every forest beat of Panchet Forest area. Moreover, this technique was also applied in the Dalma Forest region to compare the habitat characteristics of both the source and destination regions. The DAFOR index (Density, Abundance, Frequency, Occasionality and Rarity) was prepared for both regions to compare the vegetation composition, richness, density, canopy cover, ground cover, canopy height, micro climate, branching height and other features. These indicators depict the nature and health of the forest in a particular area. A detailed herbarium chart was prepared for both regions. This information was further used to assess food habits and preferences of elephants in both regions.

Year-wise secondary data and information on the number of migrated elephants and migration routes were collected from beat and range offices and then were finally compared with the information collected from divisional offices. Detailed year-wise information on elephant conflict and damage data were collected from the divisional forest office. As far as characterisation of the human–elephant conflict zone is concerned, a detailed questionnaire was conducted among the villagers from more frequently attacked villages. Each of the 20 forest beat offices was visited, and the heads of the offices were interviewed in depth. Thus, the total study covered five parts, as follows:

1. *Appraisal of wildlife habitat*:

   To measure habitat characteristics like patch type, richness and diversity (Bascompte et al. 2002); patch dynamics (Wu and Loucks 1995); patch isolation (Bender et al. 2003); fragmentation (Silva et al. 2003); fractal dimension; corridors (Mabry and Barrett 2002); edge effect and edge contrast (Chen et al. 1992) were compared. We performed multiple regressions using these matrixed data to characterise the habitats in the Panchet Forest area. Habitat heterogeneity and spatial arrangement of habitat patches were identified and analysed in GIS platforms. For habitat heterogeneity, indices such as shape, edge, patchiness, porosity and interspersion were selected (Morrison et al. 2006). The study also included the degree of disturbance, which focused on habitat suitability and preference. These are important, as they determine the foraging strategy of elephants.

2. *Understanding migration behaviour of elephants*:

   One of the main objectives of this study was to understand the nature and trend of migration of the elephant. It was necessary to understand the elephant distribution, abundance and requirements. A behavioural analysis revealed how animals actively use their environment. Principal methods used to explore animal behaviour in the context of resource abundance included assessment of foraging strategy and diet of the elephants, which can be three categories—structure, consequences and spatial relation (Martin and Bateson 1993). Structure describes the appearance or physical form and temporal pattern of animal behaviour. Consequence describes the effect of animal behaviour in terms of damage or changing animal behaviour and their impact on the landscape. Spatial relation describes behaviour in terms of the animal's spatial proximity to features of the environment, for example, preference for shelter and water source. Some statistical methods like regression analysis were done on an SPSS platform for this purpose. Information on daily and seasonal weather conditions was collected to understand the actual cause of elephant movement.

3. *Assessing habitat intervention and its consequences*:

   The consequences of human intervention in the natural habitat result in degradation, fragmentation and isolation of natural habitat. The most pervasive and detrimental impacts have been loss of habitat and habitat fragmentation, which are dynamic processes. They are the result of human intervention in the forests for timber extraction, monoculture, shifting cultivation, grazing activity and extraction of NTFPs. Disturbance promotes secondary growth of bamboo, grass and weeds, which form a tangle and attract elephants. Thus, manipulation of the natural landscape has a doubled-edged sword effect. On the one hand, it may create more favourable habitats for herbivores, and on the other hand, human intervention deteriorates the forest quality. An assessment of habitat dynamics was thus necessary. It was done through patch analysis of the study area. Primary data collected from field surveys were used to measure the volume of resource extracted from the forest and the dependence of forest fringe dwellers on the forest.

4. Modelling *habitat–elephant relationship*:

   A variety of models was used to predict the habitat–elephant relationship. Such modelling included the wildlife habitat relationship matrix model (Verner and Boss 1980). That concept was applied theoretically. The habitat suitability index model was applied. Various components, including distance from main road, distance to nearest water source, distance to forest fringe agricultural lands, were considered. This kind of model predicts the presence and distribution of wild species based on vegetation and land cover conditions. Hence, these were applied to understand the habitat—elephant relationship in the study area.

5. *Nature of human–elephant conflict*:

   Increased human uses of the natural landscape for different types of forest products and extension of human settlements have significant impacts on vegetation and consequently on the elephant population. Again, elephants are attracted to cultivated crops as a source of food. As a result, human–elephant conflict is intensified over this resource and over space, resulting in crop depredation, human death, human injury, deterioration of forest and agricultural land ecology. Continuous conflict between humans and elephants changes the behaviour of elephants and also the attitude of humans towards elephants. Both primary and secondary data on the frequency of crop raiding, human density in the forest fringe villages, agricultural pattern, and seasonality of the crop raiding and behavioural ecology of elephants were considered. On the basis of information collected from forest departments and newspapers, a list of the most affected villages was made. Then a random sampling technique was applied with a structured questionnaire that included nearly 33 % of the affected villages. Twenty households from each of these 50 villages were randomly selected, so that an equal number of household samples from each of the social strata could be included in the study. Thus, a total of 1,000 households were considered from the most affected villages of the study area.

1.6.1 Data Collection Procedure

1.6.1.1 Questionnaire

Field-based information was collected through a structured questionnaire. The major aspects of this enquiry were to relate villagers' livelihood patterns and their dependence on the forest and to relate land use, cropping pattern and their seasonality to the migration behaviour, especially selection of routes, of the elephants as perceived by local people. The second part of the questionnaire was associated with the collection of data on the types and volume of damages caused by elephants, methods adapted by local people for guarding crops and their effectiveness and many such questions that bring out the perception and experience of the local people. The last section of the questionnaire assessed the locals' awareness of the need for forest habitat conservation and related actions (a list of dos and don'ts) in the event an elephant herd arrived in their locality, crops that elephants relish, provision for compensation to affected people, role of the forest department to tackle the conflict and more. Both open- and close-ended questions were set, and in some cases, such as when determining the relative importance between the categories, responses were recorded in terms of ranks. The data thus collected were ready for analysis.

Secondary information was collected from forest beats, ranges and division office. Data on conflict issues were also supported by newspaper information. Census maps were used to create the division boundary and village boundaries that come under the jurisdiction of the Panchet Forest Division. All the published maps were rectified and digitised. A total of 409 villages were considered, but But the villages without a forest area were excluded by the Panchet Forest Division. So out of 409 digitised villages, we took 236 villages under the Panchet Forest Division. Topographical sheet numbers 73 J/9, 73 N/1, 73 M/8 and so forth were used for geo-referencing. Open-source Google maps were used to get the spatial pattern of migration routes, corridors and patches used by the elephants from Dalma to the Panchet area.

Chapter 2
Ecological Biodiversity of Panchet Forest Division and Dalma Wildlife Sanctuary

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_2

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 km^2. 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.

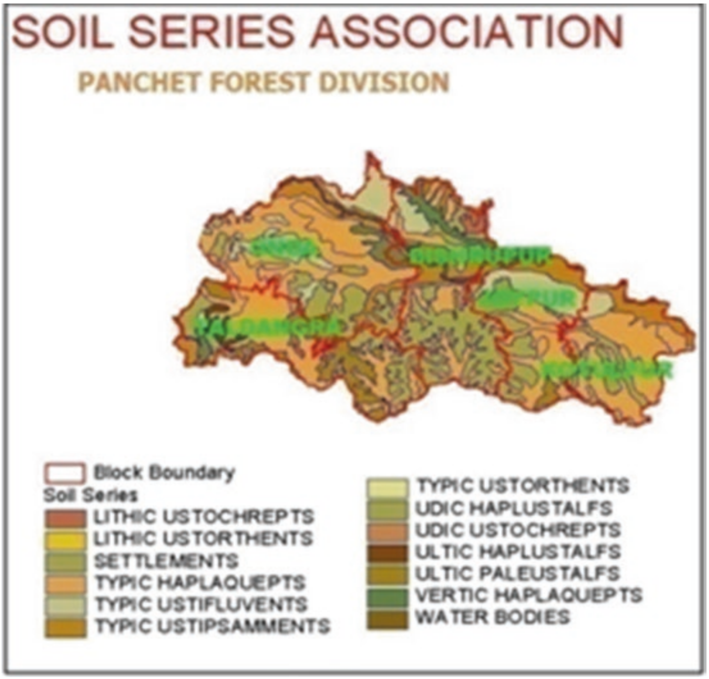
2.2.3 Administrative Setup

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, unclassed 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.

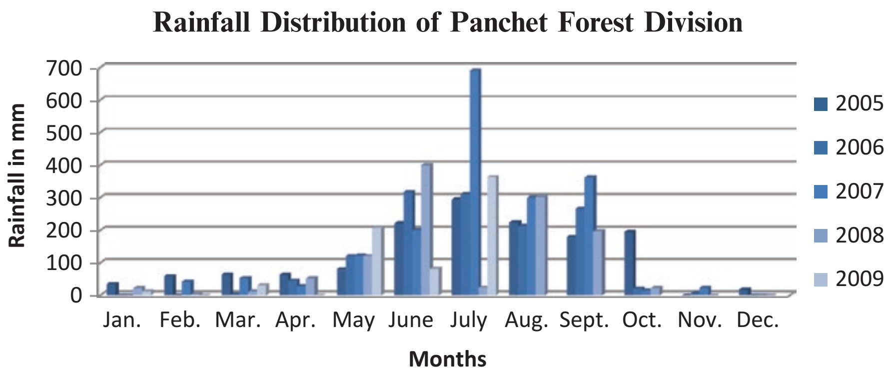


Fig. 2.1 Rainfall distribution of the Panchet Forest Division from 2005 to 2009

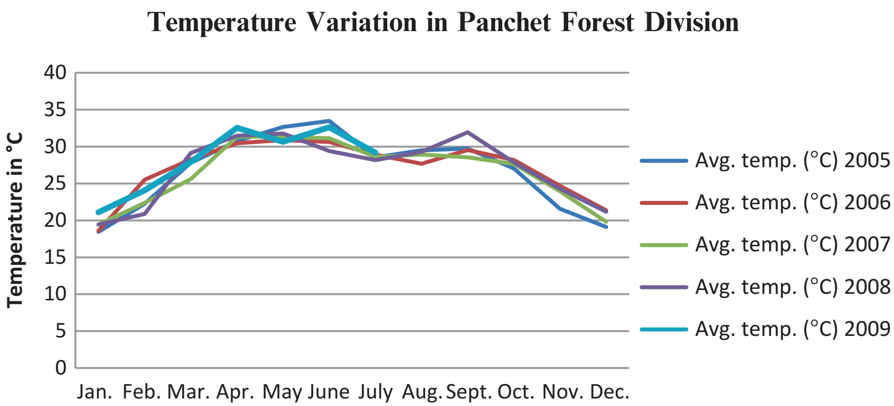


Fig. 2.2 Temperature distribution of the Panchet Forest Division in 2005–2009

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

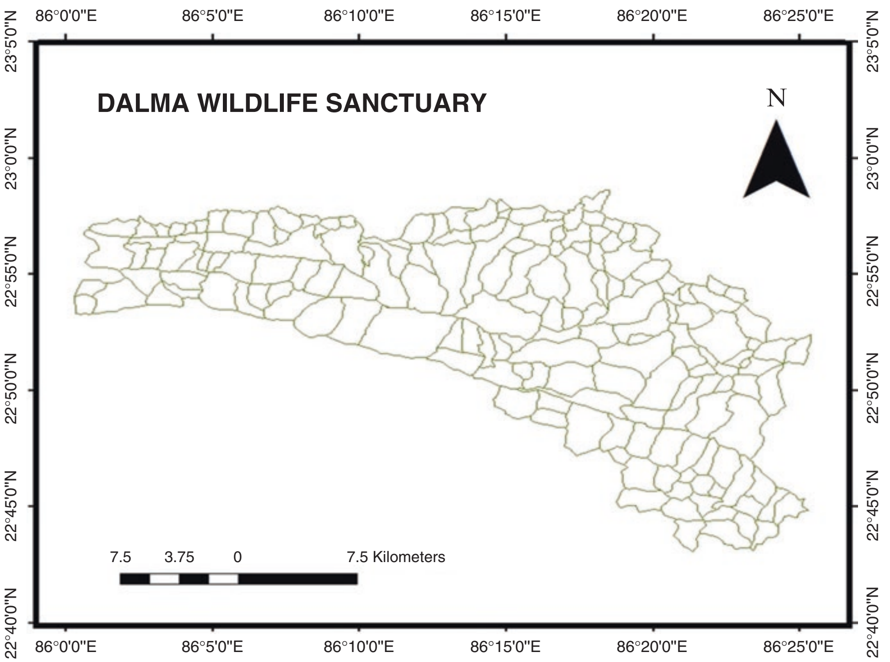
Table 2.1 Natural vegetation at Panchet Forest Division

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



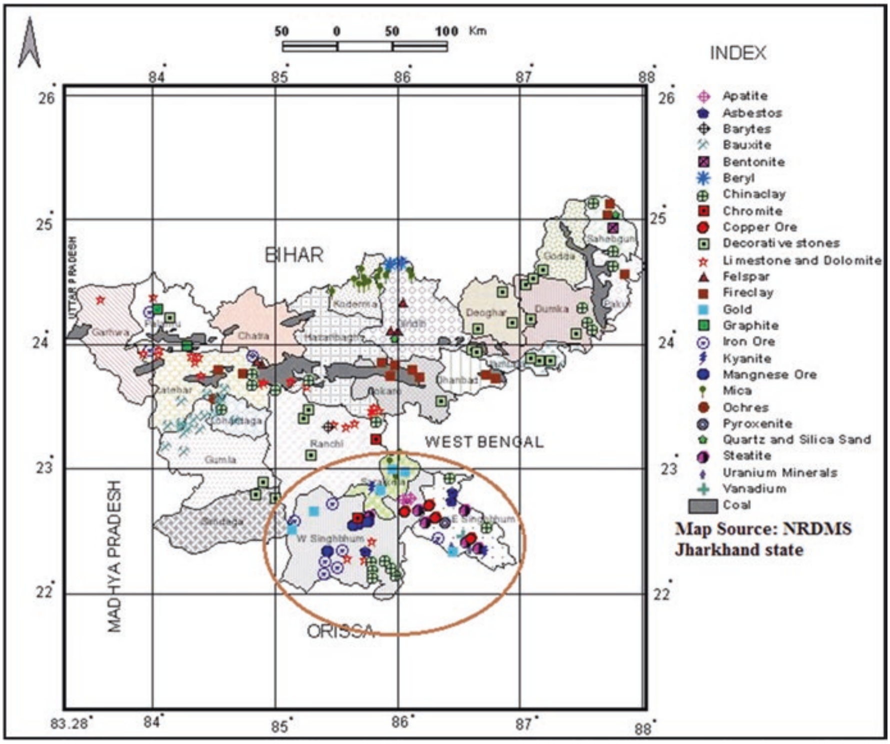
Map 2.2 Map of Dalma Wildlife Sanctuary

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 km^2 (*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.

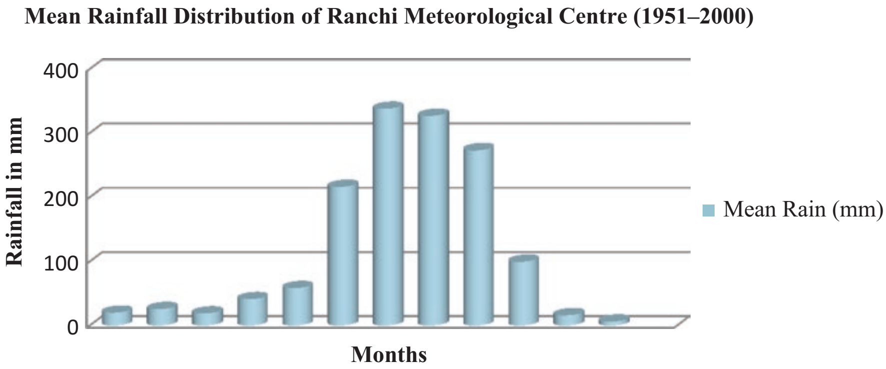


Chart 2.1

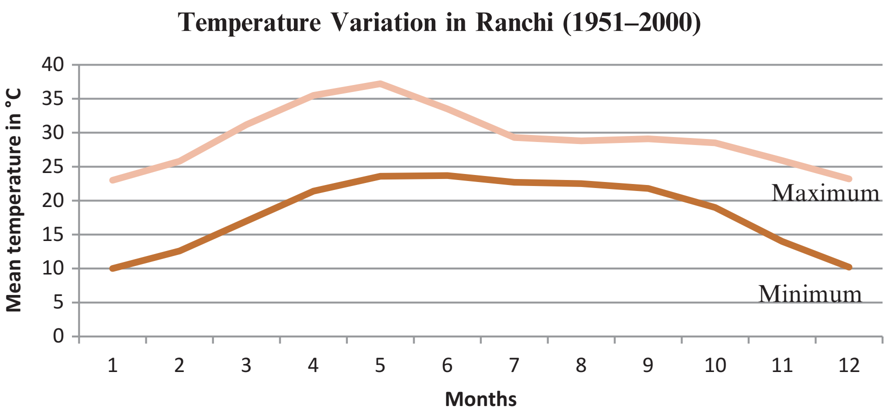


Chart 2.2

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 km^2 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
A. Trees		
1	*Acacia arabica*	Babul
2	*Acacia catechu*	Khair
3	*Adina cordifolia*	Karam
4	*Aegle marmelos*	Bel
5	*Ailanthus excelsa*	Ghorkaranj/Ghorkaram
6	*Alangium lamarckii*	Dhela
7	*Albizzia lebbek*	Siris
8	*Albizzia odoratissima*	Jang siris
9	*Albizzia procera*	Safed siris
10	*Alstonia scholaris*	Chatni
11	*Anogeissus latifolia*	Dhautha
12	*Antidesma ghaesembilla*	Bhabiranj
13	*Arotocarpus integrifolia*	Kathal
14	*Artocarpus lakoocha*	Barhar
15	*Azadirachta indica*	Neem
16	*Bauhinia retusa*	Kathul
17	*Bauhinia purpurea*	Koenar
18	*Bauhinia racemosa*	Katmauli
19	*Bauhinia variegata*	Kachnar
20	*Bombax ceiba*	Semal
21	*Boswellia serrata*	Salia
22	*Bridelia retusa*	Kajhi
23	*Buchanania lanzan*	Piar
24	*Butea frondosa*	Palas
25	*Careya arborea*	Kumbhi
26	*Casearia tomentosa*	Beri
27	*Cassia fistula*	Dhanraj/Amaltas
28	*Chloroxylon swietenia*	Bharhul
29	*Cordia Macleodii*	Belwanjan
30	*Cordia myxa*	Bahuar
31	*Cochlospermum gossypium*	Galgal
32	*Dalbergia lanceolaria*	Hardi
33	*Dalbergia latifolia*	Kala shisham
34	*Dalbergia sissoo*	Shisham
35	*Diospyros embryopteris*	Madartendu
36	*Diospyros melanoxylon*	Tend/Kend/Tiril
37	*Dillenia pentagyna*	Rai
38	*Elaeodendron Mukorossi*	Ratangur
39	*Ehretia laevis*	Bhaire
40	*Emblica officinalis*	Amla
41	*Eugenia heyneana*	Katjamun

(continued)

Table 2.4 (continued)

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

(continued)

Table 2.4 (continued)

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

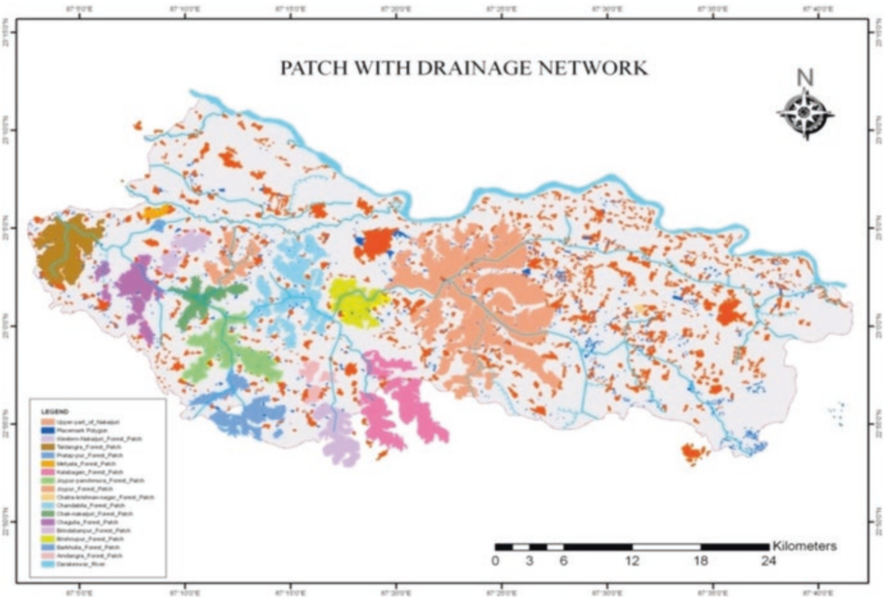
A landscape under consideration consists of heterogeneous components that give a typical pattern to the landscape. To analyse the pattern of an area, it is necessary to quantify the components of the spatial pattern, that is, the composition and configuration of the landscape mosaic (Li and Reynolds 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. 193; 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.

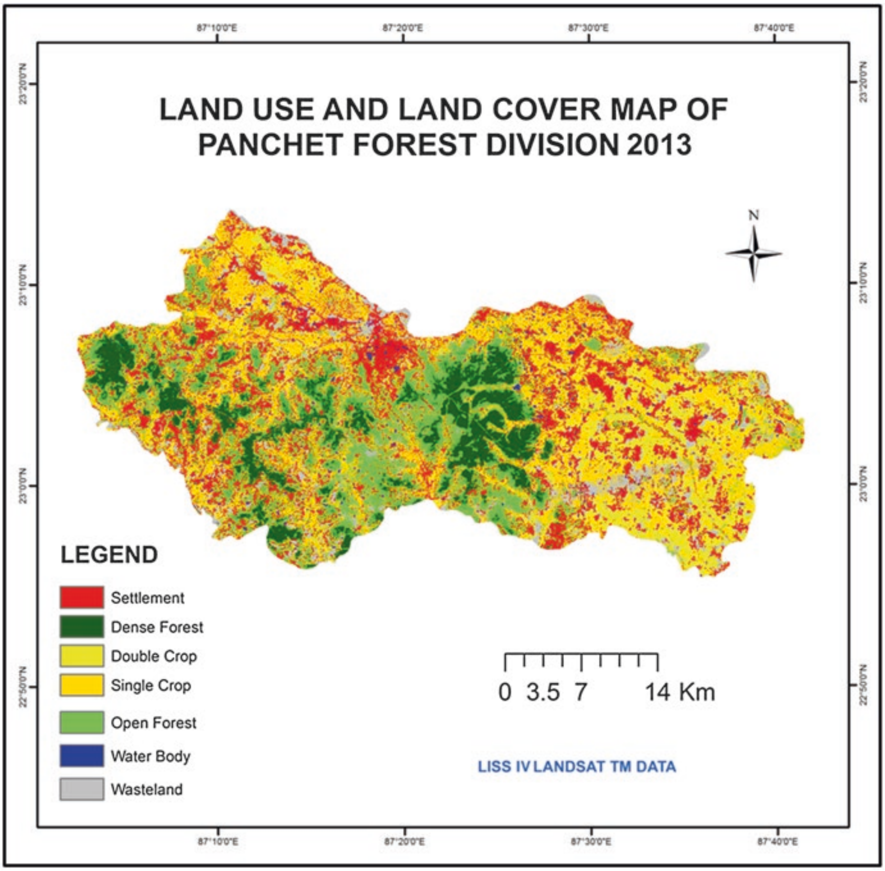
2.4.2.4 Metrics

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.

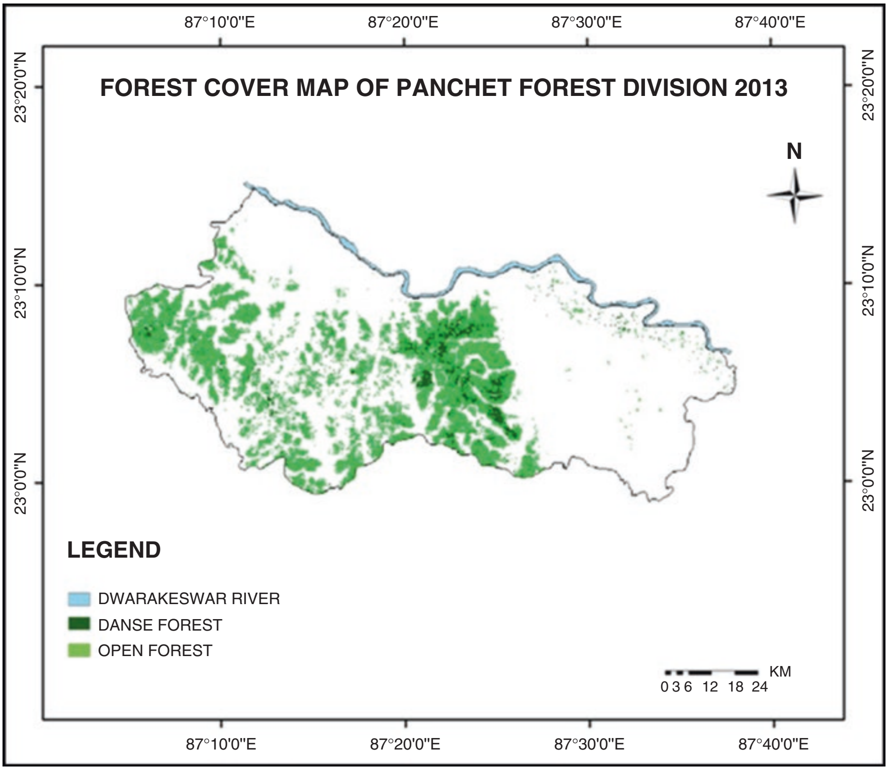
Elephant movement in the study area is strongly related to the composition and configuration of forests. In previous decades, the movement of elephants was restricted within the fragmented forests surrounded by agricultural lands in the western parts. However, it has recently been observed that elephants 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 C_1/1C, 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).

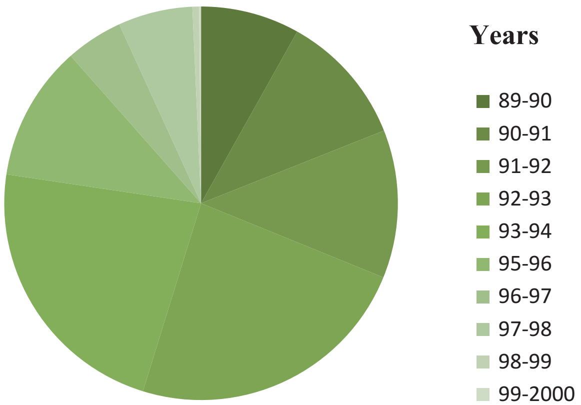
The reckless forest destruction took place during the expansion of the Bengal Nagpur railway line in 1889 followed by the railway tracks through Midnapur district in 1903 (Palit 1991; Malhotra 1995). This huge destruction of forest prompted the government to establish a committee in 1938. The committee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

$\text{PLAND} = P_i = \frac{\sum_{j-1}^{n} a_{ij}}{A}(100)$	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)
Description	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
Units	Percent
Range	$0 < \text{PLAND} \leq 100$
	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)	
$\text{PD} = \frac{n_i}{A}(10{,}000)(100)$	n_i = number of patches in the landscape of patch type (class) i A = total landscape area (m^2)
Description	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
Units	Number per 100 ha
Range	PD > 0, constrained by cell size

Mean patch area calculation methodology (*source*: McGarigal and Marks 1995)	
$\text{MN} = \frac{\sum_{j=1}^{n} a_{ij}\left(\frac{1}{10{,}000}\right)}{n_i}$	n_i = number of patches in the landscape of type (class) i a_{ij} = area (m^2) of patch ij
Description	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
Units	Hectares
Range	MN area > 0, without limit

Largest patch index calculation methodology (*source*: McGarigal and Marks 1995)	
$\text{LPI} = \frac{\overset{a}{\underset{j=1}{\max}}\,(a_{ji})}{A}(100)$	a_{ji} = area (m^2) of patch ij A = total landscape area (m^2)
Description	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
Unit	Percent
Range	$0 < \text{LPI} \leq 100$
	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)	
$$\mathrm{ED}=\frac{\sum_{k=1}^{m} e_{ik}}{A}(10{,}000)$$	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)
Description	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)
Unit	Meters per hectare
Range	$\mathrm{ED} \geq 0$, without limit

Mean core area calculation methodology (*source*: McGarigal and Marks 1995)	
$$\mathrm{MN}=\frac{\sum_{j=1}^{n} X_i a_{ij}^{c}\left(\frac{1}{10{,}000}\right)}{n_i}$$	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
Description	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
Units	Hectares
Range	Core $\mathrm{MN} > 0$, without limit

Core area percent of landscape calculation methodology (*source*: McGarigal and Marks 1995)	
$$\mathrm{CPLAND}=\frac{\sum_{j=1}^{n} a_{ij}^{c}}{A}(100)$$	a_{ij}^{c} = core area (m^2) of patch ij based on specific edge depths (m)
	A = total landscape area (m^2)
Description	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
Units	Percent
Range	$0 \leq \mathrm{CPLAND} < 100$
	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)	
$PAFRAC = \dfrac{\dfrac{2}{\left[n_i \sum_{j=1}^{n}\left(\text{In}p_{ij} - \text{In}a_{ij}\right)\right] -} \left[\left(\sum_{j-1}^{a}\text{In}p_{ij}\right)\left(\sum_{j=1}^{n}\text{In}a_{ij}\right)\right]}{\left(n_i \sum_{j=1}^{n}\text{In}p_{ij}^2\right) - \left(\sum_{j=1}^{n}\text{In}p_{ij}\right)^2}.$	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 (area) = $b_0 + b_1$ (perim). Note that PAFRAC excludes any background patches
Units	None
Range	$1 \le PAFRAC \le 2$

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

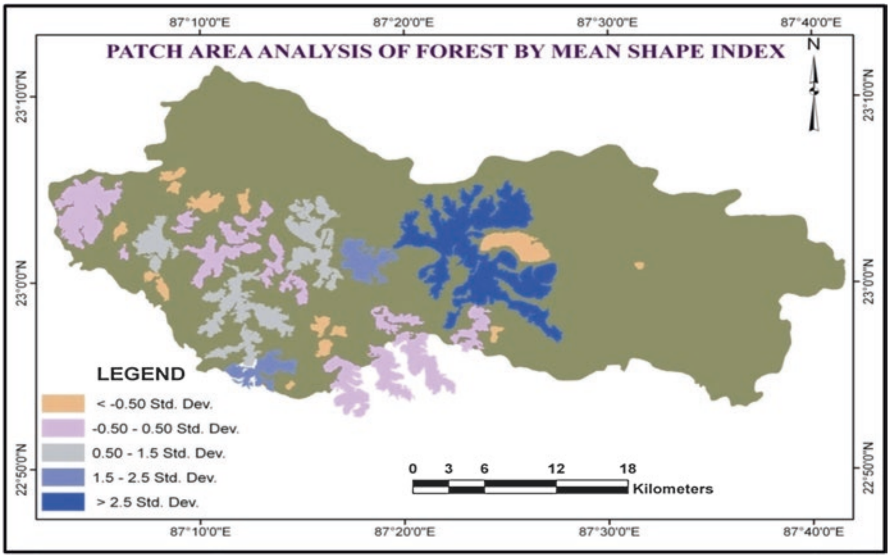
It examines the distance between the fragmented patches. A more fragmented landscape is expected to have more patches and consequently the distance between these patches may be less than a more contagious landscape with a few large forest patches. Thus, if the patch density increases and landscape composition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

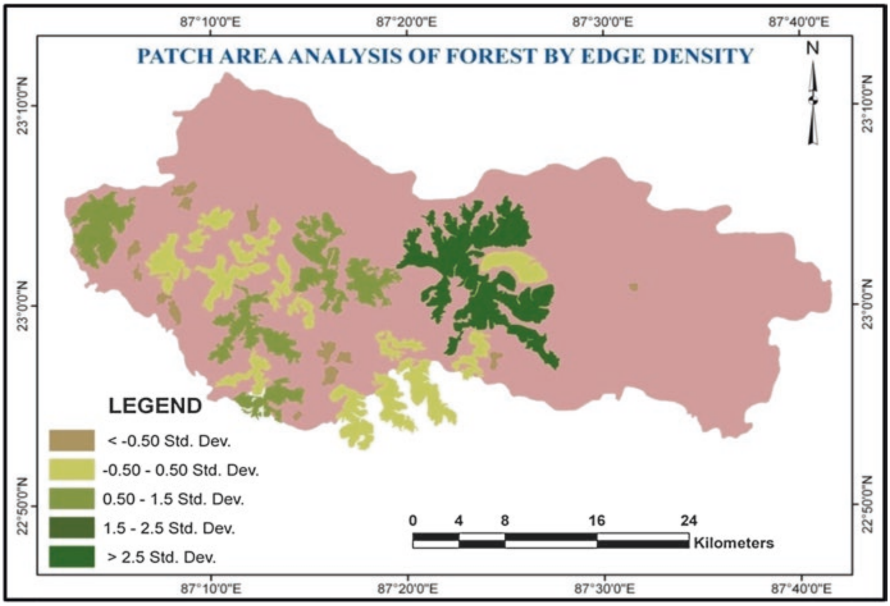


Map 2.8 Patch area analysis of forest by the mean shape index

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

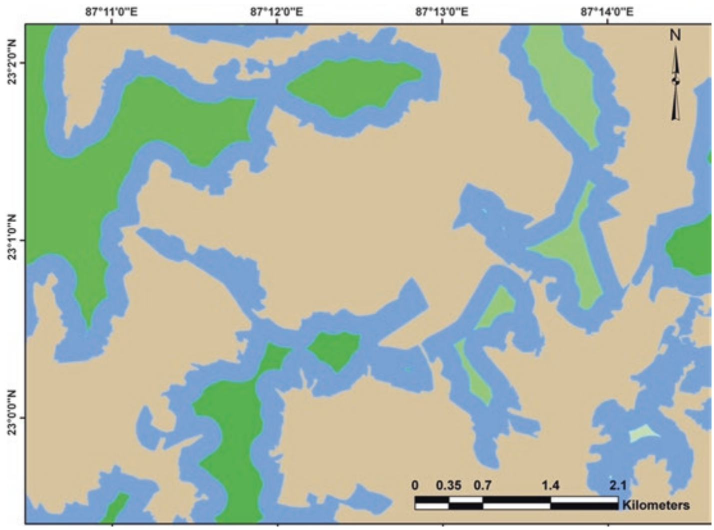
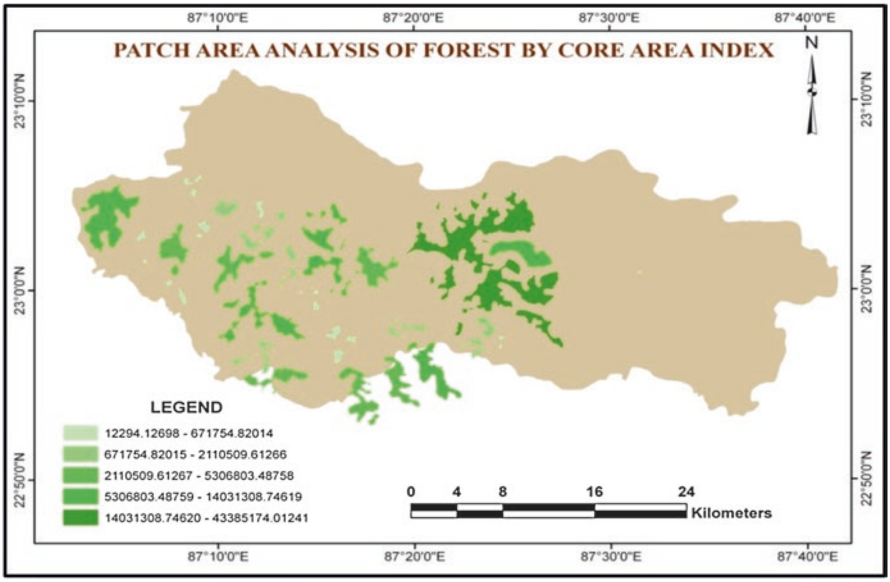


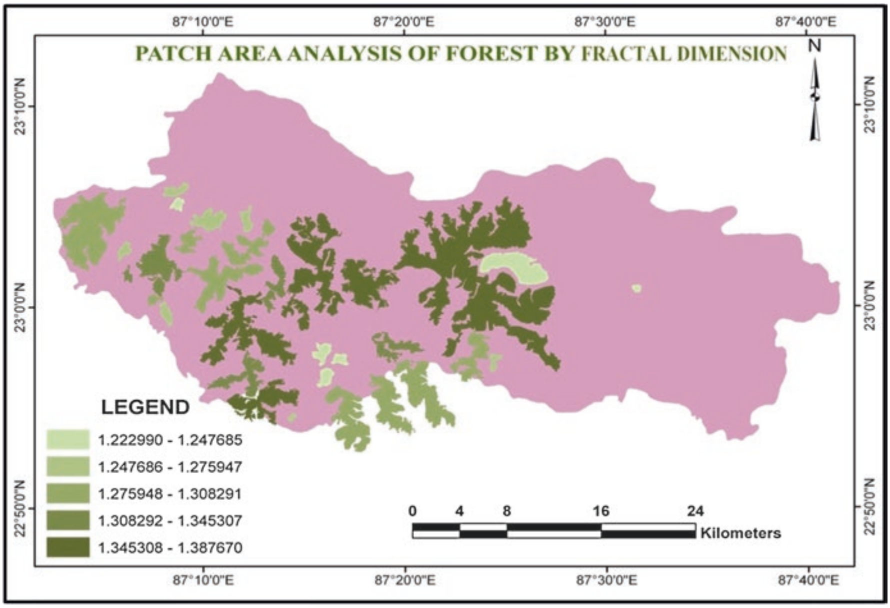
Plate 2.3 Core at 200 m buffer

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

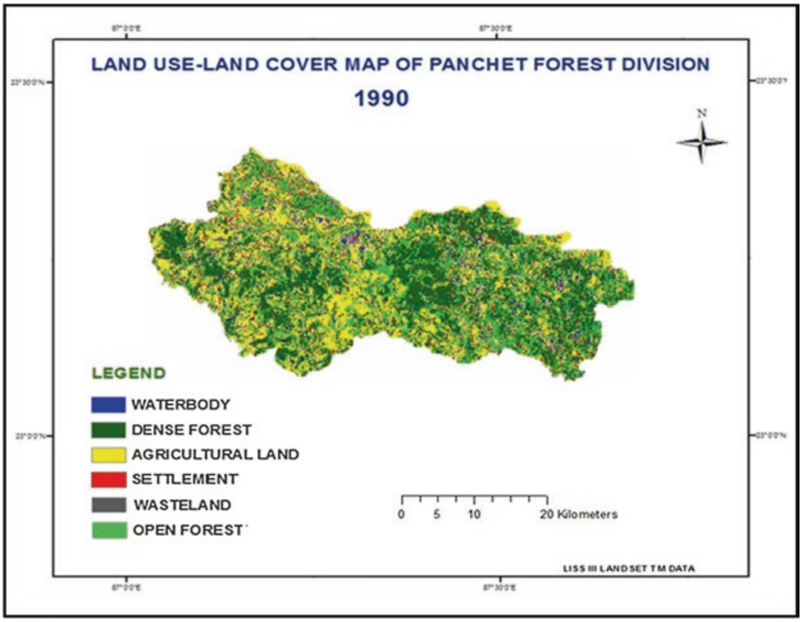
2.5 Factors of Forest Fragmentation

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.

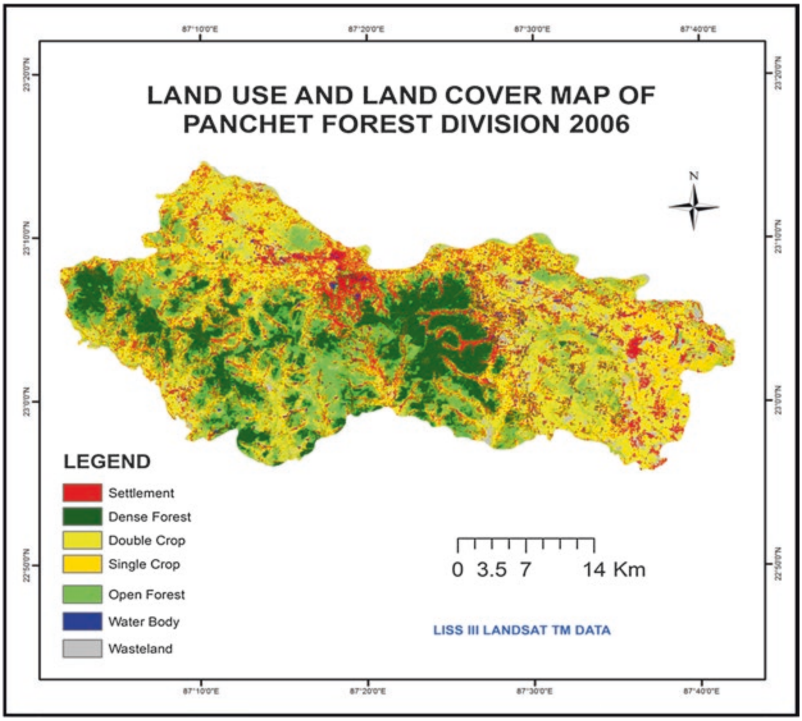
There are so many causes of forest fragmentation. Some are ecological, whereas some are anthropological in nature. In the study area, the main causes of fragmentation are land use and land cover change, shrinkage of forest cover and habitat fragmentation, reduction of forest covers for agriculture, construction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

2.5.1 Land Use and Land Cover Change

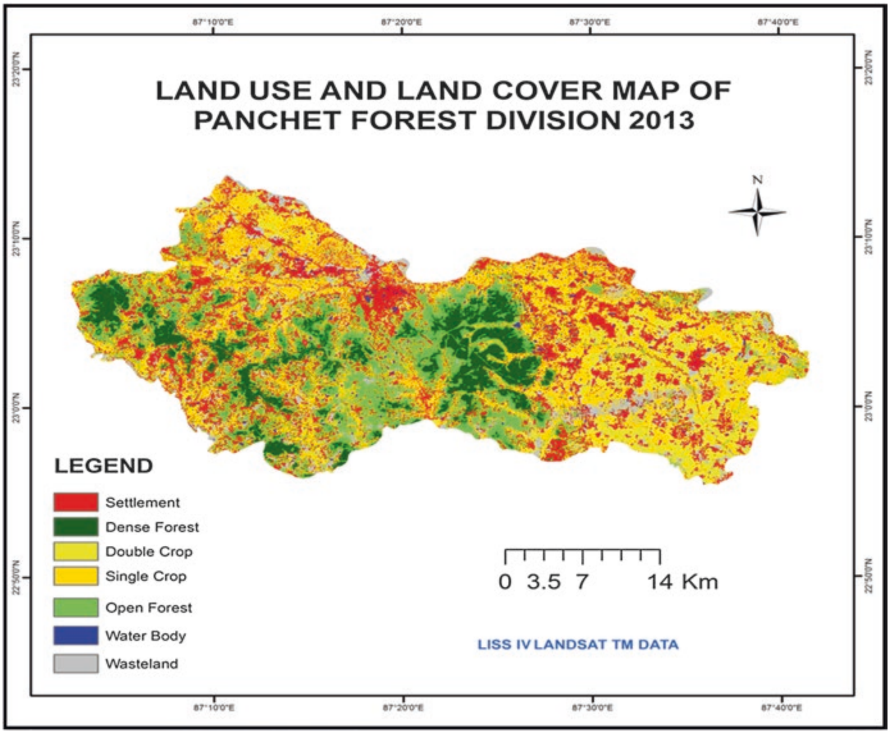
To detect the land use and land cover change in the study area, three satellite images (1990, 2006 and 2013) were taken. For 1990 and 2006, LISS III images were used, and for 2013, LISS IV data have been used. The land use map of the study area shows land under various uses. The south-western part is 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

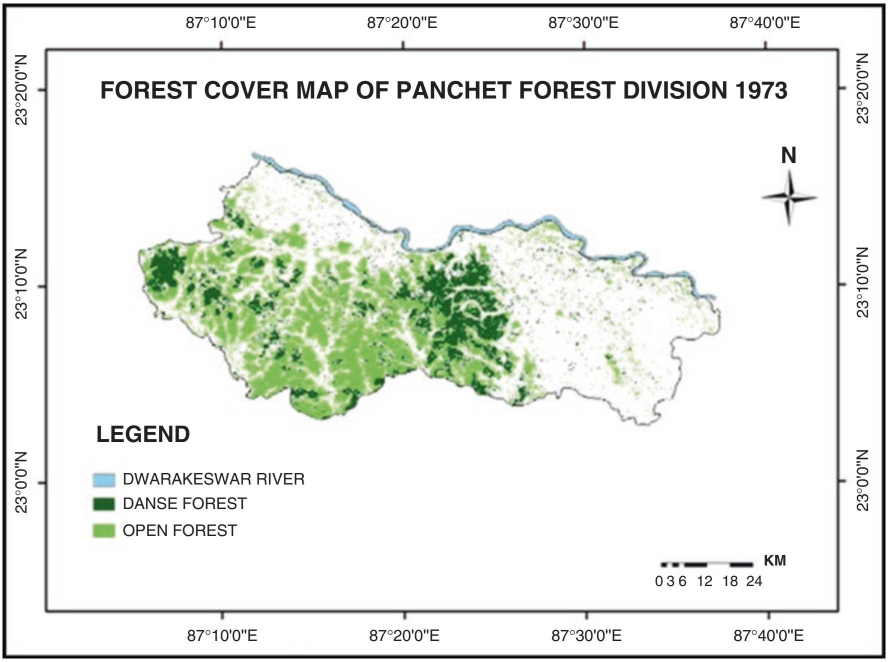
2.5.2 Shrinkage of Forest Cover and Habitat Fragmentation

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

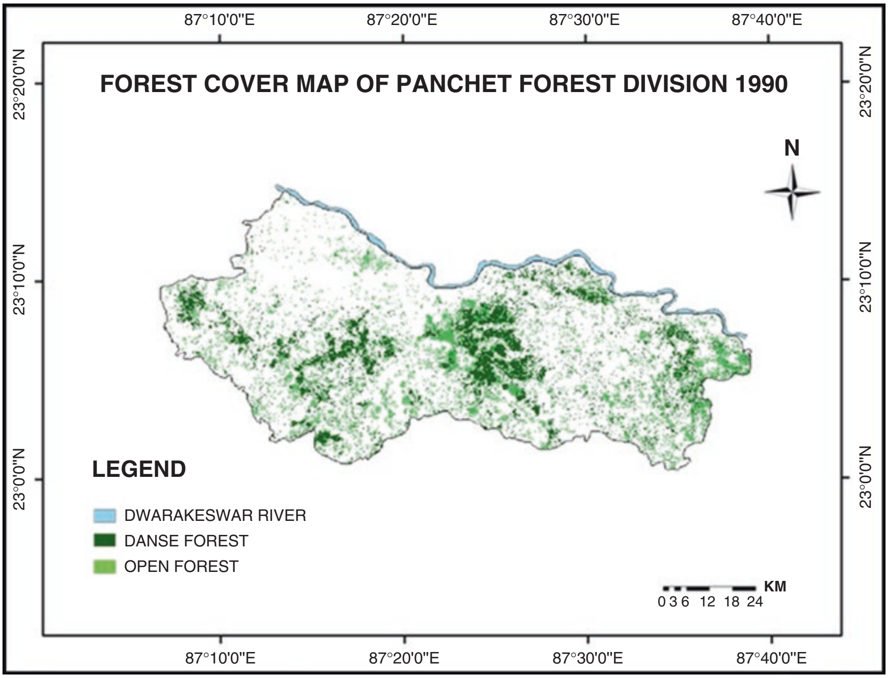
Year	Land encroached (in ha)
2007	1191.00
2008	780.97
2009	1022.55
2010	951.55
2011	708.37
2012	708.37

Source: State Forest Report 2007–2012

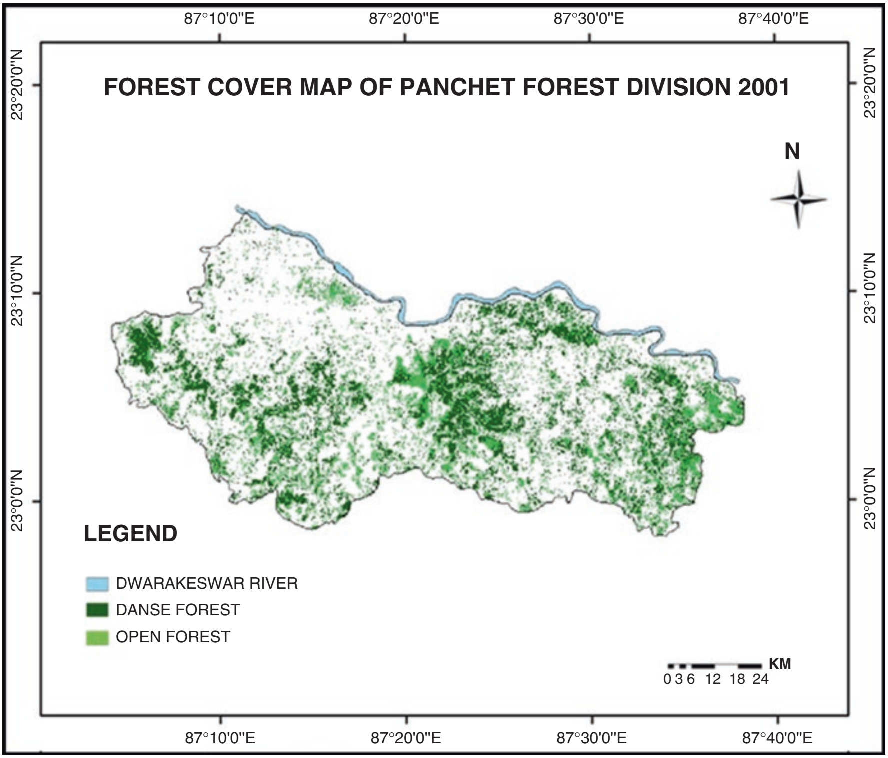


Map 2.15 Forest cover map of Panchet Forest Division in 1973

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

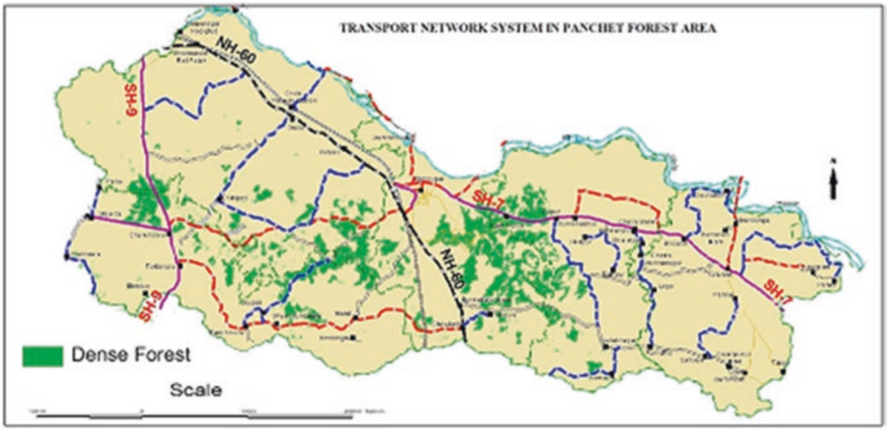
The main land use in our study area is agriculture. Agricultural land has been developed at the cost of forest, which has a great impact on the primary productivity of the habitat. The land use map shows that natural tree cover is present all over the area, at a considerably higher rate than in Bankadaha 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.

Chapter 3
Habitat Requirements of the Elephant

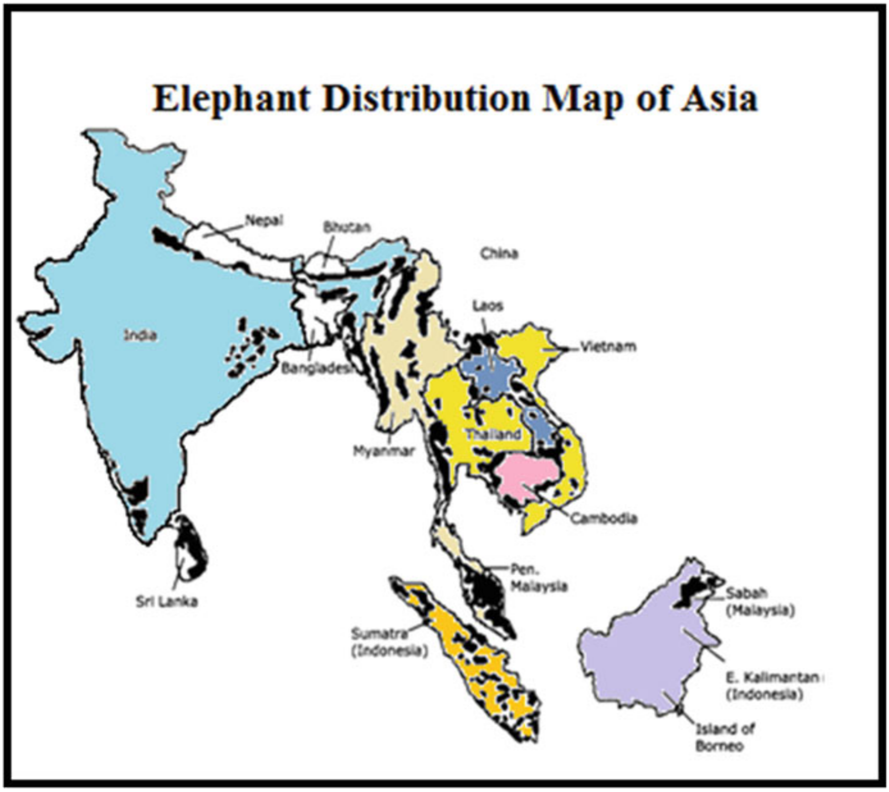
N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_3

Abstract This chapter is based on the behavioural analysis of the elephant. Elephants are biologically not a seasonal migratory species. But in this case the movement of the elephants is found to be seasonal and repetitive. Each year they used to move from their original habitat (Dalma) to the destination habitat (Panchet Forest Division). They stayed a certain period in the destination area and after that returned back to their original habitat. One of the main objectives of this research work is to trace the reasons for such atypical behaviour. To do so, it is necessary to identify the home range of elephants. A detailed review work was done to characterise the home range of elephants over varied landscapes in the Indian subcontinent and in the study area. Not only have forest statistics been used to reveal the facts of migration, but field enquiry has also been required to identify the exact cause. The nature of food habits, nutritional requirements and changing food habits in the newly invented habitat are elucidated through empirical survey. The character of shelter is delineated by examining the forest cover, vegetation succession, ground coverage, distance from water source, road, noise and so on. These factors are responsible for both the fragmentation of the natural forest habitat and the movement of elephants within the forest patches.

Keywords Home range character • Food habit • Changing food habit • Ecological sampling

3.1 Introduction

Elephants can adjust themselves within a broad array of habitats. Throughout India their habitat extends from mountains to plains through plateau areas. They are found to reside in the natural forest cover areas as well as in fragmented patchy or plantation areas. Their home range area varies from 105–155 to 650 km^2 based on the availability of fodder, water and shelter and the number of elephants present in the herd. A herd of 100 elephants would require a minimum area of about 650 km^2.



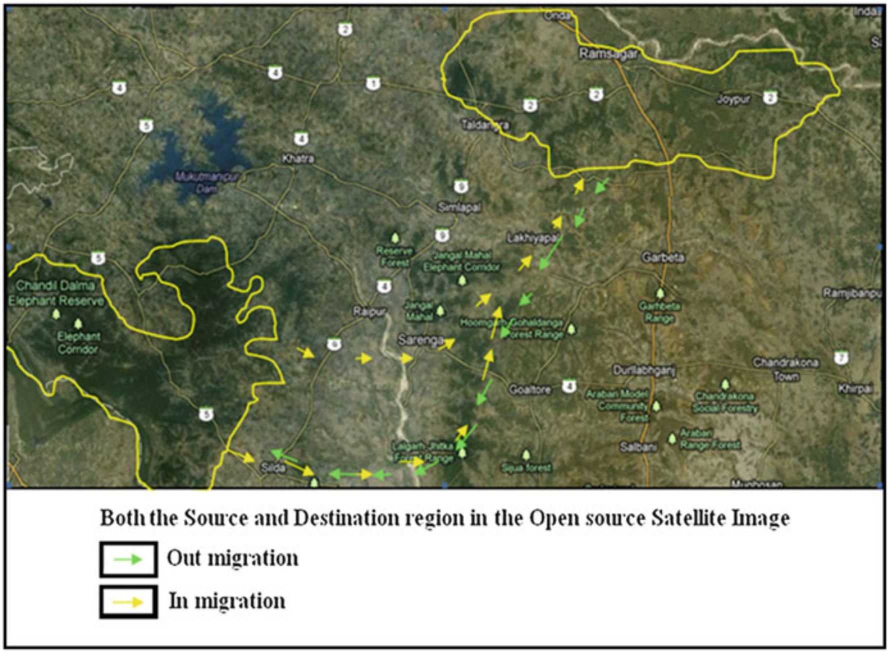
Map 3.1 Elephant distribution map of South East Asia

3.2 Home Range of Elephants

Elephants naturally prefer more virgin habitats, but they can also be found in a series of small, isolated populations within a highly fragmented landscape. The migrated elephants in the study area exhibit the same behaviour as did a subpopulation of about 50 elephants that had been largely confined to the Dalma sanctuary and its environs and began to make deep forays eastward into southern West Bengal in 1987. Hemant Datye and A. M. Bhagwat followed the course of some of these elephants and found that these elephants cover a home range of nearly 3400–3850 km^2 each year. The entire region between Dalma to southern West Bengal is predominantly covered by agricultural lands. These elephants are still expanding their range to the Paschim Medinipur, Bankura and Purulia districts. In the Bankura district, where the study area is situated, an increasingly large number of areas have been explored by these migrated elephants.

3.3 Habitat Analysis

From the West Bengal Forest Department Report and information collected from the Dalma Wildlife Sanctuary, it is evident that elephant migration has become a regular event in Panchet Forest Division (PFD). Each year elephants extend their forage area in PFD. The landscape ecology of the new habitat (PFD) is more fragmented in nature than their original habitat in Dalma. Thus, it is necessary to assess the habitat character of PFD.



Map 3.2 Elephant migration route from Dalma Wildlife Sanctuary to Panchet Forest Division on open source image

3.3.1 Food, Nutrition and Changing Food Habits

Elephants spend about 70 % of their time foraging although the amount of time varies seasonally. Their food choices range from grass, bamboo, tree, bark, paddy, fruits and any kind of palatable vegetation. They usually consume 150 kg of wet food per day. Elephants are known to spend between 17–19 h/day feeding on more than 100 species of plants. They eat most of the food crops usually grown adjacent to their forage ground, consuming, for example, paddy, millet, binger millet, sugarcane, wheat, palms and bamboo. Feeding occurs at different levels.

3.3.1.1 Branches of Trees, Shrubs and Grasses

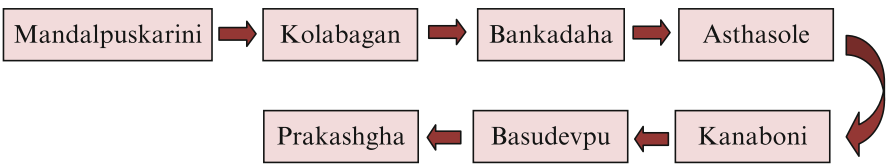
The range of fodder, however, varies with the locality and the season. They eat many kinds of grasses, including *Saccharum spontaneum, Ischaemum pilosum,* species of *panicum, sorghum* and *Themeda, Apluda mutica, arundinnella halocoides, eragrostis gangetica, hackeloch granulavis* and *paspalum scrobiculatum* (Daniel 1998).

They are entirely vegetarian and have been found to eat hard stems and twigs, but the bulk of their food consists of foliage and soft plant parts or succulent herbs. Bamboo (*Bambusa and Dendrocalamus*), ochlandra, sugarcane and standing crops in the fields are among other types of grasses preferred by elephants. Succulents like pandanus spp. and *Ardisia solanacea* are preferred as these provide a source of water (Daniel et al. 2008). The bark of certain trees, such as *Kydia calycina, Grewia tiliaefolia* and teak trees, is stripped and eaten. They prefer sapling bark rather than dry bark. Many shrubs and small trees are eaten, foliage and twigs together. Species such as *Helicteres isora, Grewia aspera*, *Hibiscus lampas*, *Acacia concinna*, *A. intsia*, *A. ferruginea*, *A. catechu*, *Cordia myxa*, *Zizyphus xylopyrun* and *Phoenix humilis* are the preferred species of elephants. Other species whose foliage elephants regularly eat include *Terminalia tomentosa*, *Premna tomentosa*, *Buchanania latifolia* and *Bauhinia racemosa*. Even the aerial roots of the banyan are broken off at the level of the elephant's reach.

A variety of forest fruits are eaten, for example, *Aegle marmelos*, *Artrocarpus integrafolia*, figs of various types, *Acacia hirsuta*, *Careya arborea*, *Cordial myxa* and *Feronia elephantum*. In addition, typical natural crop raiding is found all over the elephant habitats in India. It may be caused by the conversion of natural forest to monoculture plantation, a switch that usually lowers forage availability and compels elephants to raid crops in the forest margin agricultural lands. Another habit of elephants in the tropical moist forest region is their marked preference for secondary growth habitats over a primary forest habitat (Sukumar 2003). A secondarily grown habitat of bamboo, grass and weedy plants attracts elephants. In the study area, much barren soil has been turned green through social forestry programmes. Coppice sal (*Shorea robusta*), akashmoni (*Acacia auriculiformis*) and eucalyptus species plantations have changed the existing floral diversity. There are no grasslands or major food and fodder sources to meet the high food demands of migrated elephants. Hence, elephants have to search for fodder for their own caloric demands. As a result, they encroach outside the forest in the settled areas and agricultural fields, raiding crops. It has become a routine event in the Panchet Forest areas. Paddy is a favourite target. Dalma elephants started to migrate towards southern West Bengal when the paddy started to mature in the Panchet region. The movement pattern and raiding during the crop season thus reflect their foraging needs. Usually, elephants raid cultivated crops almost exclusively at night. During daytime they confine themselves in the natural forest habitat and start raiding at night. So they have good knowledge of the location of crop fields. It has also been observed that as a landscape becomes more fragmented and its ratio of the perimeter of the forest cultivation boundary to forest area increases, the frequency of raiding by elephants also increases (Sukumar 2003). The patch analysis reflects the fragmented nature of forest here in the Panchet area, which increases the probability of crop raiding. A variety of vegetables including potato, tomato, carrot, spinach and pumpkin and fruits like mango, banana, and jackfruit are consumed. It is very interesting to note that elephants in the study area changed their food habit from agricultural crops (paddy and wheat) into juicy and palatable horticultural crops like cucurbits, cabbage and cauliflower, potato, brinjal, colocasia (Ketsu) and tender jackfruit (Kulandeival 2010). As a result of these changing food habits, farmers in the affected area greatly suffer because most of the crops and vegetables are commercial crops and are very vital to the local villagers' economy.

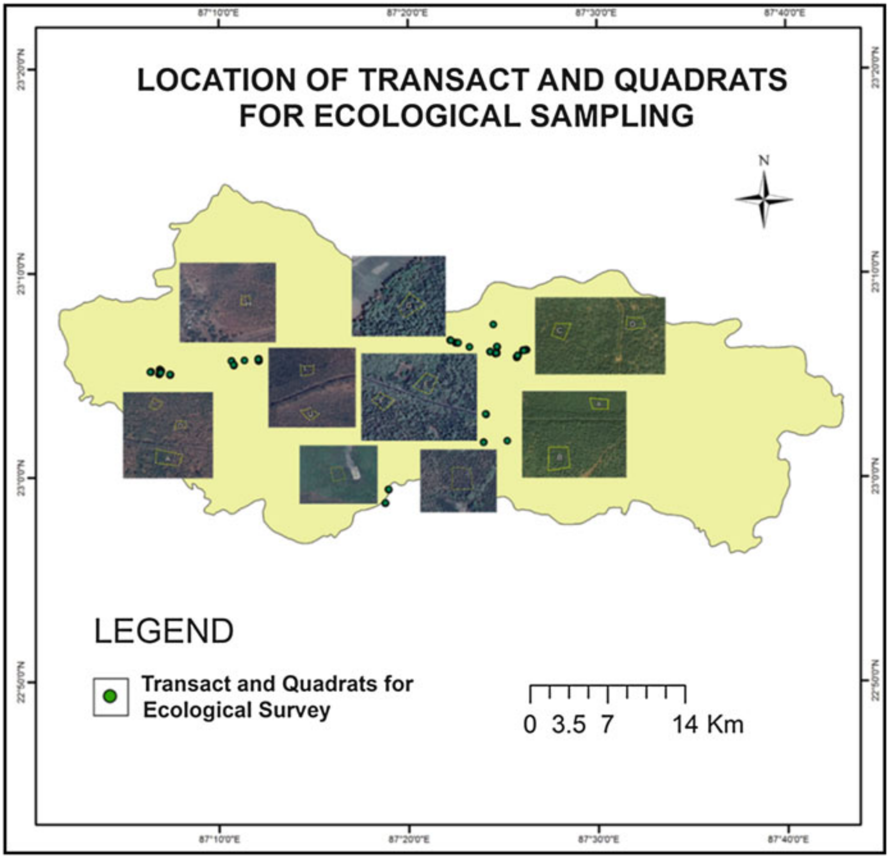
3.3.2 Shelter

Migratory elephants start roaming within the fragmented forest patches after entering into Panchet from Dalma and they stay throughout the harvesting season. Movement statistics taken from different beat offices show that after entering their destination forest, they usually get separated into small groups and roam from one forest patch to another. They usually stay 7–13 days in a forest patch and then move to other places within the study area. Their movement is generally confined to

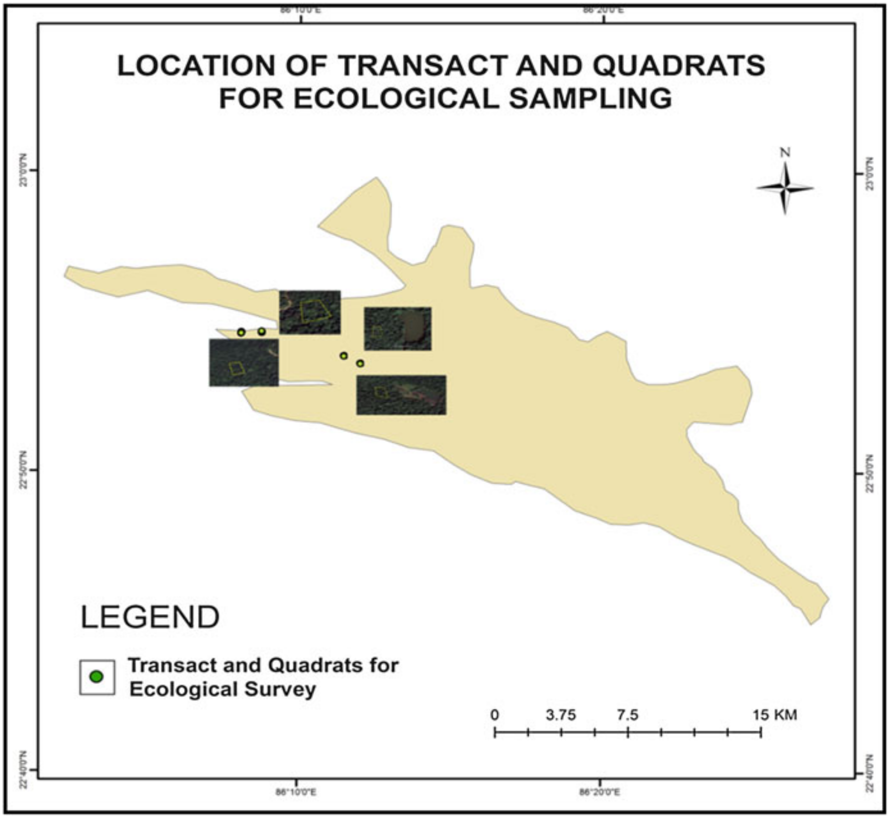


Temporal observation on the movement of these elephants revealed that the elephants are moving very frequently in new areas in search of food. During this movement they take shelter in the forest patches during the day and raid crops and agricultural lands at night. To assess the nature of shelter preferred by elephants, we evaluated the habitat quality of different forest patches. For this purpose several transects and quadrats were randomly selected (a total of 44 transects and quadrats) in each of the forest beats.

Information was collected on the composition of species, density of the patch, average height, diversity of species, abundance of species, microclimatic condition, ground and canopy cover and so on. Additionally, we conducted prescheduled questionnaire-based surveys in randomly selected households in affected villages. Through this questionnaire survey, we tried to identify the causes underlying elephants' shelter preference. The availability of water, that of food and the peacefulness of the area are three main criteria primarily considered by elephants in choosing shelter.



Map 3.3 Sample sites for ecological surveying at Panchet Forest Division



Map 3.4 Sample sites for ecological surveying at Dalma Wildlife Survey

3.3.2.1 Forest Cover, Vegetation Succession and Movement of Elephant

The ecological analysis of habitat showed that patches distributed in Bankadaha, Joypur, Machantala, Basudevpur and Peardoba are highly preferred by elephants. The quadrats and transacts for ecological survey were selected on the basis of species association, density, degree of ground cover, intensity of canopy cover and layering in forests.

We applied the transect and quadrat method to the foothill, mid-hill and upper part of Dalma Hill of Dalma Forest area. Though the result of ecological analysis revealed that , Dalma Wildlife Sanctuary is superior in terms of species richness and diversity than the PFD areas, the disturbances in the former habitat have pushed the elephants to leave their original place. Regular mining and quarrying activities blast dynamite, which hampers the natural environment (Figs. 3.1, 3.2, 3.3, 3.4 and 3.5).

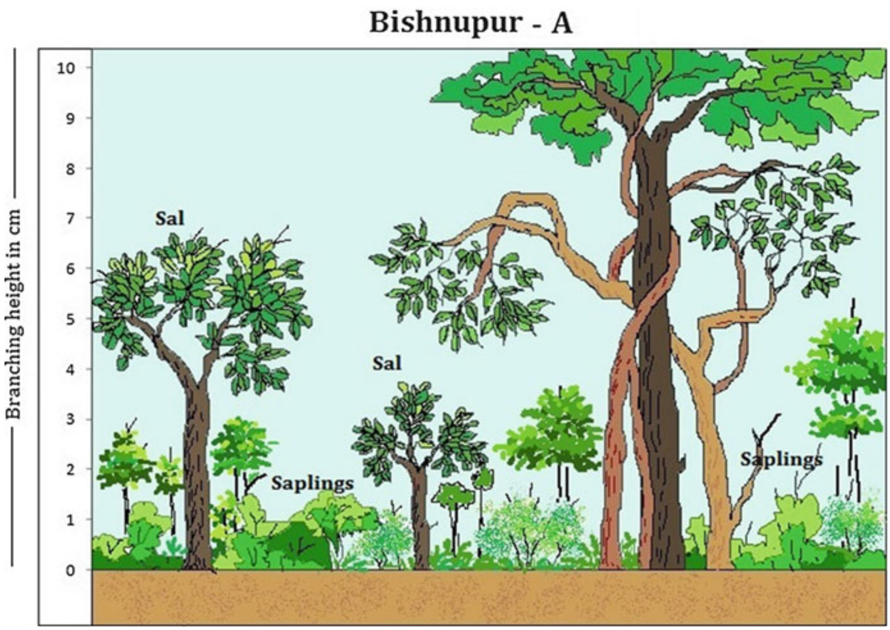


Fig. 3.1 Ecological survey at Bishnupur—transect A

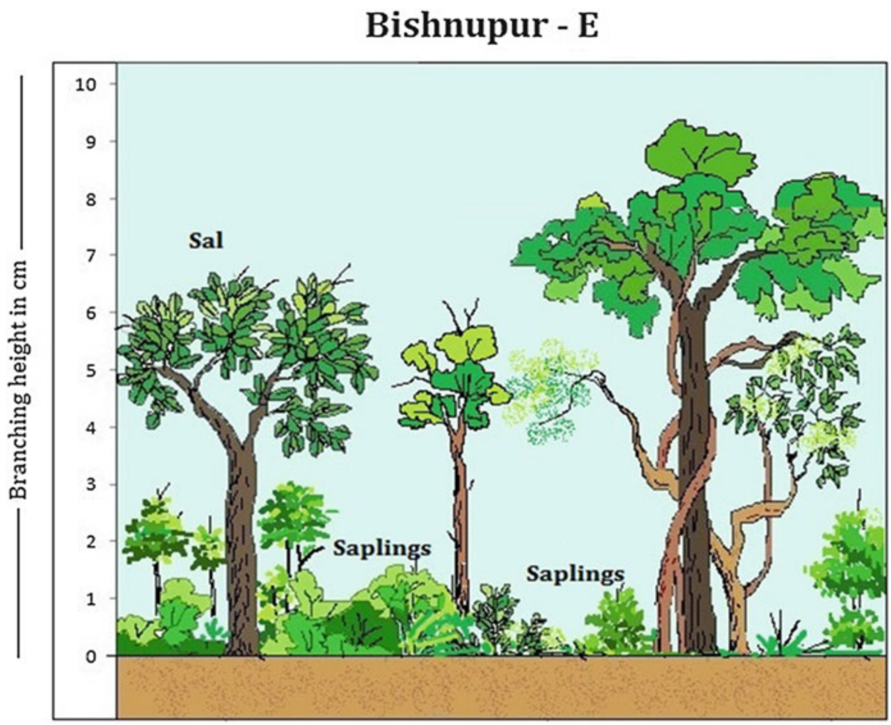


Fig. 3.2 Ecological survey at Bishnupur—transect E

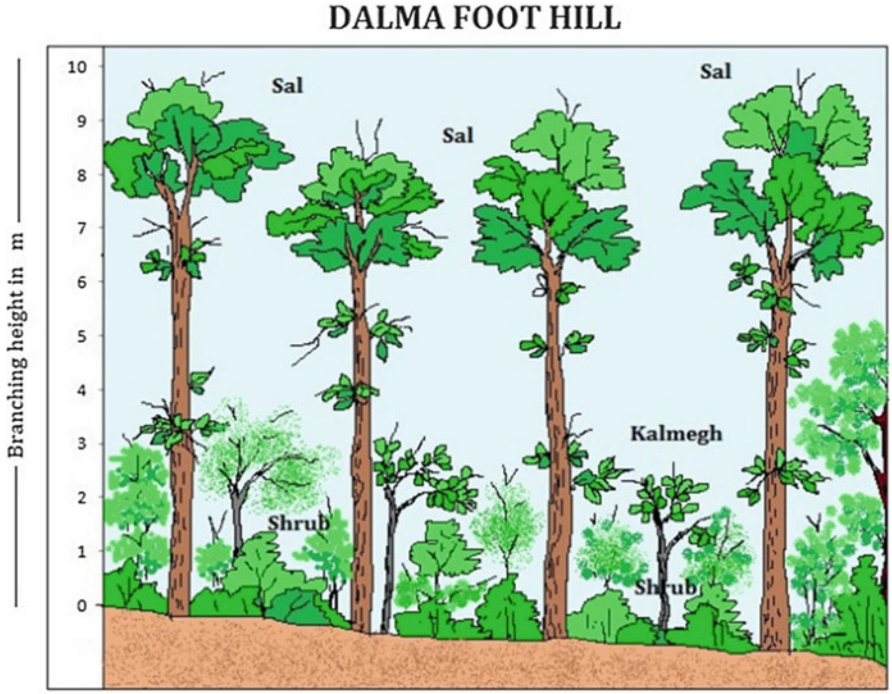


Fig. 3.3 Ecological survey at Dalma—foothill

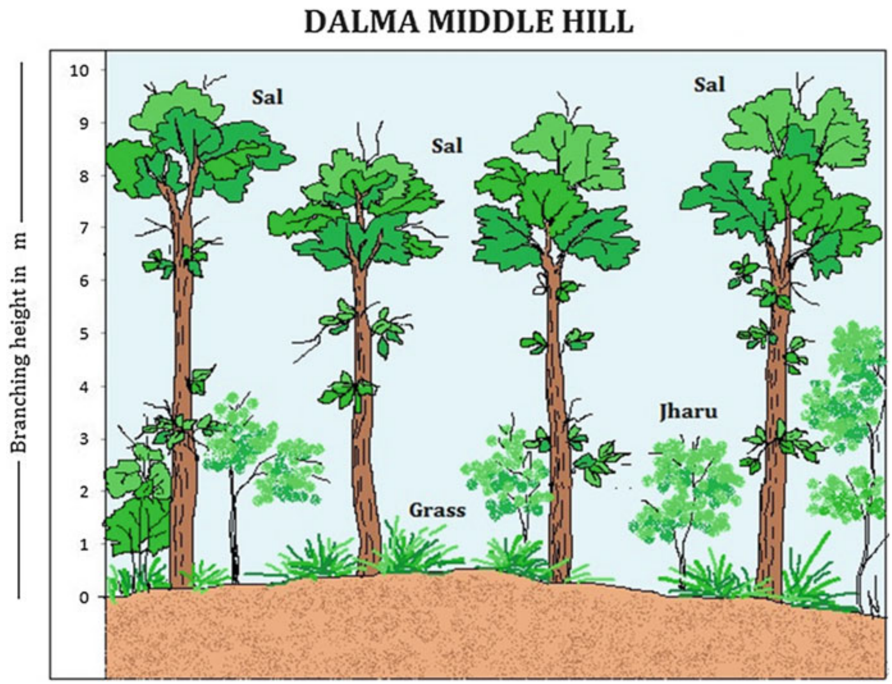


Fig. 3.4 Ecological survey at Dalma—middle hill

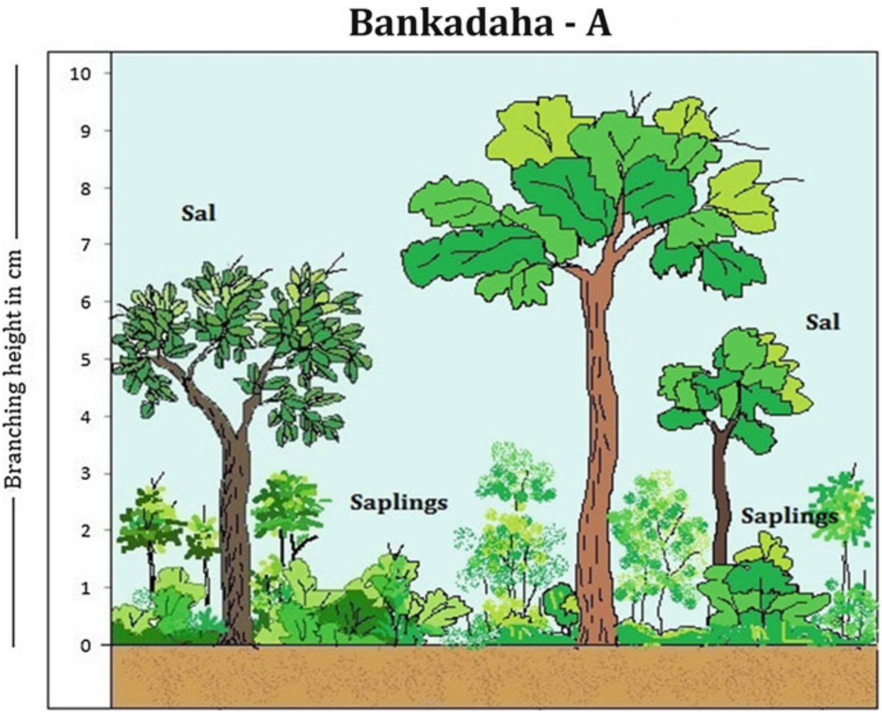


Fig. 3.5 Ecological survey at Bankadaha—transect A

Plate 3.1 Ecological surveying at Adkhatha forest range

3.3.2.2 Ground Cover

Elephants in the Panchet area prefer the patches with ground cover on more than 80 % of the total patch area. For example, Basudebpur Forest area near Bishnupur is preferred by elephants for this reason. Transect profile and quadrat information shows that the patch is characterised by climbers of different types. This huge association of species make the forest difficult to penetrate for villagers. So it is undisturbed in nature.

3.3.2.3 Nearness to Agricultural Land

The entire elephant habitat in PFD is surrounded by agricultural lands. These agricultural lands are either single- or double-cropped. Paddy, wheat, sugarcane, corn, fruit crops and different types of vegetables are grown in these agricultural fields. The regenerated forests in the study area make a corridor for elephant movement, but it cannot satisfy their large demand for food. So the elephants raid crops and vegetables. It has become a regular phenomenon. There is a positive relation between elephant resting ground and distance from agricultural land. The following ergograph shows the relationship between rainfall temperature and crop calendar of the PFD. It depicts that there are three main seasons: summer crop, monsoon crop and winter crop. In some cases it has been observed that they follow the maturity season of specific agricultural crops, especially paddy and vegetables. The interesting fact is that they have a 'mental map' of the location of agricultural fields from which they will get their food. Information on 'duration of stay' in different forest beats was collected from forest beat offices. After plotting the information, we obtained a comprehensive picture of the elephant movement behaviour in the study area. We also observed that they extended their habitat into the new areas in successive years.

Figures 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12, 3.13 and 3.14.

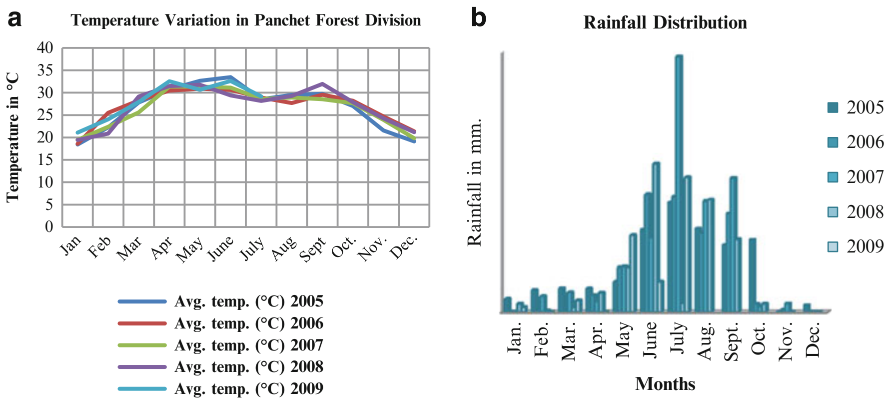


Fig. 3.6 (**a**) Temperature variation in Panchet Forest Division (PFD). (**b**) Rainfall distribution in PFD

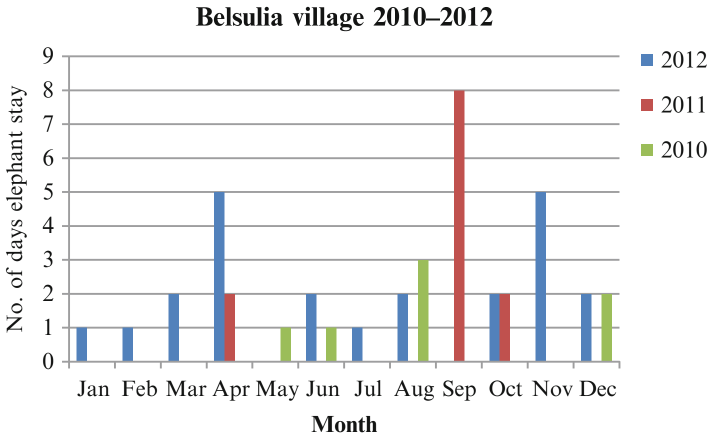


Fig. 3.7 Duration of elephant stay at different stations in Belsulia village

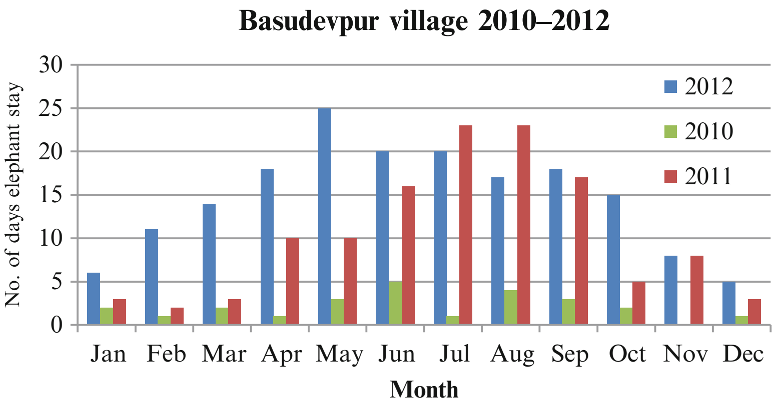


Fig. 3.8 Duration of elephant stay at different stations in Basudevpur village

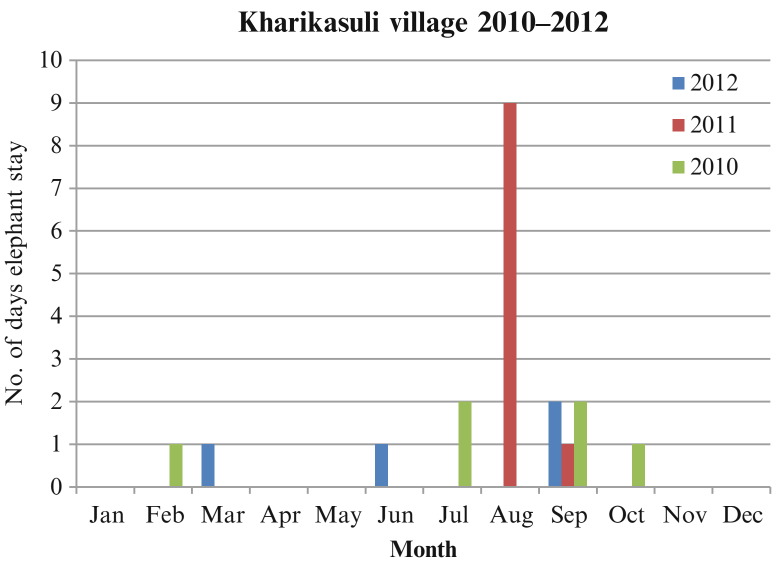


Fig. 3.9 Duration of elephant stay at different stations in Kharikasuli village

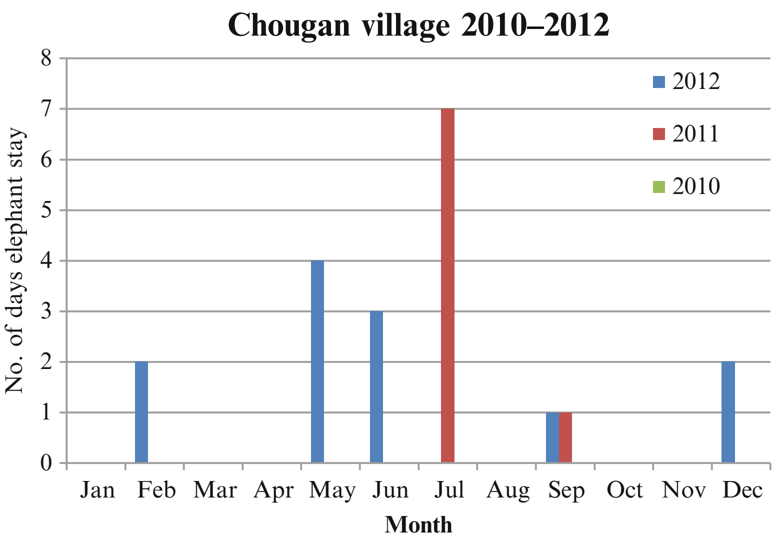


Fig. 3.10 Duration of elephant stay at different stations in Chougan village

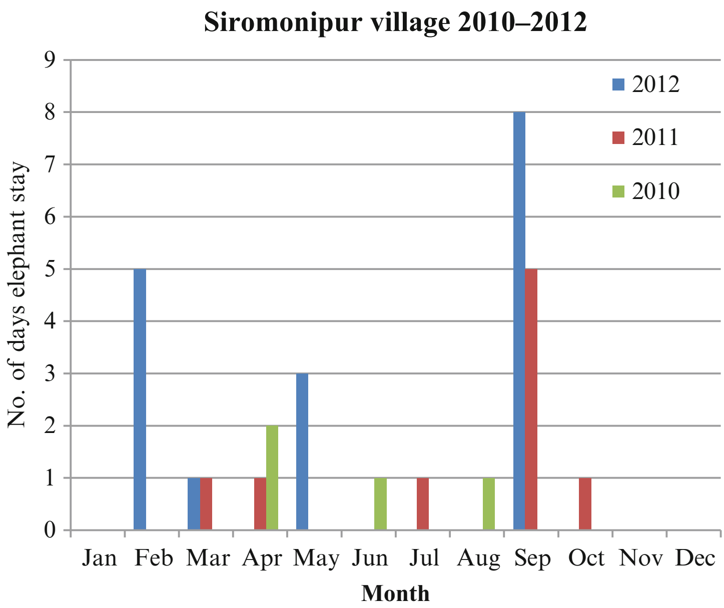


Fig. 3.11 Duration of elephant stay at different stations in Siromonipur village

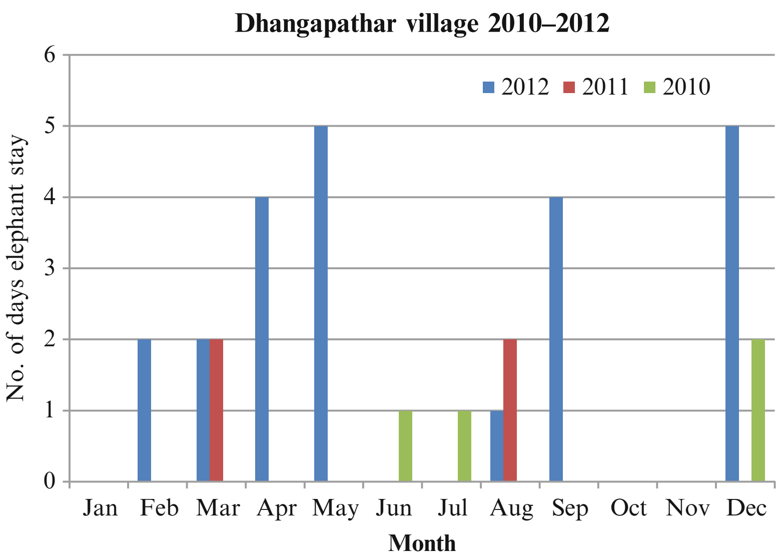


Fig. 3.12 Duration of elephant stay at different stations in Dhangapathar village

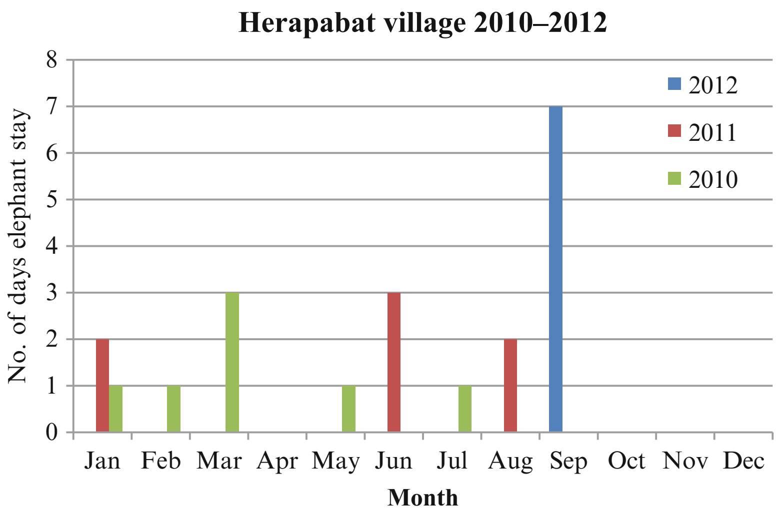


Fig. 3.13 Duration of elephant stay at different stations in Herapabat village

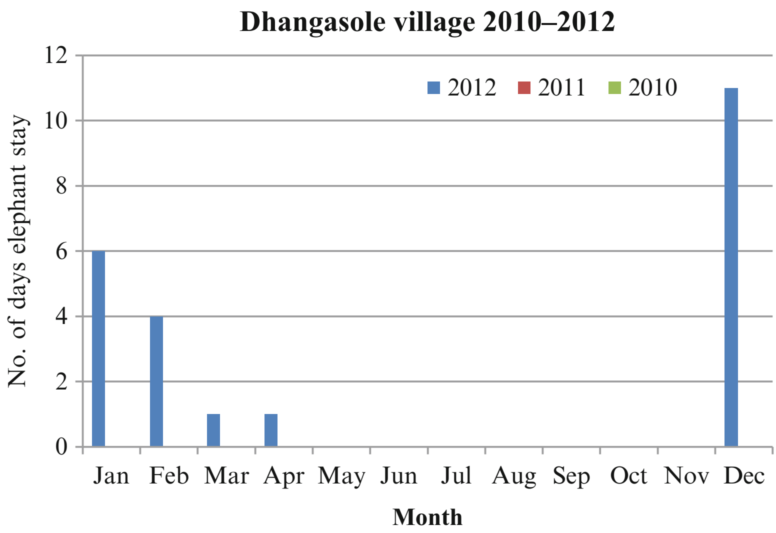


Fig. 3.14 Duration of elephant stay at different stations in Dhangasole village

Plate 3.2 Elephant venturing the crop field

Plate 3.3 Agricultural fields on the vicinity of forest

3.3.2.4 Distance from Road or Noise Source

While analysing the preference for resting ground, we found that elephants prefer a calm and noise-free environment; therefore, their resting grounds are usually located at a distance from a road or noise source. But in the human-modified fragmented forest patches, it is not possible to maintain a distance from settlement. Some of the roads and canals pass through the forest area, which interrupts the free movement of elephants. They face accidents or are injured while crossing the roads within the forest.

Plate 3.4 Elephant are crossing motorable road

Plate 3.5 Elephant are across railway track

3.3.3 Water Source

Along with shelter and food, water is one of most important factors that regulate the movement of elephants. The main water sources are the Dwarakeswar River, Kangsabati Canal, Berai (tributary of Dwarakeswar), human-made ponds in the settled areas and potholes dug by the forest department within the forest. The agricultural fields near the Dwarakeswar River are regularly raided by elephants. Kangsabati Canal, which is the main source of irrigation, passes through the forest patches and is an important source of water for elephants. In addition, ponds near the forest fringe areas are also used as a source of water.

Plate 3.6 Kangsabati canal, as source of water in PFD

Plate 3.7 Elephant herd near Dwarakeswar River

Plate 3.8 Metalled road through the forest

Chapter 4
Habitat–Wildlife Relationship and Different Models

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_4

Abstract After getting the habitat characteristics of the study area, we tried to establish the habitat–wildlife relationship with the help of different models. Habitat heterogeneity is the main controlling factor for the movement of animals within different forest patches in the study area. Different variables, such as pattern of energy/nutrient and water flow or quality and composition of plant species, were plotted. By applying models of vegetation composition and structure—a disturbance model, a gap analysis model and a habitat suitability model—we established the relationship between elephants and the habitat in the Panchet Forest area. Ecological information was plotted against different manmade factors like abundance of plant species and distance from motorable road; concentration of pond and distance from forest core; and forest edge distance and abundance of plant species to obtain the impact of anthropogenic activities on the elephant habitat. A gap analysis model was applied to identify gaps in the conservation area. This model is helpful for getting the zones of floral species' richness or 'hot spot' or rarity. Accordingly, the habitat or niche of a specific animal is determined. A habitat suitability model was applied to show the habitat–animal relationship. We took a number of environmental variables into consideration.

Keywords Habitat–elephant relationship • Disturbance model • Gap analysis model • Habitat suitability model

4.1 Introduction

The history of animal ecology has mainly studied the pattern of habitat utilisation by animals. In this chapter, we tried to find out why elephants choose a particular habitat as their 'niche gestalt' and what factors a species considers in choosing a habitat. The major cause may be the temporal and spatial variability in habitat characteristics. Plant species composition plays a much greater role in determining the pattern of habitat occupancy. But there may be other important factors that also influence the movement of animals and selection of their habitat. There are inadequate theories to assess the habitat–wildlife relationship model, and in some cases they are contradictory too. Various statistical models like regression, correlation, multivariate analysis, habitat suitability index and gap analysis model were applied to assess this kind of relationship. These are very location- and time-specific. The scale also plays a key role in assessing the habitat–wildlife relationship. It has been found that at smaller scale these models yield good results. For this reason we tried to apply some of the models on the habitat–wildlife relationship. Thus, we selected forest patches selected along with the surrounding environmental envelope. These have been verified with the help of different models to yield a final result for habitat selection by elephants.

4.2 Habitat Heterogeneity and Disturbance

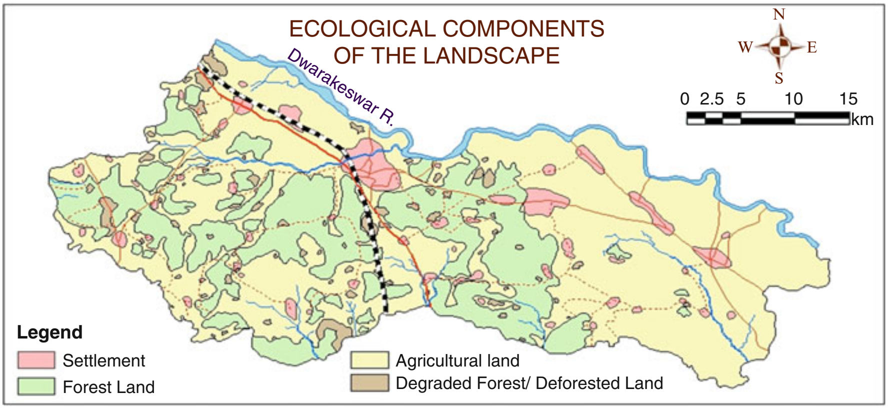
As stated earlier, habitat is characterised by multiple factors, including food supply, weather conditions, association of plant species, prey–predator relationship, micro- and macroclimatic conditions, and many other biotic and abiotic factors. These various spatial and non-spatial factors characterise a specific habitat and make up the habitat heterogeneity. An animal's selection of habitat depends on these factors. The movement and migration of animals usually depend on a pattern of resource patches, dynamic flows of energy, nutrients, water and air along with the other factors mentioned above. Any habitat has certain parts like *ecotone* or *ecocline,* where the aspect of these components is different from the total area. These are the border areas of a whole system and are affected by fragmentation and disturbance. As a result of disturbance, resource or vegetation patches can be isolated into islands from the surrounding entire habitat. These phenomena directly influence the movement and behaviour of animals. It may decrease or increase the population per unit area and impact the carrying capacity. Thus, these correlations have cyclic effects on the total ecosystem, as the diagram below shows.

Habitat disturbance can be categorised on the basis of degree of disturbance and geographical area affected that is, widespread or local (Morrison et al. 2006). It may be summarised in the following diagram.

		Geographical area affected	
		Widespread (>1000 ha)	Local (1–1000 ha)
Degree of disturbance	High	Type I: Major environmental catastrophe (volcano, earthquake, etc.)	Type II: Local environmental disturbance (wind, ice storms, insect, disease, etc.)
	Low	Type III: Chronic or systematic change over wide areas (predators, competition for forestry)	Type IV: Minor environmental change (local fires, development, etc.)

The current degree of disturbance in the Panchet Forest Division (PFD) falls under types II, III and IV. In a type II disturbance, the dominant factors responsible for changing the natural habitat are forest canopy gaps or micro serules, local succession change (which contributes to the overall vertical forest stand structure) and species composition (Moeur 1997; Degen et al. 2005).

A type III disturbance is a result of systematic or chronic changes over wide areas. It happens because of a slow alteration of the natural landscape into a human-modified landscape, ecological succession and long-term climate change. These factors impact the species abundance and distribution (Weltzin et al. 2003). The effect of El Niño and other kinds of climatic phenomena comes under this category. Finally, type IV disturbances include minor and local environmental changes, such as local forest fire, development of settlement along edges of natural landscape, death or decay of habitat due to insect infestation and so on.



Map 4.1 Ecological component of Panchet Forest Division

Field investigation in both the Dalma and Panchet areas shows that both areas represent a high degree of habitat heterogeneity. In Dalma, habitat heterogeneity is the result of excessive mining and quarrying activities within the forest covered areas. The natural landscape is also highly transformed into a human-modified environment. Since independence from Great Britain, a number of ancillary steel industries were built up in areas surrounding Dalma Wildlife Sanctuary. Expansions of industries at the forest boundaries generate edge effects. The Panchet area is less disturbed than the Dalma Forest region in terms of being an environmental resource, that is, mineral excavation or industrial development. Though the Panchet Forest is more fragmented, it is less disturbed than the Dalma region. Another important fact is that forests around Dalma become fragmented because of industrial and settlement expansion, but the reason behind forest fragmentation in the Panchet Forest is agricultural expansion, plantation and regeneration of degraded forest in patches. Thus, in the latter case it supplies supplementary food and fodder to the elephants, and so they prefer to migrate to the PFD (Map 4.1).

With the help of models of the vegetation composition and structure, disturbance, gap analysis and habitat suitability index (HSI), we tried to establish the relationship between elephants and the habitat in Panchet Forest areas.

4.2.1 Vegetation Composition and Structure Model

The vegetation composition and structure model displays current and future vegetation stands. It includes forest stand growth. This model assumes that vegetation present in a habitat is correlated with the wildlife's preference. Marcot et al. (1998) proposed a model to show this kind of relationship. He showed that wildlife species'

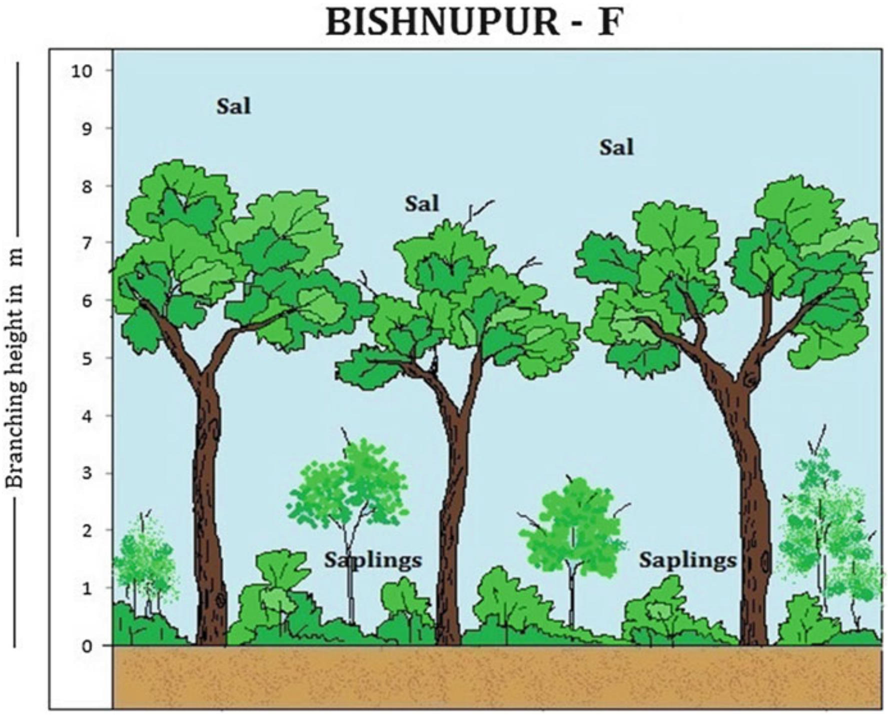


Fig. 4.1 Ecological transect of different station, Bishnupur—F

response (**S**) depends upon environmental factors (**E**). This response may or may not be a causal relation, may be a sequence of environmental and species variables or may be unexplained.

Wildlife species response (**S**) = **f**(**E**) Environmental variables

If we consider the composition, structure and association of vegetation as environmental variables (**E**) in the study area, then it can be seen that there is a causal relationship between **E** (environment) and **S** (elephant) (Figs. 4.1–4.4).

Elephant movement and duration of stay in a particular forest patch are governed by vegetation species, characteristics, their structure and composition. Ground and canopy coverage also play a significant role for the habitat selection of elephants. The forest cover in the study area is the dry deciduous type. The canopy cover in most of the forest patches ranges from 20 to 40 %, and the ground cover ranges from 50 to 80 %. Ground cover is more important than canopy cover in the study area because it prevents human interference within the forest patch. Hence, elephants can live in a less disturbed habitat.

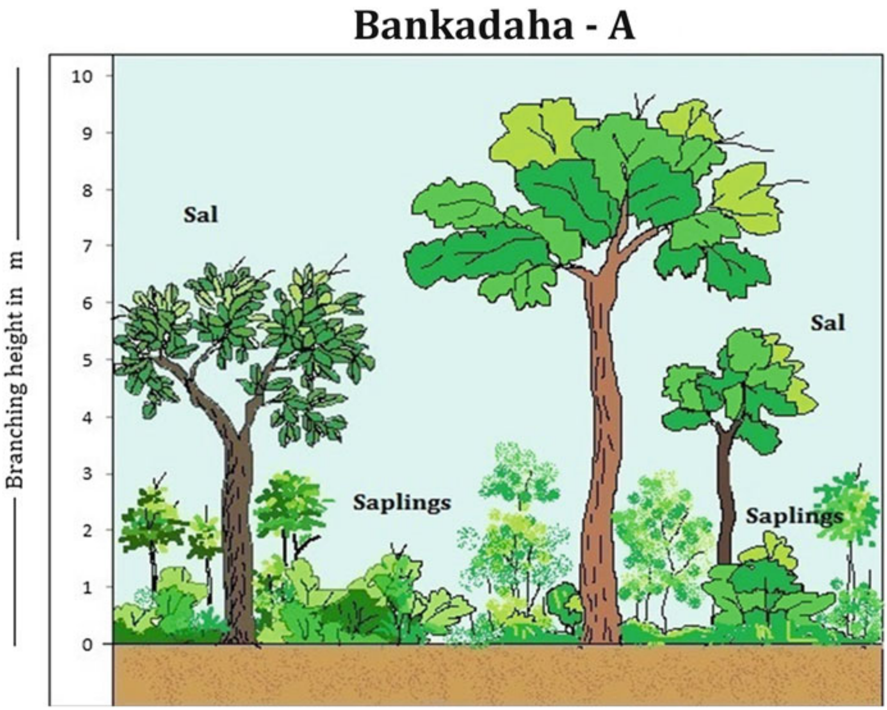


Fig. 4.2 Ecological transect of different station, Bankadaha—A

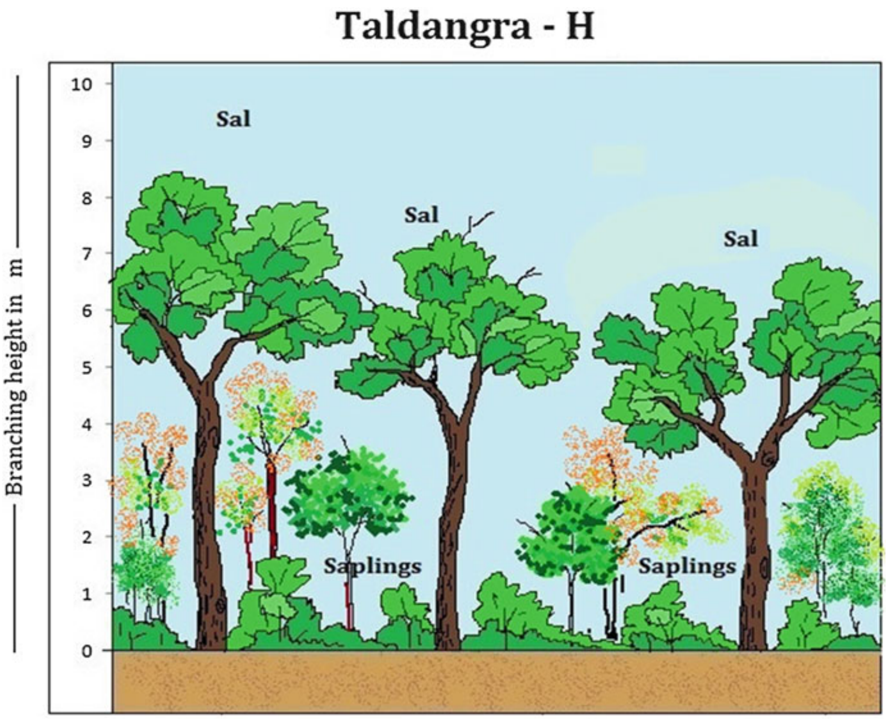


Fig. 4.3 Ecological transect of different station, Taldangra—H

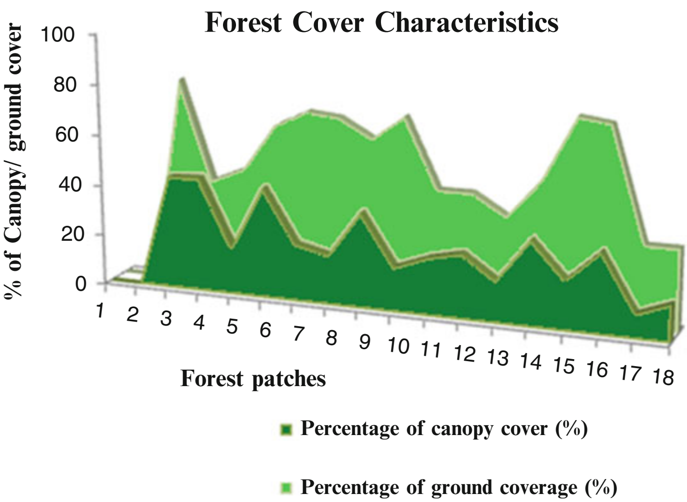


Fig. 4.4 Percentages of canopy and ground cover

4.2.2 Disturbance Model

Disturbance within or near the habitat is a very common and important factor regarding habitat selection and movement of wild animals. Movement refers not only to a foray within their own habitat but also in the corridors used by animals in between two or more habitats. This type of relationship of wild animals with their habitat can be accessed through the disturbance model. Major environmental factors, for example, flood, drought and climate change, are considered disturbance factors on a higher level. Yet factors like forest fire, canopy gap and so forth are equally important to wild animals while they select their habitat. Disturbance models can be useful for conservation or recovery of threatened species (Root 1998) and for measuring the resilience of individual species in a disturbed habitat (Gunderson et al. 2002).

In our study, anthropogenic activities in the form of mining and quarrying, human intrusion to collect non-timber forest products within the forest habitat, expansion of roads through the habitat, motorable roads and the noise of vehicles are considered disturbing components. Data collected from the field surveys were assessed through regression. The result shows that as the distance from the source

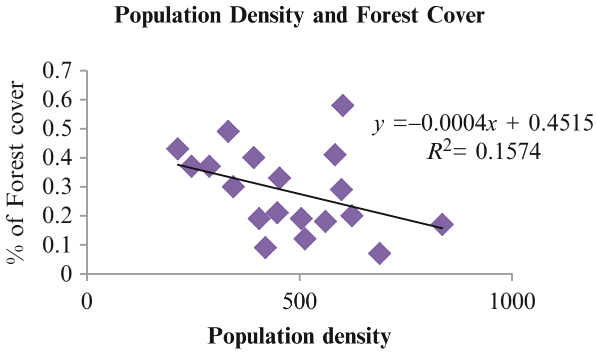


Fig. 4.5 Relationships between population density and forest cover

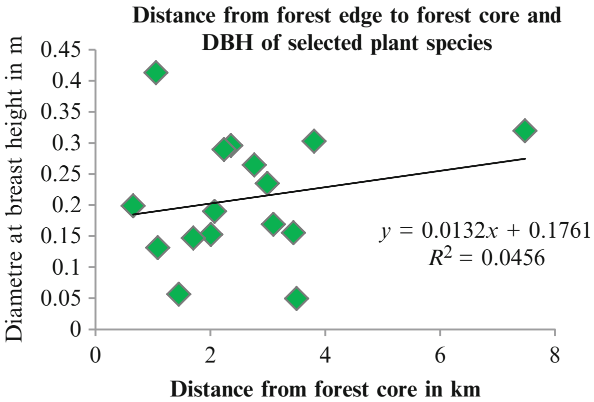


Fig. 4.6 Distances from forest edge and diametre at breast height (DBH)

of disturbance increases, the abundance of elephants increases. When we characterised their preference for habitat selection, we found that they prefer to stay in places that are less disturbed (Figs. 4.5–4.9).

4.2.3 Gap Analysis Model

The gap analysis model is generally applied to identify gaps in a conservation area (Morrison et al. 2006). This model is helpful for getting the zones of floral species richness, or ‘hot spot’, or rarity. Accordingly, the habitat or niche of a specific animal is determined. Gap analysis maps are generally produced by overlaying land use/land cover maps, vegetation cover maps and distribution zones of animals. These are very helpful for the conservation and management of vegetation as well as animals.

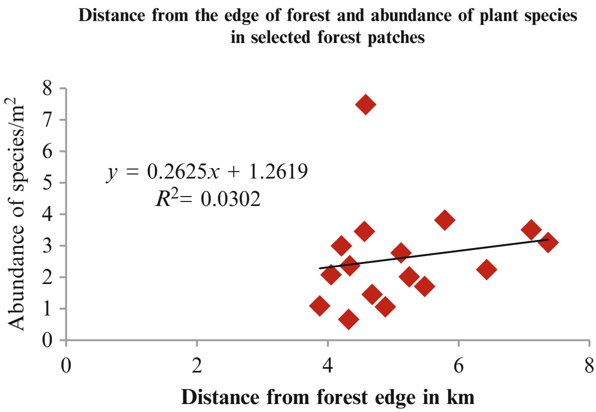
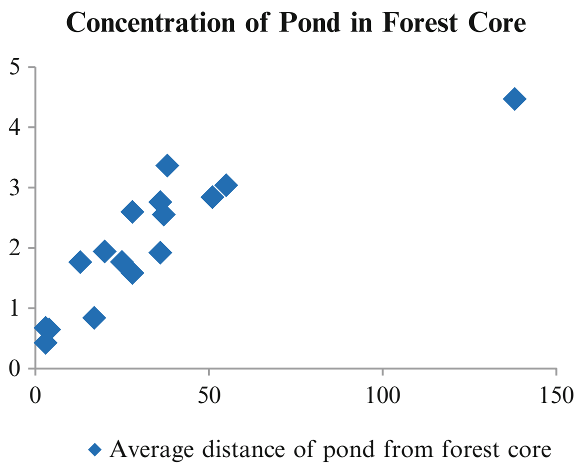


Fig. 4.7 Relation between forest edge and abundance of plant species

Fig. 4.8 Concentration of pond in forest core



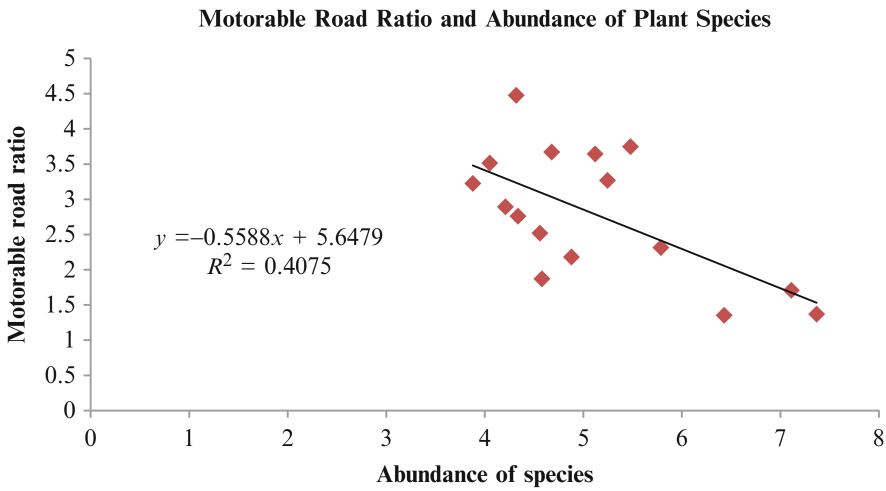
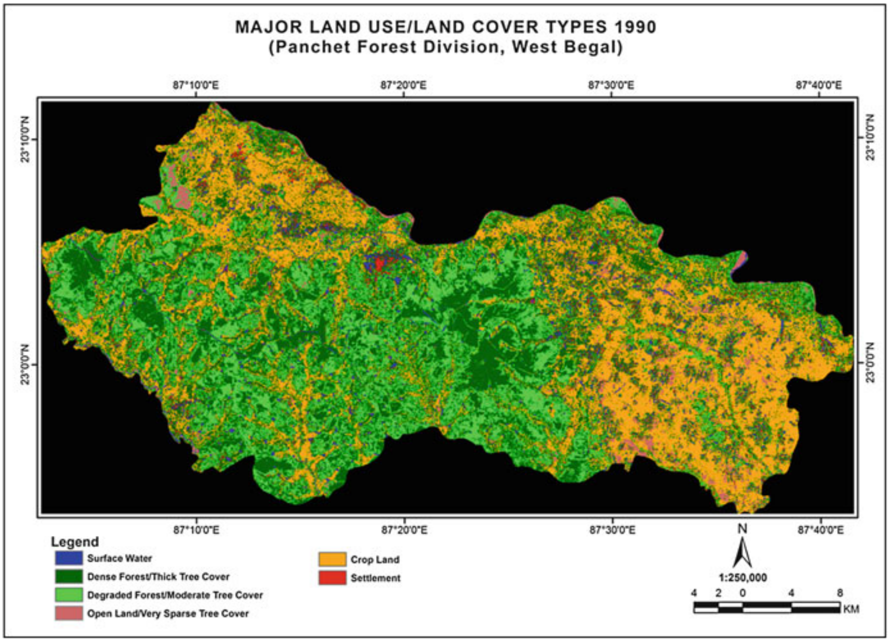


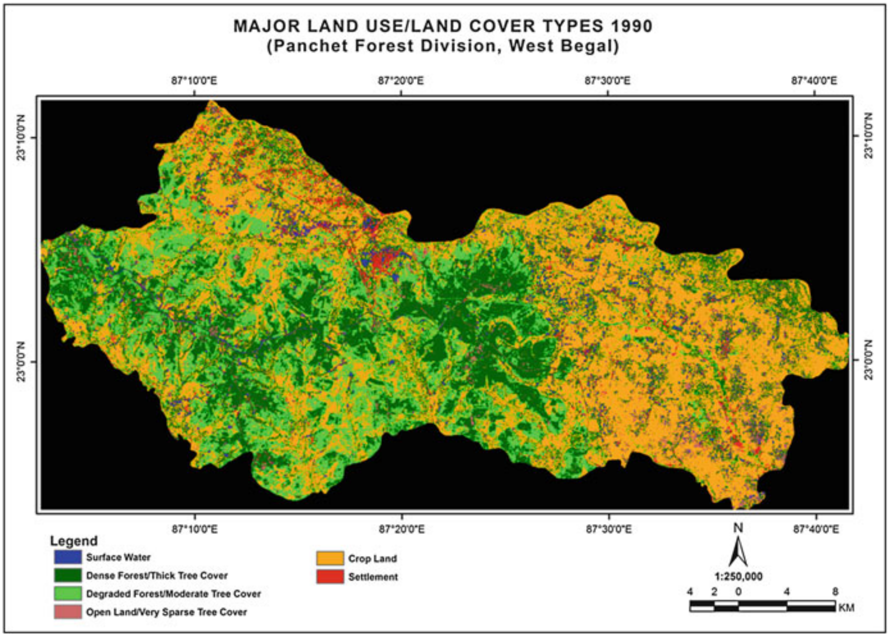
Fig. 4.9 Motorable road ratio and abundance of plant species

The land use and land cover map of the study area have been prepared with the idea to assess the temporal change of land use and land cover. For this purpose, LISS III TM images of 1990, 2001, 2006 and 2013 were created through supervised classification. This showed that the forest cover of this area is highly fragmented in nature. Most of the forest fringe areas are surrounded by either settled areas or agricultural lands. The western part of the study area is characterised by fragmented forest patches with agricultural land, but the eastern portion is dominated by agricultural land use. As a result, the western part is more affected by elephant movement and crop raiding than the eastern part. The forests in the west, mainly regenerated sal forest, are severely affected by elephant attacks. If these fragmented forests can be connected by generating corridors in between the patches, the phenomena of crop raiding and human–elephant conflict can be checked. Elephants in the PFD are extending their forage ground toward the north and in the east. The northern part of the study area is characterised by forest patches of Bankura North Forest Division, and the eastern part is mainly dominated by agricultural lands. Through this model the movement trend can also be identified.

Additionally, two satellite images of 1990 and 2013 are compared with the help of patch metrics. This comparison depicts various land utilisation under different patches at the raster level in two different periods (Table 4.2 in Appendix A).



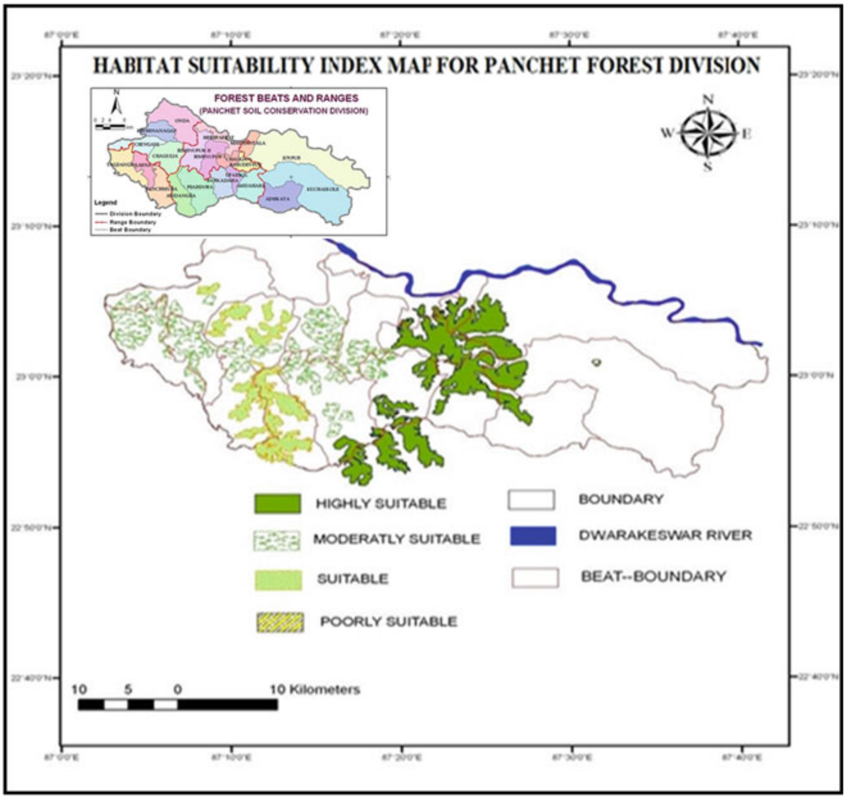
Map 4.2 Major land use/land cover types of Panchet Forest Division in 1990



Map 4.3 Major land use/land cover types of Panchet Forest Division in 2013

4.2.4 Habitat Suitability Index Model

The HSI is a very simple yet popular model to show a habitat–animal relationship. Here numbers of environmental variables (*V*) are taken into consideration. The value of each variable in this model scales from 0 to 1. After getting the scale for every variable, one prepares a final HSI through a simple geometric mean. It is a very simple measurement of the impact of different environmental variables on the abundance of wildlife within a specific habitat. Though it does not represent the size, number and trend of animal movement, it gives a clear picture of habitat selection by specific animals. While applying this model in our research work, we considered some local factors along with common environmental factors to successfully establish the habitat–elephant relationship. The HSI of the PFD can be represented through Table 4.1 and maps.



Map 4.4 Habitat suitability map for Panchet Forest Division

Table 4.1 Table for habitat suitability index

Sl no:-	Name of the forest patch	Road density	Average distance from core	Nature of micro climate	Canopy cover	Water availability	Management steps	Fragmented nature	Density of forest	Ground cover	Health of trees	Total score out of 50
1	Bishnupur forest	2	3	3	3	2	2	2	3	5	3	28
2	Taldangra forest	4	4	2	2	3	1	3	2	3	2	26
3	Chak-nakaijuri forest	1	3	4	2	4	1	4	2	3	2	26
4	Joipur forest	3	5	5	5	1	2	1	5	5	4	35
5	Chandabila forest	3	4	3	3	2	1	1	4	4	3	28
6	joipur-panchmura	2	3	4	2	3	1	2	2	4	2	25
7	Chaguliya	2	4	4	4	2	1	1	3	4	2	27
8	Barkhuliya	1	3	2	2	4	1	1	2	4	2	22
9	Upper part of nakaijuri	1	3	4	3	2	1	3	2	3	2	24
10	Western part of nakaijuri	1	2	4	3	4	1	2	2	3	2	24
11	Westjambedia	3	2	2	2	5	1	4	2	2	2	26
12	Amdangra	1	2	4	4	2	2	4	2	3	2	26
13	Brindabanpur	4	3	3	2	3	1	4	4	4	3	31
14	Kalabagan	3	4	4	4	3	2	2	3	4	3	32
15	Chatra Krishna nagar	1	1	1	1	4	1	4	1	2	1	17
16	Metalya	1	2	2	2	4	1	4	2	2	2	22

The HSI of the PFD divides the whole area into four suitability zones. Basudevpur, Uporsole, Bankadaha, Amdahara and Joypur forest beats are in the highest suitability zone for elephant habitation. These forests are the densest forest cover zones. Forest patches of Bishnupur, Peardoba, Hereparbat and Amdangra are moderately suitable. Forest patches at Chagulia, Taldangra, Chingani and Krishnanagar are considered poorly suitable for elephant habitat. The movement of elephants is thus restricted within the first three suitability zones.

Chapter 5
Elephant Migration and Dispersal: A Biogeographic Process

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_5

Abstract This chapter focuses on the biogeographical processes of elephant migration. The chapter is based on different dimensions of elephant migration in the study area. It starts by briefly reviewing the historical perspectives of elephant migration. Secondary information on the number of migrated elephants and the duration of stay in the destination habitat was collected from different forest beat, range and divisional forest offices and was analysed through statistical tools. Migration routes and their temporal shift have been identified through geographic information systems and were verified by ground information. When one analyses the nature and characteristics of elephant movement, some interesting facts come up. There is a strong relationship between crop calendar and migration and it can be seen that the movement is season-dependent. These facts were justified by correlating different variables and are represented through different cartograms. Movements of elephants within different patches were tracked and depicted in forest fragment maps. It may be useful to forecast the movement of elephants to avoid conflicts and agricultural loss. Another tendency is that migrated elephants turn into residential elephants, which becomes a major issue in the destination habitat as it raises the issue of human–elephant conflict as well as that of conflict between residential elephant and migrated elephant. This chapter addresses both of these issues.

Keywords Migration process • Trend of migration • Migration routes

5.1 Introduction

Human–animal conflict is a common phenomenon for animal species that migrate from their original habitat to another destination habitat. This kind of animal movement may be seasonal or annual. On the basis of the type of movement, the biogeographical processes of migration can be divided into non-recurrent directional movements and recurrent seasonal movements. Animals usually migrate from one place to another place that has more congenial environmental conditions, in search of new breeding grounds or food. The broad spectrum of migration includes movement behaviour of the respective animal species stressed by food uncertainty and the spatial heterogeneity of the resource base over a time scale, climate change and so on. Seasonal migration is found among birds, fishes and insects (Dingle and Drake 2007). Such animals are mainly '*r*' strategists with respect to their behaviour for survival and are capable of developing their colony through a higher rate of reproduction in a harsh, unproductive environment. For such species, a time span of one generation more or less equals the life span of their habitat. Because of the shorter span of their habitat, they manage to survive through migration to newer habitats and their population dynamics is characterised by migration and a population boom-and-burst cycle (high rate of reproduction).

The large and long-lived animals living in a habitat, whose life span is much longer than the time span of a generation, follow '*K*' strategy for their survival. Elephants are the '*K*'-strategists living in a less harsh, fairly constant and predictable but competitive environment, and their population follows the carrying capacity of the habitat. They maintain a lower rate of birth and death. Hence, the migration of '*K*'-strategists is determined by the environment, nature of habitat, availability of food and ecological settings. In a fragmented landscape, their movement behaviour is more sensitive and they are found to leave their original habitat in search of a suitable habitat. Probably the elephant migration from Dalma to Panchet Forest occurs because of habitat disturbance in the Dalma region.

5.1.1 Habitat Requirements for Elephants

Another important theoretical consideration of our proposed work is the habitat requirements for the elephants. Elephant habitat selection depends on their forage behaviour. Elephants are wide-ranging animals requiring a large extent of continuous stretches of forests for food, shelter and water. The main habitat requirements are listed here:

- A herd of 100 elephants would require a minimum of about 650 km^2 of area.
- The home range size varies according to topography and types of vegetation.
- They spend about 70 % of their time feeding, which varies with seasons.
- Grasses, bamboo, paddy and any kind of vegetation are the main foods.
- Iron, copper, boron, calcium and sodium are the important necessary minerals; they have developed bark-feeding behaviour to obtain them.
- They consume 1.5 % of their body weight in 12 h of feeding.
- They require 100 L water at one time and 225 L of water in a day (Fig. 5.1).

We collected information regarding elephants' preference for habitat selection from the affected villages through a questionnaire survey. Three main factors chosen for habitat selection are food, shelter and source of water. The responses for these three factors indicate that food and undisturbed area are mostly favoured by migrated elephants.

5.2 Historical Perspective of Elephant Migration in the Study Area

In *Bengal District Gazetteers* in 1911, L. S. S. O'Malley recorded that a large number of wild animals including wild boar, spotted deer and porcupine were found to exist in the dense forest of Bankura district. But in southern West Bengal, elephants were abundant in the dense sal forest of Midnapore district and its adjoining areas in the early 1900s (O'Malley 1911a, b). When private forests were transferred to the forest department in 1955, few wild animals, including no resident herd of elephants, could be found anywhere in the forest. They remained rare until the 1980s because of forest degradation and poor areal coverage of coppice sal forests (Malhotra 1995; Palit 1991; Panda 1996).

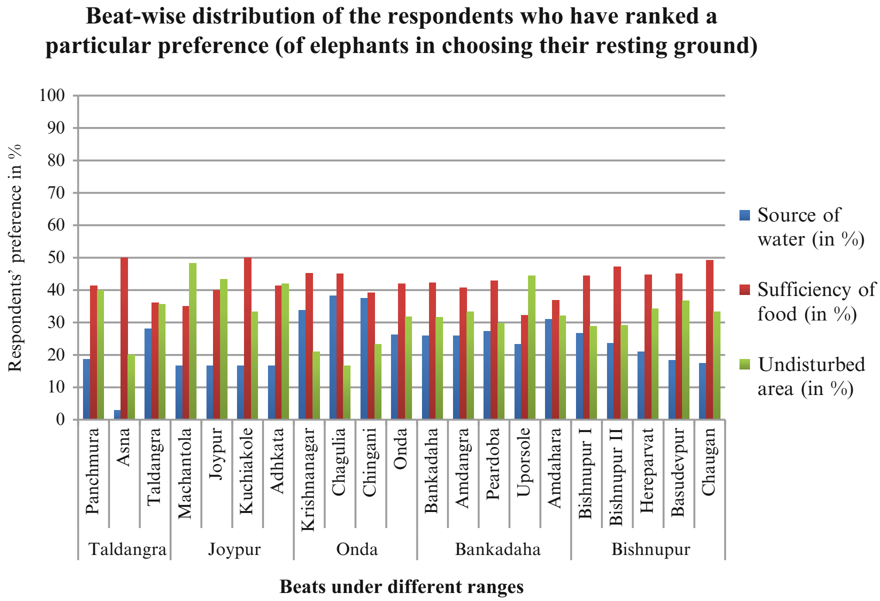


Fig. 5.1 Preferences for habitat selection

A few scattered individuals lived in the hilly region of Ajodhya Pahar and Bandwan range of Purulia district (situated along the western border of the study area). Thus, before the 1980s, there was no incidence of elephant migration in the southern West Bengal area except in the year 1976, when a herd of 42 elephants migrated from the Dalma area to Sindri of the Purulia district and stayed there for 20 days. They caused damage to paddy and killed two people (Shahi 1980).

As of the 1980s, elephant migration became a regular issue. In 1987, a herd of 50 elephants from southern Bihar moved to West Bengal after the wet season and stayed through the winter season (Sukumar 2003). Ironically, the elephants' decision was aided by the success of forestry projects in West Bengal (Datye and Bhagwat 1995) under which large patches of degraded forest were turned into regenerated forest. These forest patches provide corridors for movement and convenient shelter to elephants. In December 1987, the elephants left Dalma Wildlife Sanctuary and moved east by crossing Kangsabati River and entered Lalgarh range of West Medinipur district. Forest in these tracts was regenerated through successful implementation of the Joint Forest Management Programme. The forest patches in these tracts are surrounded by populated villages with paddy and ample water sources. Since 1988, the elephants have ventured into Bishnupur after crossing the Silabati River. As of 1995, the elephant herd had crossed the Dwarakeswar River and moved towards the northern forest division of Bankura district. They extended their territory to Beliatore Forest of Bankura North Division as of 1999. During this time, another new herd entered the study area, crossed the Damodar River to the Burdwan district and returned. Today about 3–4 herds consisting of 15–70 elephants come each year in the Panchet Forest Division (PFD), and a group of elephants now stays throughout the year along with the residential elephants. They frequently move around the forest patches of Bankadaha, Bishnupur, Piardoba and Joypur during their stay in the Panchet Forest area.

5.3 Elephant Migration Trend: Volume and Duration of Stay

Data collected from the Forest Department show that the number of migrated elephants increases day by day. In 1997, a herd of 46 elephants migrated from Dalma Wildlife Sanctuary, but this number increased to 130 or 140 in 2011–2012. After entering the study area, the herd are segregated into smaller groups and roam within the forest patches, raiding crops, damaging mud houses and vegetables and creating serious problem that ultimately end with human–elephant conflict. In 1996, 44 elephants migrated in PFD. That number increased to 145 in 2012, including 110 elephants from Dalma and 35 from Purulia district. Forest department records depict a continuous increase in migrated elephants.

The diagram is self-explanatory. It clearly shows that there is a continuous increase in migrated elephants. The interesting fact is that initially only the Dalma herd invaded the southern West Bengal area, but a recent forest department report states that another herd is coming from Orissa through the Mayurjharna Elephant Reserve area. The physical appearance of this herd is different from that of the Dalma herd. These elephants are short in stature and their body colour is lighter. Their depredation is more harmful than that of the Dalma herd. According to forest department officials, this herd of elephants is more intelligent than the Dalma herd (Figs. 5.2 and 5.3).

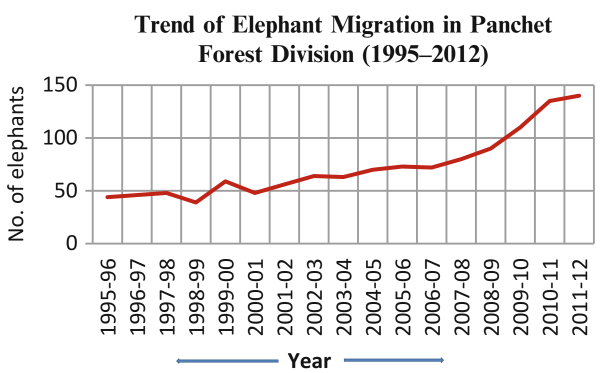


Fig 5.2 Trend of elephant migration in Panchet Forest Division in 1995–2012

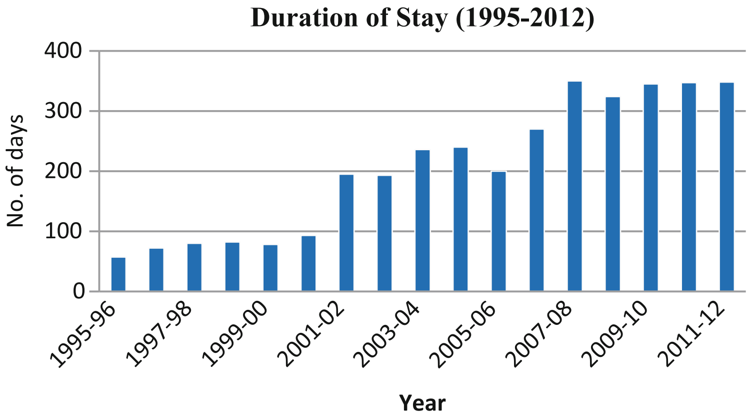


Fig. 5.3 Duration of stay at Panchet Forest Division in 1995–2012

Along with an increasing number of migrated elephants, the duration of stay in the study area has also increased. Initially, these elephants used to come just after the rainy season in late September and early October and return back to Dalma in January. But recently a change regarding the duration of stay was noticed (Kulandeival 2010). The information taken from the forest department reveals that 6–12 residential elephants roamed in the fragmented forest throughout the year 2010. Now one can see a trend of migratory elephant transforming into residential elephant. The number of elephants becoming residential is increasing, while the number of elephants that return back to their original habitat is noticeably decreasing.

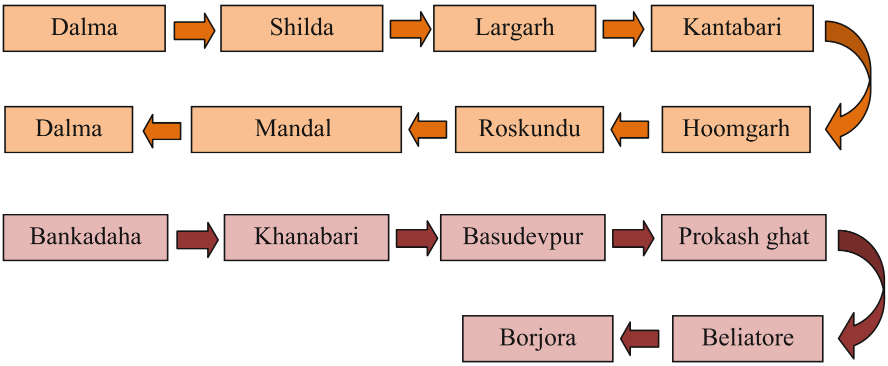
Plate 5.1 Solitary bulls raiding in agricultural field

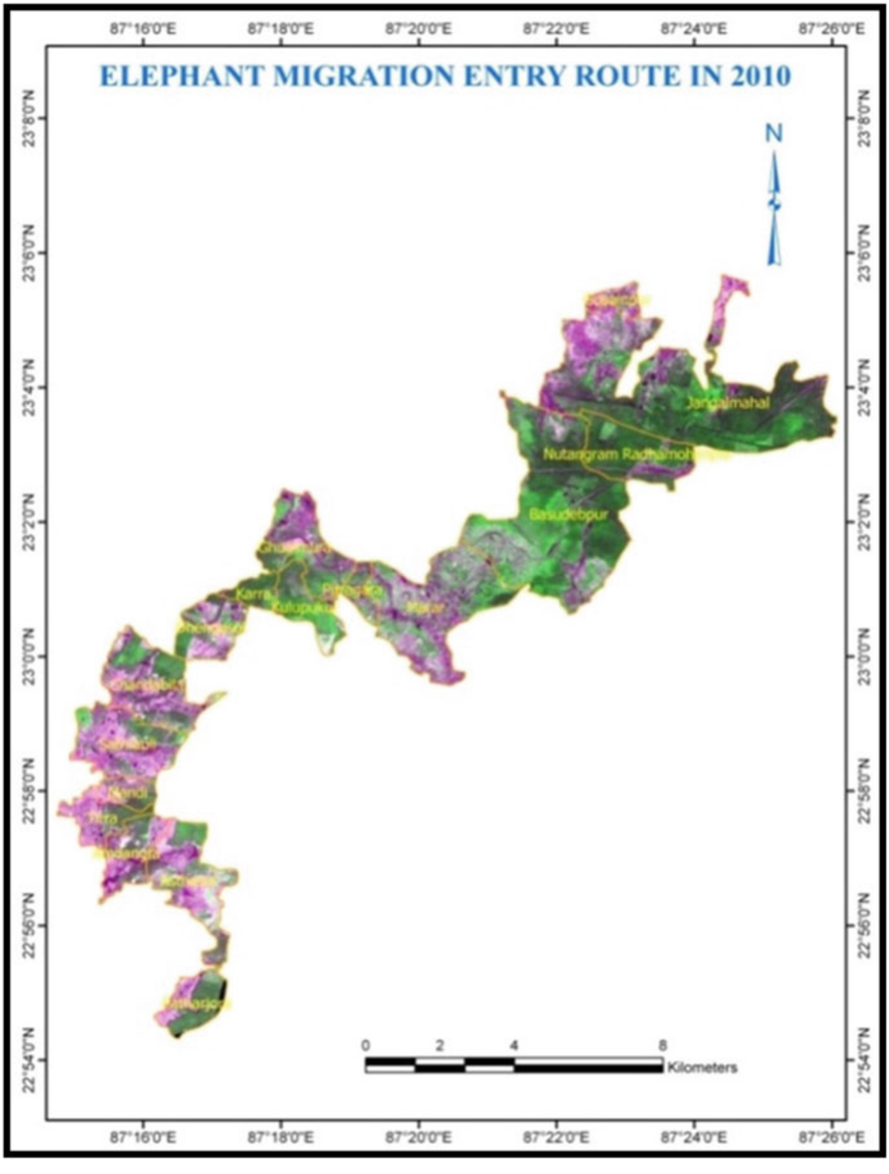
Plate 5.2 People throwing stone at elephant

5.4 Elephant Migration Routes and Their Temporal Shifts

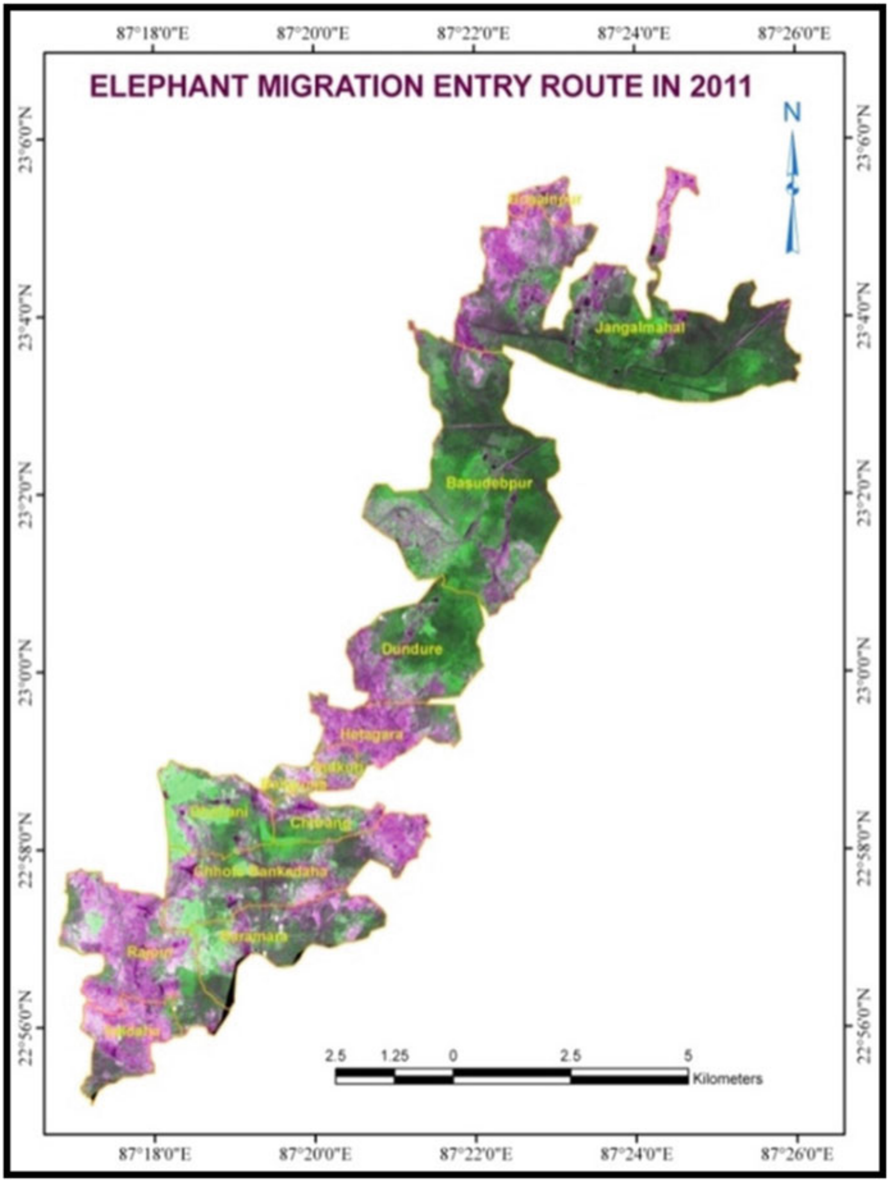
Elephants migrated from Dalma select the fragmented regenerated forest patches as their route or corridor. This corridor can be well identified on open source images. Initially, the herd used to come to Paschim Medinipur district from Dalma and return back to Dalma. But in 1987 they started penetrating different parts of Bankura district. Because of this situation, the government declared a new elephant reserve, Mayurjharna Elephant Reserve, in 2002 consisting of parts of Bankura, Purulia and Paschim Medinipur districts. Now, however, hardly any elephants stay at Mayurjharna. All of the Dalma elephants move to the study area and venture into new areas for food. They cross the Damodar River and enter Burdwan district.

After entering the study area, they bifurcate into different groups. Their entry route generally covers the areas of

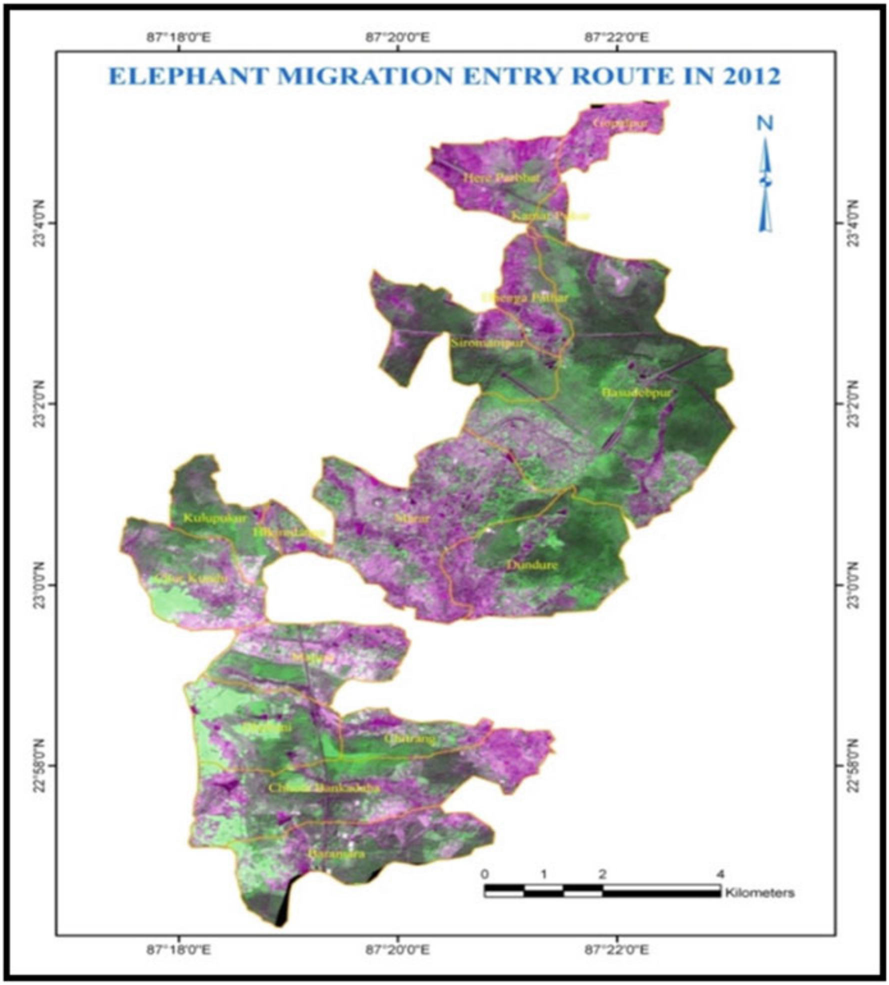




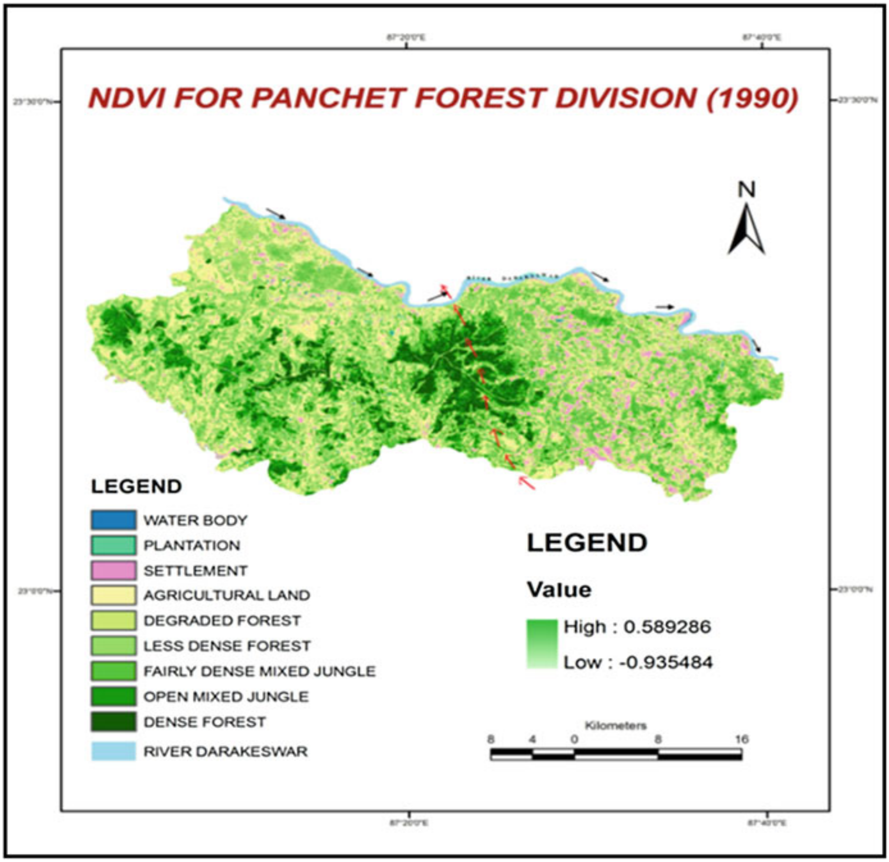
Map 5.1 Elephant migration entry route at Panchet Forest Division, 2010



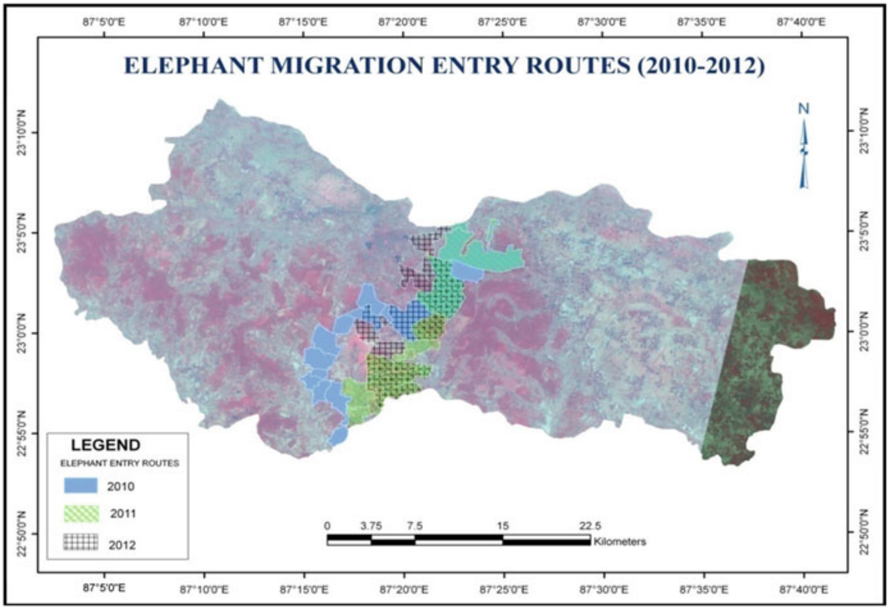
Map 5.2 Elephant migration entry route at Panchet Forest Division, 2011



Map 5.3 Elephant migration entry route at Panchet Forest Division, 2012



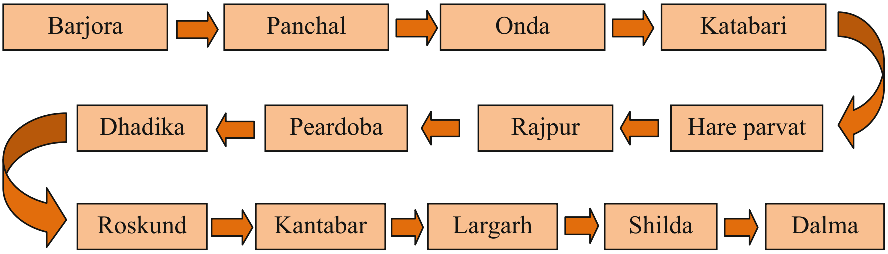
Map 5.4 Normalised differential vegetation index and entry route at Panchet Forest Division, 1990

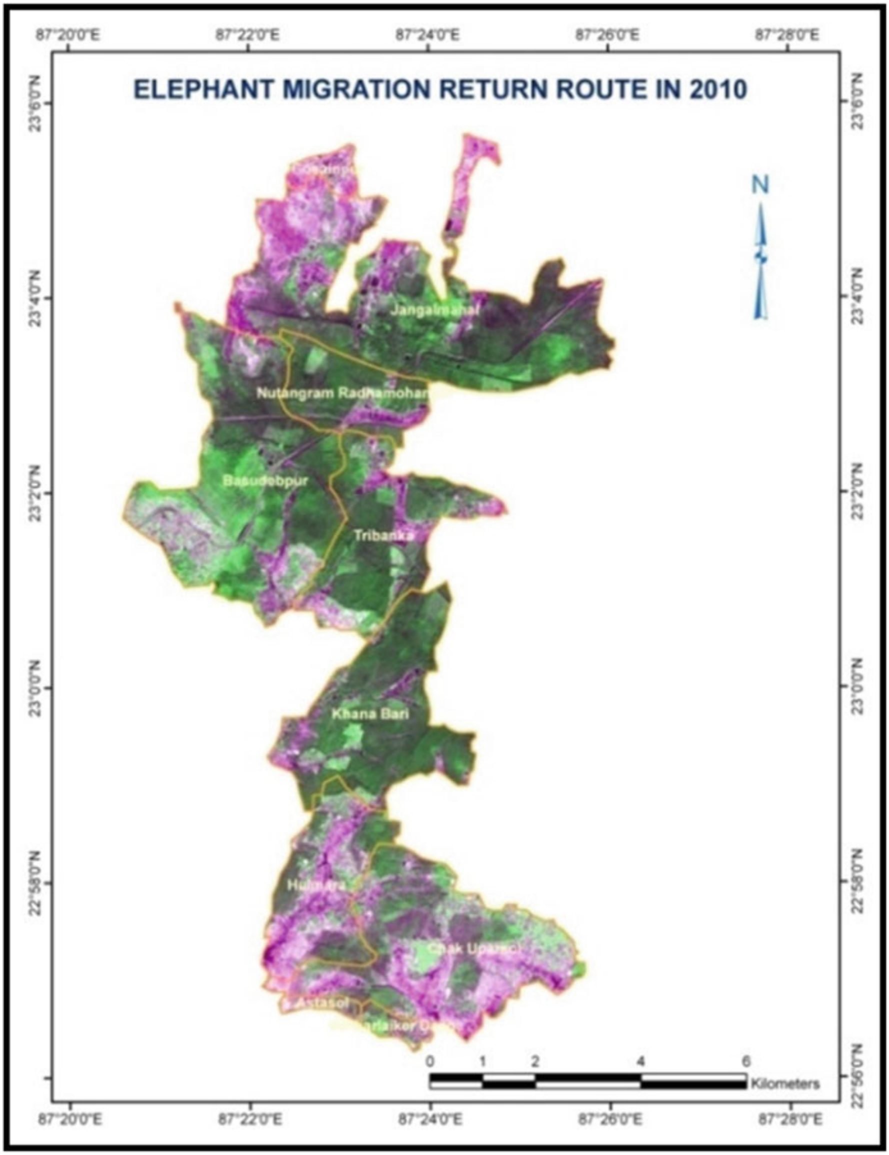


Map 5.5 Shifting entry route in the years 2010–2012

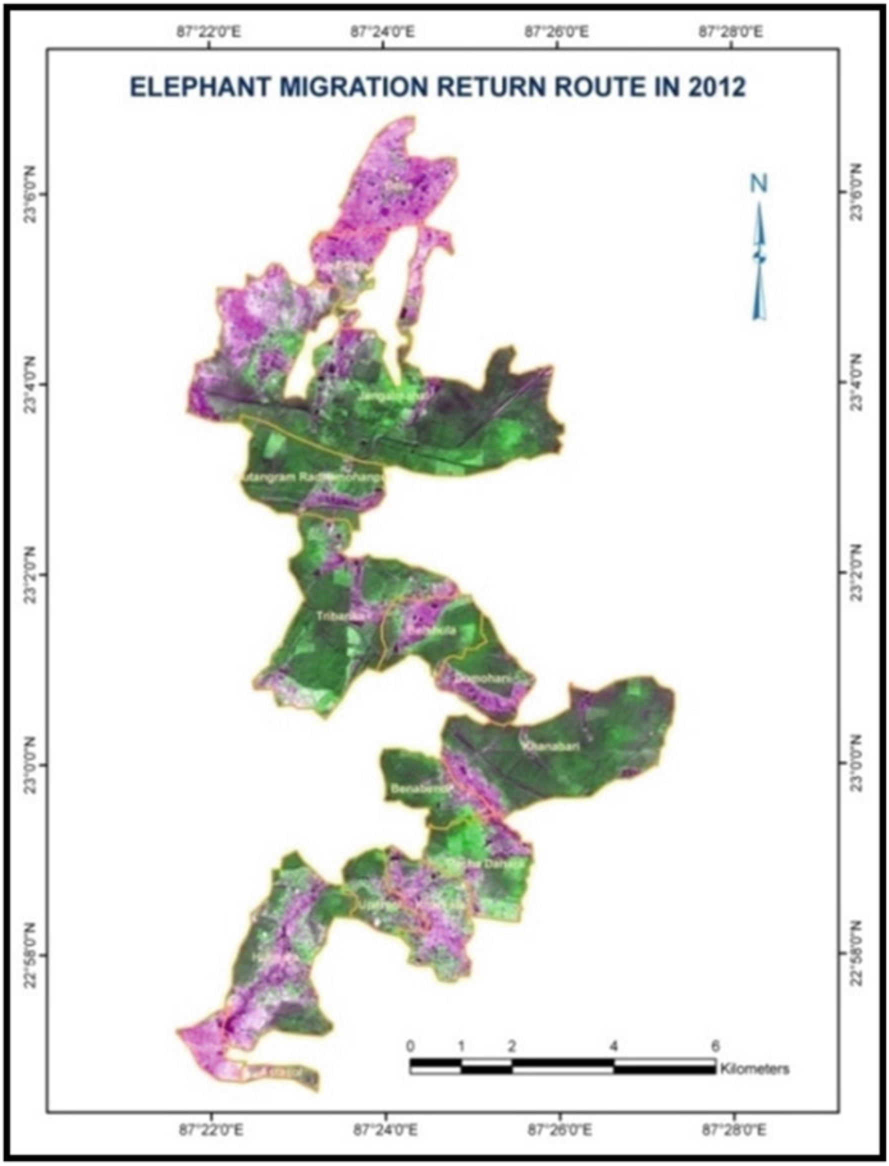
5.4.1 The Common Return Route

The temporal data on elephant migration routes have been taken from the divisional forest office and field survey. The data reveal that the migratory elephants change their routes very frequently. In the study area there has been a shift of routes to the east gradually over the years. The main reason behind this is that the land use in the eastern part is dominated by agriculture. From these crop fields they can easily access food. We have plotted the entry route on the normalised difference vegetation index (NDVI) map of PFD (Map 5.4). The NDVI value is physiologically related to the canopy chlorophyll content, which absorbs the photosynthetically active radiation. The index value shows sensitivity to the degree of canopy chlorophyll content and to the absorbed photosynthetically active radiation. Thus, when there is an increase in plant growth, the value increases, and vice versa. The moment of elephant is positively related to the NDVI value of the forest patch.

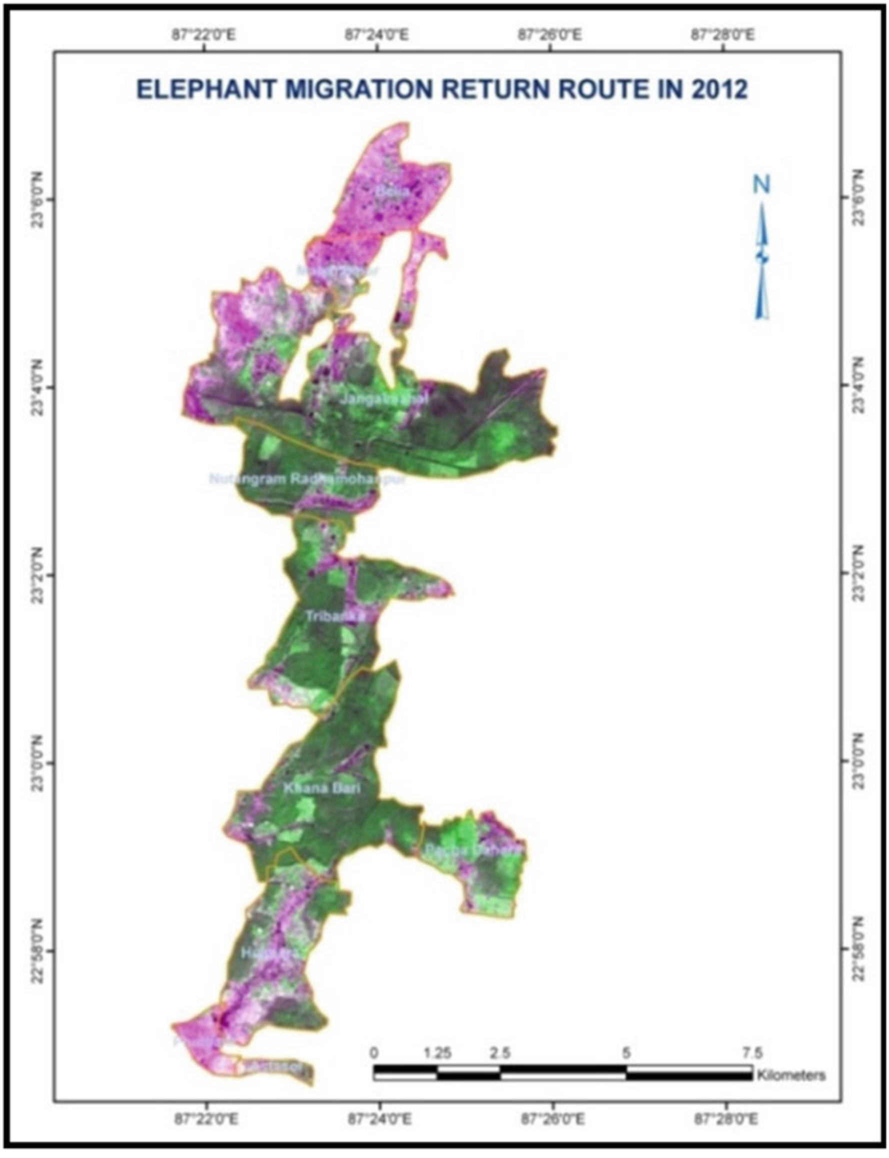




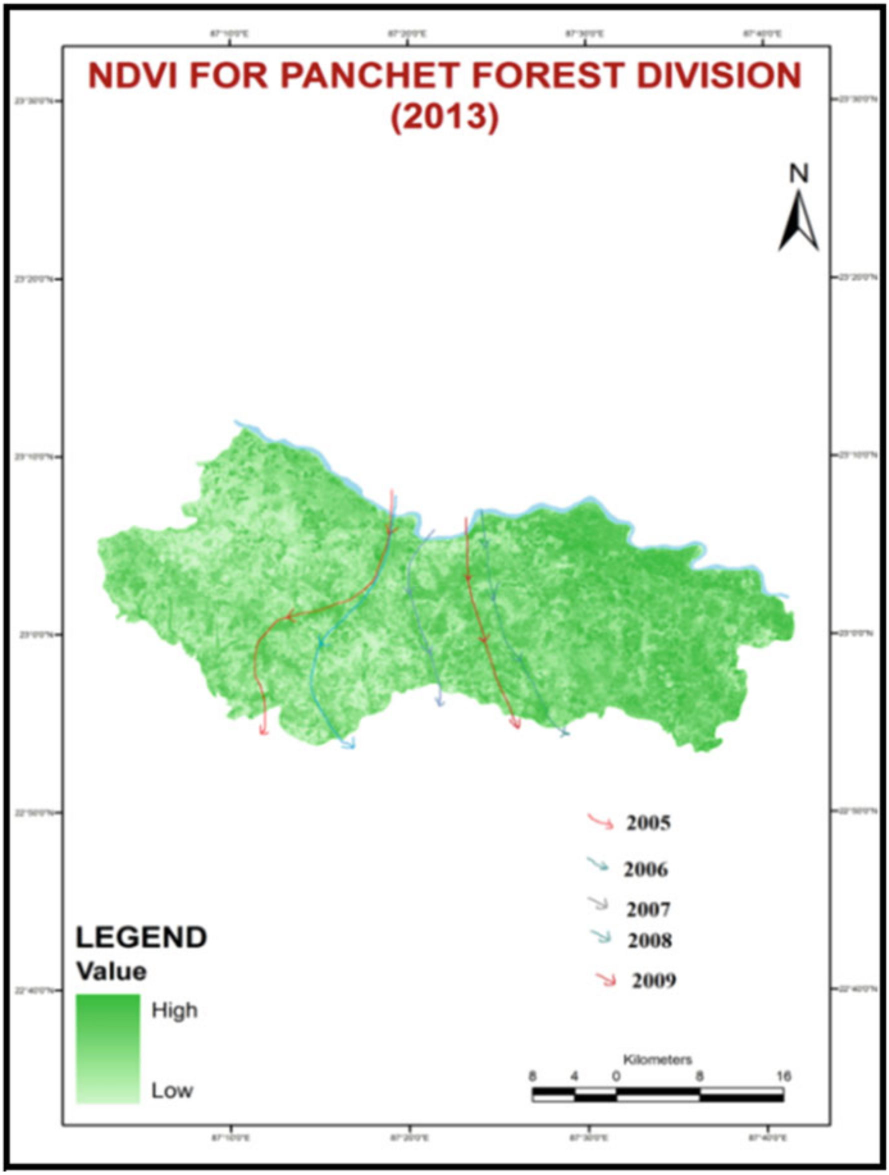
Map 5.6 Elephant migration return route from Panchet Forest Division to Dalma, 2010



Map 5.7 Elephant migration return route from Panchet Forest Division to Dalma, 2011

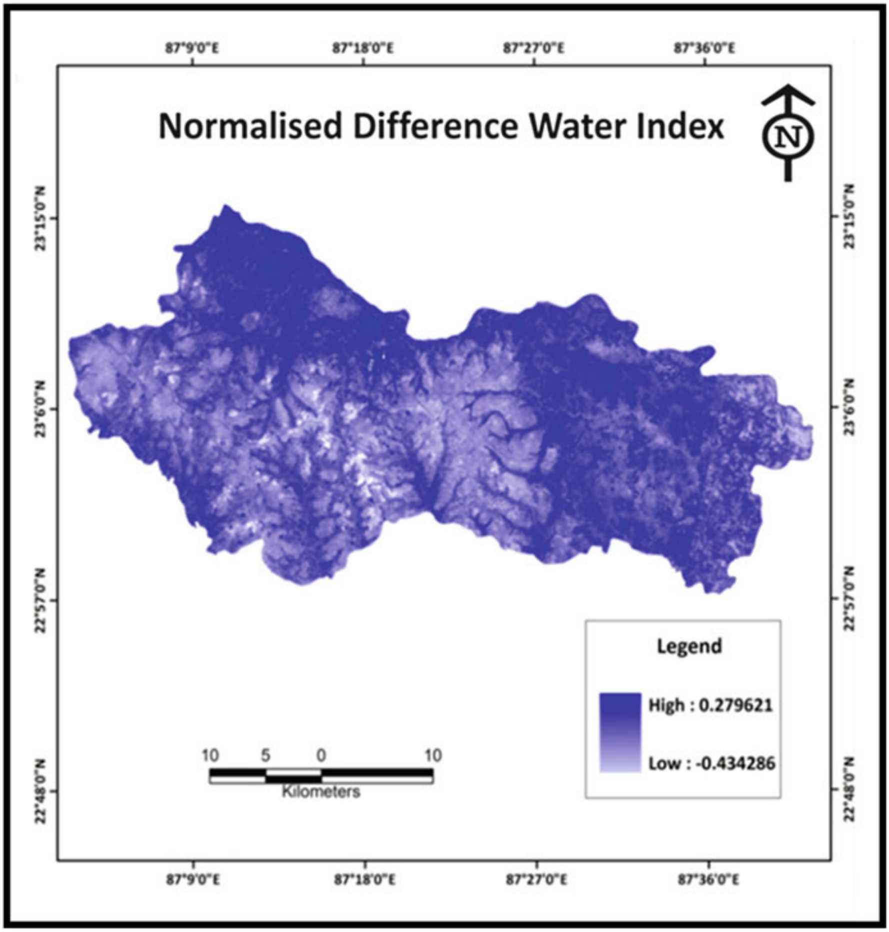


Map 5.8 Elephant migration return route from Panchet Forest Division to Dalma, 2012

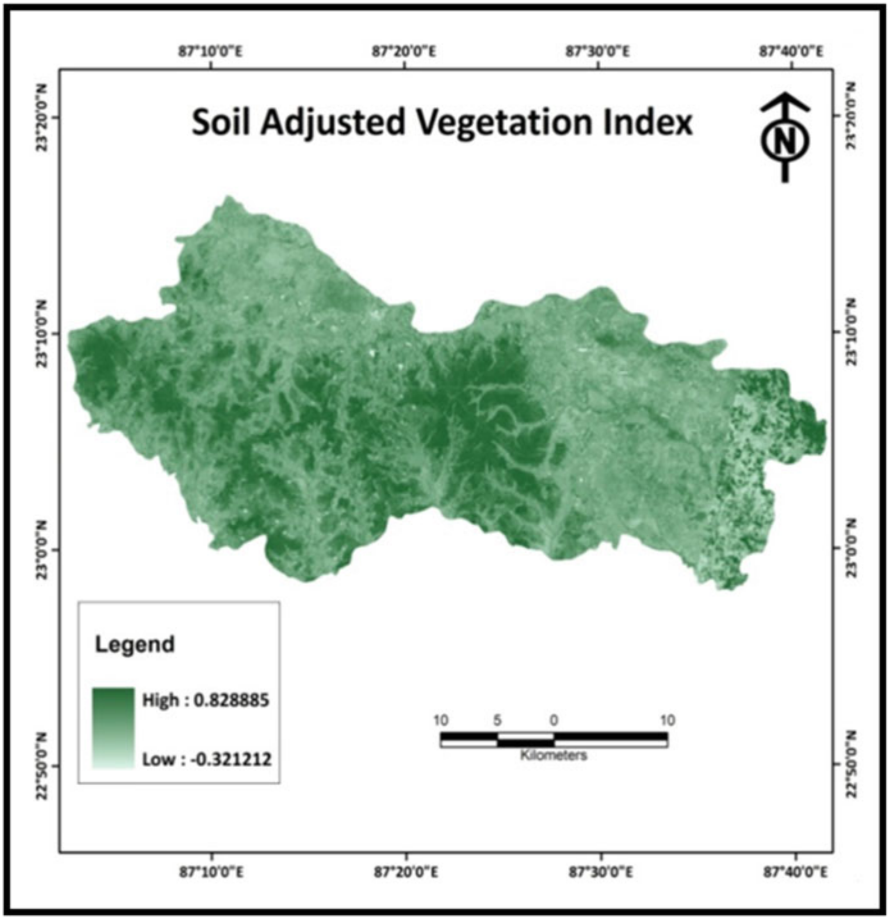


Map 5.9 Elephant migration return route in relation to the normalised difference vegetation index, 2005–2009

Though the entry route is more or less the same in different years, the change occurs in their return routes towards the east, towards the more fertile agricultural lands. It also matches the habitat quality of the region. The normalised difference water index (NDWI) represents the water-sensitive zones and the soil adjusted vegetation index (SAVI), which represents the soil background's influence on the canopy, also reveals the forest quality. Elephants usually follow these tracts for movement.



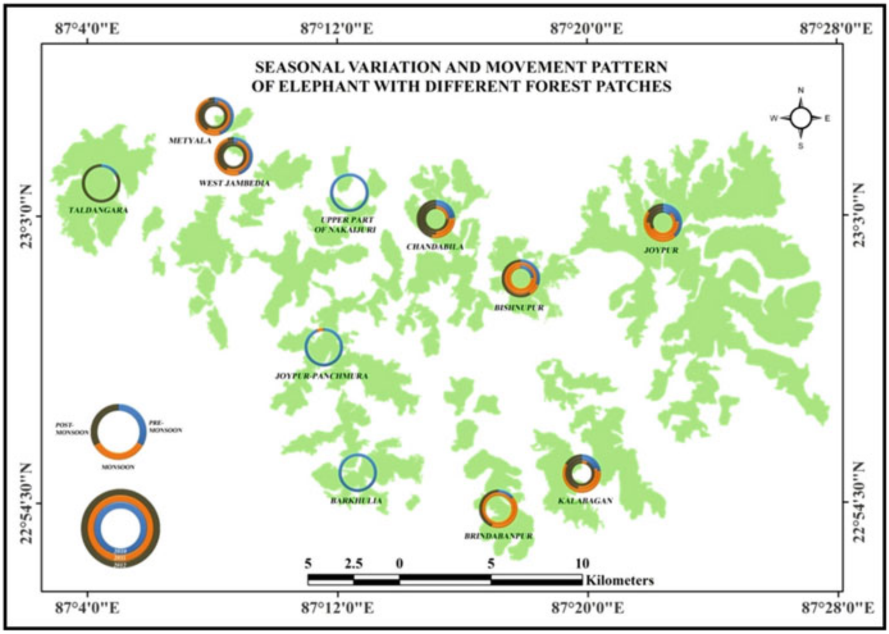
Map 5.10 Normalised difference water index for Panchet Forest Division, 2013



Map 5.11 Soil adjusted vegetation index for Panchet Forest Division, 2013

5.5 Seasonal Dependence on Migration Events

The animals migrate because of biological needs, scarcity of food and change in habitat quality. In our study, the last two factors are significant. Through analysing the information collected through field survey, we could detect a seasonal dependence in elephant migration. During the dry season there are very few elephants in different beats, and they are mainly the residential elephants. Just after the wet season, the number drastically increases. For example, the number of elephants present in different seasons in 2008–2009 harvest year has been shown. It depicts the mass elephant concentration found from August to December, that is, during the harvesting season. Crops and vegetables in the field are easily accessible during this season. Crop raiding incidents are also frequent during this time. After December the elephants tend to return back to their original habitat, and so the number decreases, yet a large number of elephants still remain in the Panchet Forest area.



Map 5.12 Seasonal variation and migration patterns

5.6 Crop Calendar and Appearance of Elephants

The episode of migration exhibits a strong correlation with the crop calendar. As stated earlier, the elephants in the study area are found when paddy crops attain maturity. The appearance of elephants and the cropping pattern have been depicted in Fig. 5.4 and Table 5.1.

Elephant migration and its relationship to seasons and the crop calendar is depicted in the ergograph in Chapter 3 (Fig. 3.6). The climatic condition (rainfall and temperature) is shown along with the migration volume. The diagram shows that elephant migration is clearly linked to crop calendar and crop productions. The ergograph highlights the harvesting, growing and cutting of paddy, wheat, sugarcane, maize, Boro paddy, jute, potato and mustard seeds and vegetables. According to this cropping calendar, the number of elephants in the area also increases or decreases. The harvesting season starts in September–November and ends in January–February. The cutting of mature crops is done mainly in October–December. Raiding of crop fields becomes frequent during this phase. In May–August, sugarcane and jute are harvested. Hence, throughout the year elephants are getting food from alternative sources. Thus, they prefer to stay in newly invaded areas of PFD. Figure 3.6 also shows the relationship between crop calendar and the appearance of elephants.

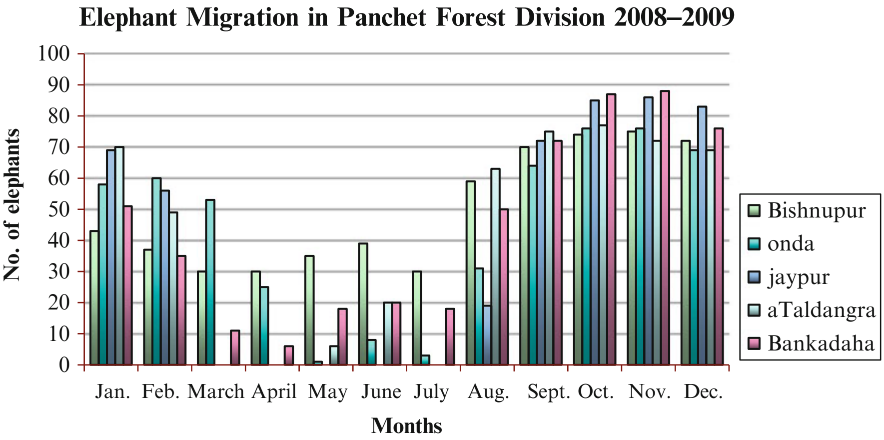


Fig. 5.4 Beat-wise elephant migration in Panchet Forest Division in 2008–2009

Table 5.1 Crop calendar and appearance of elephants

Crop type	Months	Elephant preference
Aman paddy (rice)	July–November	High
Potato	October–December	High
Pumpkin and other vegetables	November–February	High
Oil seeds	November–January	Low
Boro paddy (rice)	December–March	High

5.7 Conversion of Migrated Elephant to Residential Elephant

Originally during the migration to PFD, the number of elephants in a herd varied from 40 to 42. Later, when migration became a regular issue, the number increased. The duration of stay in the Panchet Forest also lengthened in consecutive years. Now a typical tendency is observed regarding the return of these migrated elephants. Each year some elephants stay back in Panchet and the adjoining forested areas of Bankura North, Bankura South and Paschim Medinipur Forest areas. The factors may be isolation of calf from the herd, human attack and isolation from the herd, frequent diversion of migration routes and so forth. But the easy availability of food from agricultural lands, provision for shelter in the forest patches, source of water and undisturbed environment are equally important factors. Thus, the number of residential elephants increased in the study area. As of the 2009–2010 harvest, there were 30 elephants in these areas while there were 3 or 4 in 1990. As a result, these elephants cause damage to crops, properties and human lives throughout the year. Previously the calf or old tusker who was isolated or rejected from the herd had to stay. But recently the sub-adult male and female elephants have become residential. This conversion of migrated to residential elephant has raised conflict between residential and migrated elephants. The villager's opinion is that "when a Dalma herd enters into a residential elephant's territory, the residential elephants starts to move away from those areas and creates much damage". The residential elephants become more violent and dangerous to the villagers (Kulandeival 2010). It is observed that a single bull and tuskers are more dangerous than the herd (Fig. 5.5).

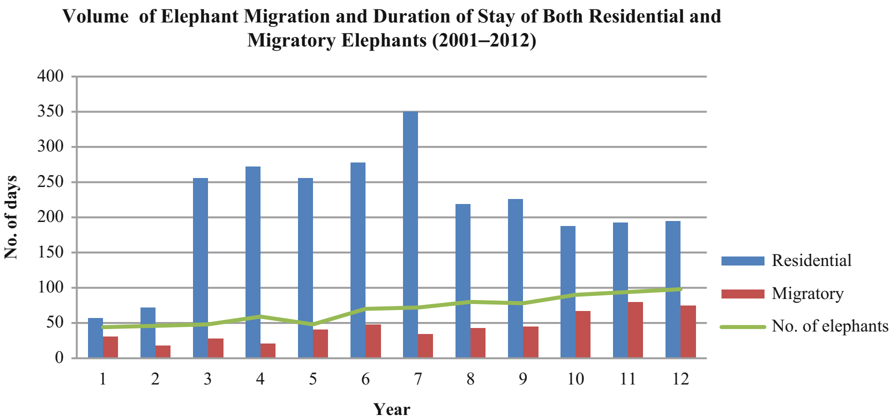


Fig. 5.5 Volumes of migration and duration of stay of residential and migratory elephants, 2001–2012

Chapter 6
Characterising the Human–Elephant Conflict Zone

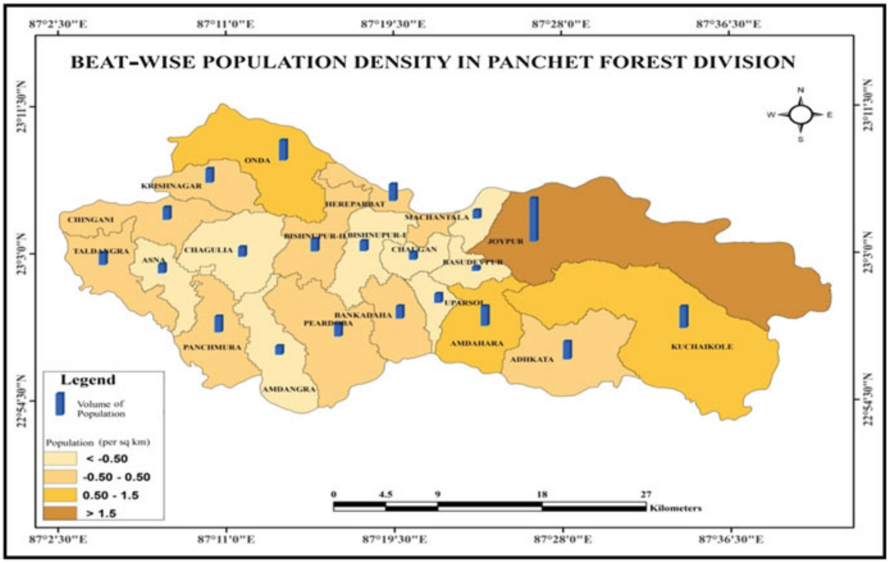
N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_6

Abstract This chapter discusses the characterisation of the human–elephant conflict zone. The demographics of the study area is represented by a rural, agriculture-based population. About 92.63 % of the total population are rural; 61.5 % of the workers are cultivators; 88.1 % of the population are agricultural labourers; 31.7 % of the populace belong to Scheduled Caste and 7.2 % to Scheduled Tribe (Bureau of Applied Economics & Statistics 2005). As evident from these statistics, the livelihood in such a zone is mainly based on agriculture. Apart from agriculture, the collection of non-timber forest products is the major source of income in forest fringe villages. The land use pattern is dominated by three major uses: agriculture, settled area and forest area. A change detection study covering the past 40 years showed a great change in the land use pattern. The total forest area has increased, but the forest area has fragmented and is covered by monospecies. Agricultural land has gradually expanded. Field observation revealed that paddy and vegetables are the main agricultural products. These changes in the land use pattern attract elephants. As a result, human–elephant conflict has become a crucial issue because of its associated loss of life, property and agricultural product. At the same time, local inhabitants use different protective measures at the community level to deal with the issue. This chapter uses a variety of diagrams to represent these facts.

Keywords Demographic character • Occupation structure • Land use pattern

6.1 Introduction

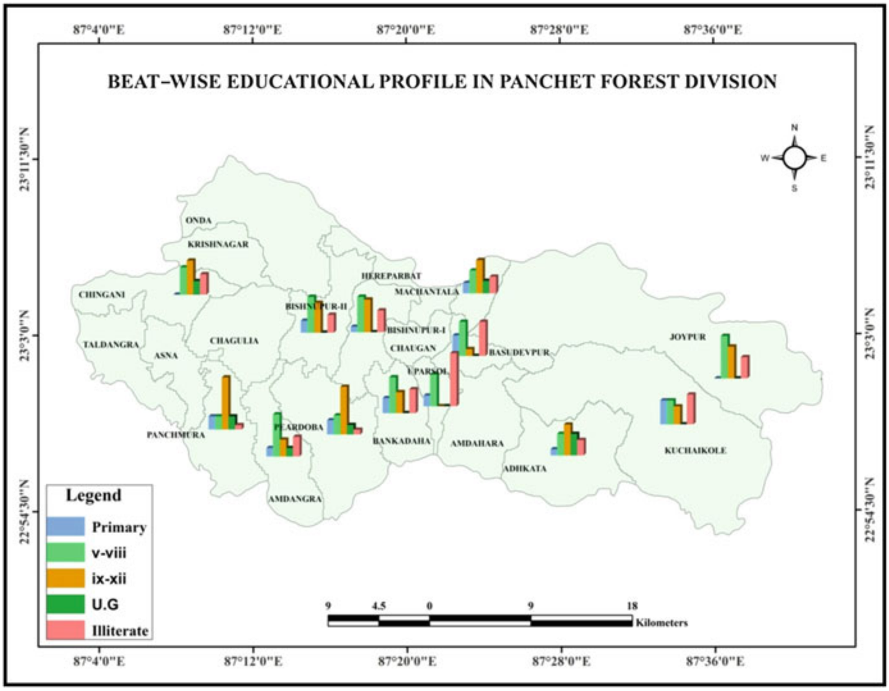
Chapter 5 presented a detailed analysis of the background matrix and ecological and environmental characteristics of the study area. However, the issues of human–elephant conflict chiefly comprise two major constituents: elephants and humans. In Chap. 3, we discussed different aspects of the elephant and its behaviour regarding the selection of habitat, its food preference, and its forage and migration characteristics. Moreover, we focussed on the elephant's changing behaviour in terms of food habits and selection of habitat. Yet the people of the study area, their demographics and their socio-economic characteristics are equally important to consider while we are characterising the human–elephant conflict zone. This chapter considers various socio-demographic aspects of the population.



Map 6.1 Beat-wise population density in Panchet Forest Division

6.2 Demographic Characteristics

The study area has a rural, agriculture-based population. About 92.63 % of the population are rural; 61.5 % of the workers are cultivators and 88.1 % of the population are agricultural labourers; 31.7 % of the residents belong to Scheduled Caste and 7.2 % to Scheduled Tribe (Bureau of Applied Economics & Statistics 2005). However, the forest fringe villages are mostly inhabited by very poor Scheduled Tribe residents. The population density varies in different forest beats. Typically, it is high in the villages located near urban centres and in the eastern part of the study area and is low in the western part. These fluctuations in population density are related to the fertility of soil; areas in the east, where agriculture is mostly practiced, are more densely populated, whereas areas in the west, which is mostly covered by natural forests, are less densely settled. People work mostly in small sectors, in cottage industries or as wage labourers in agriculture. Primary data collected from field surveys reveal a low level of formal education in the study area (Map 6.2).



Map 6.2 Beat-wise education profile in Panchet Forest Division

6.3 Livelihood Pattern of Forest Fringe Dwellers

Local people earn their livelihood mainly through agriculture-based activities. Most of the land holdings are small in size. The average size of a holding is 1–4 bighas (1621.34–6485.38 m^2). The small holdings and homestead gardens are the main source of staple foods for the poor, marginalised villagers. A large proportion of the population in forest fringe villages depends on the forest for their daily livelihood. Land marginalisation is a major factor for their dependence on the forest and forest resource. People collect fuelwood and many non-timber forest products (NTFPs) from the forest. On the whole, the population is rural and the main occupations are cultivator and agricultural labourer (Fig. 6.1).

6.4 Land Use Pattern

After analysing the land use map prepared from Landsat TM 2006 and 2013 images, we observed that the land use under different categories has changed (see Maps 2.13 and 2.14). In both cases, we found that the land use pattern is dominated by

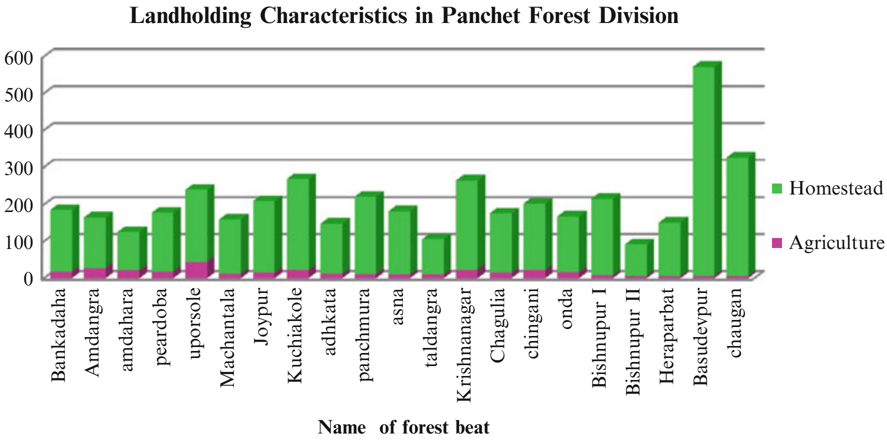


Fig 6.1 Landholding characteristics in Panchet Forest Division

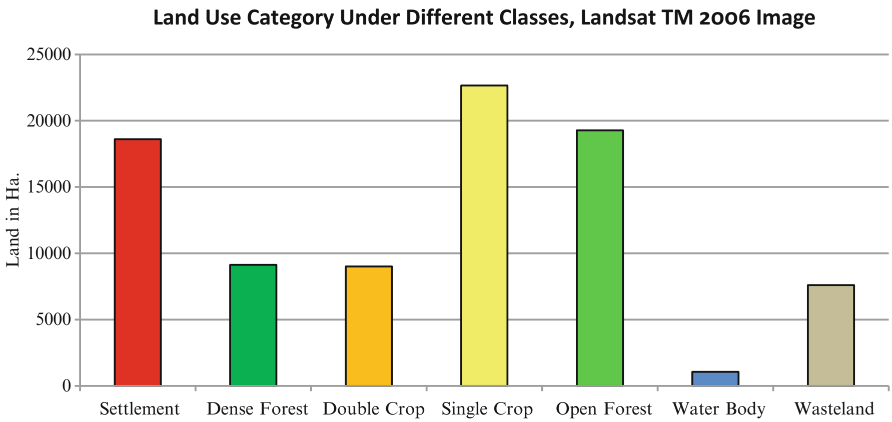


Fig. 6.2 Land use category under different classes

agricultural land. Figure 6.1 was prepared from the land use map of 2006. It clearly depicts that the area is dominated by single- and double-crop agriculture, followed in land use percentage by settlement and open forest. Dense forest has relatively less area and is also fragmented (Fig. 6.2).

6.4.1 Agriculture

Agriculture is the dominant land use in the study area. The study area can be distinctly categorised into two parts, west and east. The western part, with its lateritic and red soil, is covered with fragmented forests, sparse vegetation, laterite outcrops, wastelands and so on. Most of the agricultural lands are single-cropped. In contrast, the eastern part of the study area is covered by alluvium deposits from the Dwarakeswar River, a tributary of the Damodar River. This area is dominated by agriculture. Various crops are cultivated during Kharif (summer crops are grown using monsoon rain) and Rabi (winter crop) seasons. Agricultural products include paddy (aus, aman and boro), wheat, potato, maize, pulses, oilseeds and different vegetables (e.g., cucumber, pumpkin, gourd, bitter gourd, cauliflower, eggplant, cabbage, chilli, tomato). Other than paddy, vegetables and horticultural crops such as mango, banana, papaya, guava and jackfruit are grown in homestead areas or in gardens.

Plate 6.1 Agricultural diversity's in study area

6.4.2 Settlement

The major consequence of human–elephant conflict is found in the form of either crop depredation or damage to property. Damage to household properties and equipment, domestic livestock and so on is very common in the area. The entire elephant habitat of Panchet Forest Division (PFD) is surrounded by human settlements. The settlements are mainly rural in nature, and there are few urban growths. In some cases settlements are situated within the forest area. Conversion of forest land into agricultural land and encroachment of settlement in the forest fringe areas are very common occurrences in this area. Poultry farm establishments within the forest gaps are also found. Quarrying of *morrum* (laterite nodules) from badlands near the forested area in the Joypur range is a typical modification of the forest landscape.

Houses are mainly *kutcha* (mud brick) houses with a thatched roof or semi-*pucca* houses with corrugated sheets of tin and asbestos. These houses are easily damaged by elephant attack. Sometimes crops are stored in a granary or dumped in the houses, which are also attacked by elephants (Anandabazar Patrika 2014a).

In the tribal villages, country liquor is one of the main attractions for elephants. They prefer fruits, especially banana and jackfruits. Thus, they consume these kinds of trees or any edible things that are present along their migration route.

Plate 6.2 Hut damage due to elephant attack

6.5 Human Appropriation of Forest Ecosystem Resources

As reported in the *Bengal District Gazetteer* of Bankura (O'Malley, 1908), the study area was once under 'Jangalmahal' districts (Regulation XVIII of 1805). It played a significant role in revenue collection by the East India Company during that period. The main resource, forest, was used irrationally in the construction of a railway line that passed through this area (Joint Forest Management Programme was initiated during 1980). Precious sal and teak forests were cleared up. This mass destruction, establishment of settlement and expansion of agricultural land caused degradation of the natural indigenous forest cover. In addition, a majority of the forest fringe dwellers and tribal population depend on forests for their fuelwood, fodder, small timber for making agricultural implements and house construction and even food and medicine, which are produced from NTFPs. Selling fuelwood and NTFPs is an important source of income for many of these marginalised people. The ecological and socio-economic value of the forest is enormous to these societies. Thus, the government has taken initiatives to combat forest degradation and to increase the productivity of forest resources. A programme called joint forest management (JFM) was adopted to protect and regenerate degraded forests with the help of community involvement through forest protection committees (FPCs) (Table 6.1).

6.5.1 Joint Forest Management and Forest Protection Committees in Panchet Forest Division

The JFM programme was launched in the 1980s. A large area of damaged and degraded forest was regenerated after this programme's successful implementation. A remarkable change in green cover and biodiversity was evident by the end of the decade. The green cover increased by 29 % of the total land area. The quality of the forest also improved, with successful regeneration of coppice sal species. Sal-associated species such as piasal, mohua, bahara, haritaki, pial and haldu and wild jackfruits were also planted in the regenerated forest. The concept of a monoculture system was replaced with the cultivation of the most-suited local species. It supports

Table 6.1 Number of forest protection committees in the study area (2006–2012)

Year	No. of FPCs	Area protected (ha)	Category					
			Male	Female	Scheduled caste	Scheduled tribe	Other	Total
2006–2007	227	28,119.55	26,679	1550	10,757	4653	12,819	28,229
2007–2008	227	28,119.55	26,726	1550	10,757	4653	12,866	28,276
2008–2009	227	28,119.55	26,726	1550	10,757	4653	12,866	28,276
2009–2010	231	28,382.67	27,424	1590	11,040	4712	13,262	29,014
2011–2012	231	28,466.00	27,328	1562	11,033	4674	13,183	28,890

State Forest Report, 2009–2010

the wildlife and forest-based tribal community. As of 2009–2010 in the Panchet area, 28,382.67 ha of land (West Bengal Forest Report 2009–2010) had been protected under the JFM programme.

Strip plantation outside the forest land has also been initiated to decrease pressure on the forest. Fast-growing species like acacia and akashmoni are planted in the barren areas and wastelands in an effort to supply fuelwood for the village people.

The typical JFM strategy is to rejuvenate forest through the direct and indirect involvement of the local communities. Under JFM, the forest department and the village community enter into an agreement to jointly protect and manage forest land and adjoining areas. The village community is represented by a specified committee known as the FPC. Members of FPCs get permission to collect NTFPs and enjoy a share in timber felling in return for their responsibility in protecting against illegal felling, forest fire, illicit harvesting and grazing. As mentioned earlier, per the 2009–2010 Forest Report of West Bengal, there were 231 FPCs protecting 28,382.67 ha of forest in PFD. This is one of the significant causes of forest regeneration and quality growth of forest in PFD.

Plate 6.3 Plantations at Bakhadaha, Amdangra, and Joypur Range. *Source*: www.bankuraforest.nic.in

Table 6.2 Collection of non-timber forest products in Panchet Forest Division

NTFPs	Collection period and duration	Local price (Rs)	Average daily collection (kg/ bundle/numbers)	Average annual income (Rs)
Sal leaves	9 months	70 per thousand	1000 leaves	18,900
Pial fruit	29 days	45 per kg	0.5 kg	652
Mahua flower	(May) 30 days	20 per kg	20 kg	600
Mahua fruit	30 days	15 per kg	4 kg	360
Bahera fruit	30 days (March–April)	5 per kg	1 kg	150
Haritaki fruit	15 days	30 per kg	1.5 kg	675
Mushroom (Kurkure)	(March–April)	75 per kg	2 kg	3000
Mushroom (Karam)	45 days (Aug–Sept)	120 per kg	1 kg	5400
Ban pui	20 days (rainy climate)	4 per bundle	5 bundles	400
Ban kundri	15 days	40 per kg	3 kg	900
Satamul (asparagus)	15 days	50 per kg	3 kg	2250
Kalmegh	30 days (July–Sept)	25 per kg	0.5 kg	375
Alu (Bamla)	110 days	10 per kg	1.5 kg	1650
Kendu leaves	April–May (30 days)	15 per 100 pieces	1000 per man	3000
Bhurru (*Gardenia gummiferia*) fruit	20 days	20 per kg	1 kg	400
Ban khejur (dates)	15 days	20 per kg	3 kg	700

Plate 6.4 Forest as a resource base

6.5.2 *Use of NTFPs*

Local people are largely dependent on forests for NTFPs and small timbers. People generally collect wood and small timbers for fuel or to earn their livelihood. Tables 6.2 and 6.3 summarise the degree of locals' dependence on forest resources.

Table 6.3 Utilisation of forest and forest products in different forms

Local name	Botanical name	Log	Leaf	Fruit	Root	Flower	Bark	Seed	Stem	Extract
Akanda	*Calotropis gigantea*	√			√				√	
Tulsi	*Ocimum sanctum*	√			√		√		√	√
Datura	*Datura stramonium*	√	√	√						
Kul	*Zizyphus xylopyra*	√	√							√
Nishinda	*Vitex negundo*	√								
Lajjabati	*Mimosa pudica*	√		√				√		
Sialkanta	*Argemone mexicana*			√			√		√	
Satamuli	*Asparagus racemosus*			√						
Alkushi	*Mucuna prurita*						√			
Kulekhara	*Asteracantha longifolia*	√	√				√			
Thankuni	*Centella asiatica*	√								√
Ghritkumari	*Aloe vera*	√						√		
Harjora	*Vitis quadrangularis*							√		
Kalmegh	*Andrographic pariculata*	√								√
Kurchi	*Hylarhena antidyshterica*		√		√	√				
Susni	*Marsilea minuta*	√								
Basak	*Adhatoda basika*	√			√	√				√
Haritaki	*Terminalia chebula*		√							
Chhatim	*Alstonia scholaris*					√				
Bahera	*Terminalia bellirica*		√							

6.6 Elephant Attacks on Humans

All recent forest department reports reveal that cases of persons killed or injured by wild animals usually involve elephants. Data collected from the forest department indicate that elephant attack on humans in South Bengal has become a serious problem. Between 1976–1986, 13 people were killed by elephants in southern West Bengal (Singh et al. 2002). The death toll increases in the harvesting season, when elephants raid the crop fields (Fig. 6.3).

In Panchet, two seasons—September to December and January to April—are important in the context of human–elephant conflict. Another remarkable fact is that most manslaughter and human injury cases are caused by a single bull, or the loners. Instances of human killing happen in the villages when there is no crop in the field. Forest department death statistics show that the numbers of both injuries and deaths are currently increasing. Initially, cases of human injuries and deaths were seldom mentioned in the forest report, in newspapers or in other print media. However, since 2007, the number of cases has increased at an alarming rate. In general, human victims are injured or killed when they enter an elephant habitat, encroach the habitat corridors or are defending their crop from elephants.

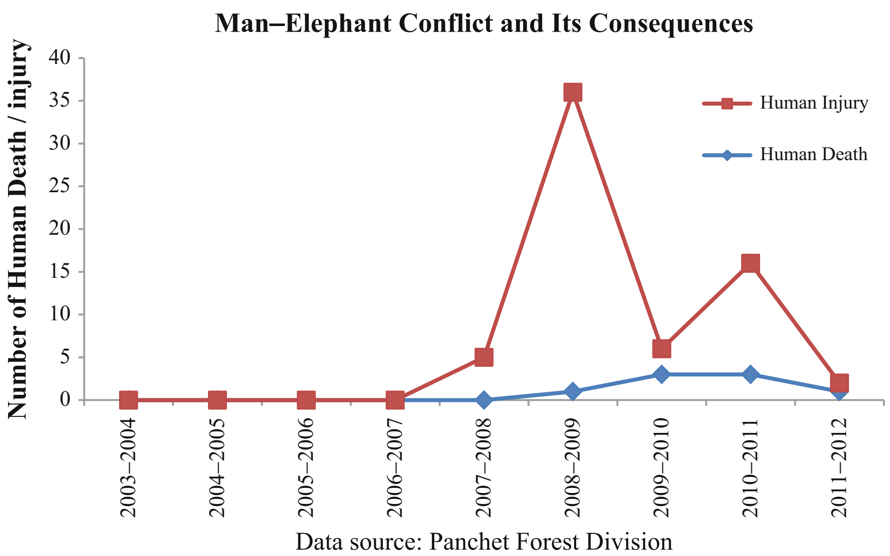


Fig. 6.3 Human–elephant conflict and its consequences, 2003–2012

6.7 Damage to Life and Assets

To assess the damage profile of the study area, we collected both secondary and primary information. From the primary information collected through field surveys in randomly selected villages, we found that as the number of elephants increased over time, the number of deaths and injuries gradually increased. The number of huts damaged and incidence of crop field destruction also rose. After paddy, the most important agricultural products are vegetables such as cucumber, potato, cabbage, cauliflower, guava and pumpkin. These crops are largely affected by elephant depredation. The land use pattern of this area entails the fact that along with agricultural lands, homesteads are also used for cultivation of vegetables. Different fruit plants, for example, mango and jackfruit, are grown in gardens or orchards, and they attract elephants. Thus, elephants enter the settled areas and destroy the standing crop or vegetables; 60 % of the damaged crops and vegetable are spoiled by elephant trampling (Fig. 6.4).

Though elephants attack the greenery in the homestead or paddy dumped in the houses, they also prefer '*hariya*', a country liquor made of parched rice and mahua fruits. The incidence of attack and its frequency vary from season to season; even a diurnal difference in attack frequency can be tracked. From our questionnaire survey, we collected information on the time of attack. From the villagers' responses, we found that elephants attack mostly in the evening or at night (Fig. 6.5).

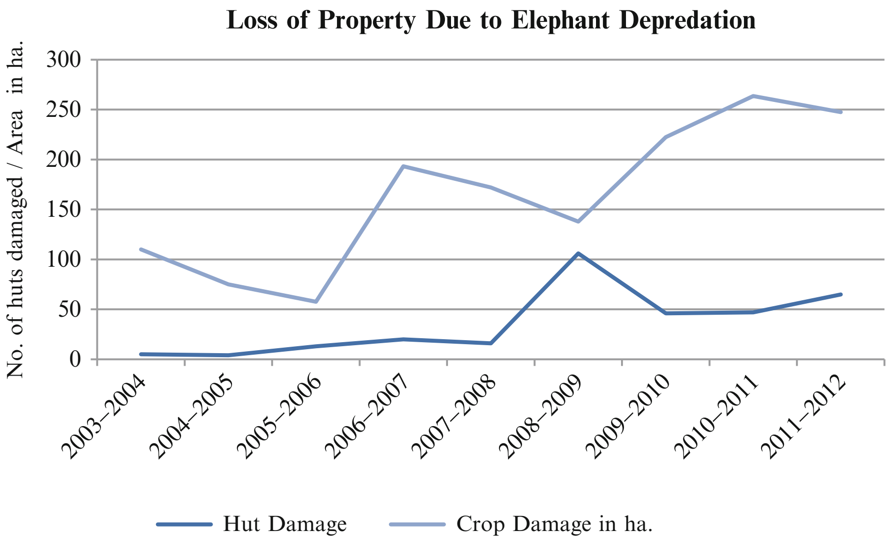


Fig. 6.4 Loss of property due to elephant depredation, 2003–2012

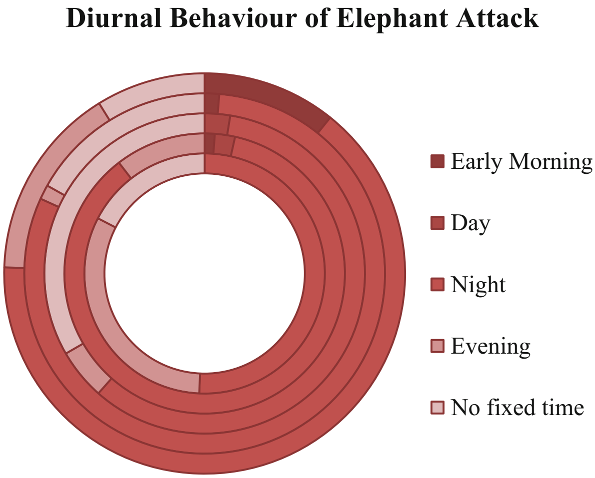


Fig. 6.5 Diurnal behaviour of elephant attack

6.8 Human Resistance Towards Elephants

Human–elephant conflict is a complex and pervasive problem in the affected areas. People and elephants share the same habitat and compete for the same resources. People in various landscapes have their own ways to combat this situation. In general, the local communities adopt fruitful measures to deal with the conflict. Locally adopted methods quickly and effectively reduce elephant damage. The community in the affected areas of PFD have adopted some simple and low-cost techniques to resist elephant attack. People generally hit drums or tins and use firecrackers, fireballs, torches and so on to drive elephants away from the area. The forest departments usually supply firecrackers and/or kerosene, but such implements are insufficient. The use of firecrackers, fireballs and/or torches is normally found in villages located near the forest beat or range offices. In remote villages, the supply is irregular as well as meagre. Hence, people in remote villages use stones and bow and arrow. Throwing stones and shooting arrows injure elephants, but not fatally. The injured elephants become more aggressive, attack humans and trample crops, causing severe damage to lives and properties. The forest department often redirects the movement of elephants through koonkie elephants or the 'hullah party'. In some cases villagers place fences with the help of the forest department, which has set electric fences or trenches along the forest margins. However, community involvement seems to be more effective than other methods in this area.

Plate 6.5 Herd elephant raiding crops

Chapter 7
Behavioural Study

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_7

Abstract This chapter addresses behavioural aspects of both elephants and humans in the context of increased conflict. A behavioural study is an important means of understanding the habitat–animal relationship. It gives ideas about the distribution, abundance and needs of the animal. Behavioural analysis reveals how animals actively use their environment. A behavioural study entails three general categories—structure, consequence and spatial relation. These three aspects have been covered. A perception survey technique was applied, supported by a pre-structured questionnaire to learn people's attitude towards elephants. Random samples were collected from affected villages. The result revealed some crucial facts. With these facts, theme maps were prepared for visualisation. Parallel emphasis was also given to the changing behaviour of elephants. Elephant behaviour should be considered before implementing any policy or strategy. Analysis of elephant behaviour is crucial in a human-modified landscape. Elephants face continuous pressure because forest personnel and local peoples are chasing them away. As a result, their behaviour has changed drastically. Specifically, the solitary bull, isolated from the herd, is more aggressive towards humans. Moreover, in our behavioural analysis we incorporated the behaviour of local peoples as well as that of forest department personnel, because their behaviour has created a problematic situation for the successful management of human–elephant conflict.

Keywords Behavioural study • Perception survey • Changing behaviour

7.1 Introduction

Behavioural study is an important means of understanding a habitat–animal relationship. It gives ideas about the distribution, abundance and needs of the animal. Behavioural analysis reveals how animals actively use their environment (Morrison et al. 2006). Generally, a behavioural study entails three general categories—structure, consequence and spatial relation (Martin and Bateson 1993). Structure describes the appearance, physical form or temporal pattern of behaviour in terms of movement. Consequence means the impact of the animals on a specific habitat or niche where they live, while spatial relation describes behaviour in terms of the animals' spatial proximity to features of the environment, including other animals.

Animals perform multifarious activities during a day. They remain engaged in grazing, browsing, foraging, feeding, sleeping and many more activities. These behaviours are controlled largely by the natural environmental condition and habitat in which they live. Anthropogenic factors in the form of habitat modification or transformation and presence of humans within the habitats also have impacts on animal behaviour. Such has been seen in the Panchet Forest area, where migrated elephants move frequently from one forest patch to another in search of food and face anthropogenic intervention. People deter the elephants to save their agricultural product, property (livestock and hut or garden vegetables), lives and so forth. This resistance interferes with the elephants' free movement within the fragmented landscape. Sometimes the methods adopted by the villagers became lethal to the herd. A member of a herd may become injured, separated or isolated from the herd and become a solitary resident in Panchet Forest. This solitary elephant will create problems because of its regular forays into fields in search of food. It is more dangerous than a herd. The local community or forest department chases the herd to drive them away to another place. Thus, the herd wanders from one place to another. This roaming is followed by crop and horticultural raiding, trampling of crops, and damage to rural huts and homestead gardens. In this way elephants come in direct confrontation with humans. This unwanted interaction between humans and elephants changes the perception of humans towards elephants. Continuous loss of agricultural crop and damage to livestock and property ultimately change the behaviour of the people who suffer in the study area. This confrontation has a detrimental effect on the elephants, too. The elephants' behaviour has also been changed. The objective of this chapter is to address this changing behaviour of both humans and elephants.

7.2 Local People's Attitude Towards Elephants

Elephants have been attached to the Indian culture since time immemorial. Elephants are treated as auspicious in the Hindu, Buddhist and Jain religions. Hindus worship the elephant in the form of the elephant-headed god 'Ganesh', Gajapati or Ganapati. People respect elephants. But the IUCN report (1976) recognised elephants as an endangered species. The major reason behind this classification is anthropogenic. India has the second-largest human population in the world. As such, forests have been fragmented because of settlement area expansion, growth and urbanisation. Elephants are forced to share their habitat with humans in the densely populated areas. The relationship between elephants and humans has gradually degraded from one of worship, acceptance and tolerance to that of intolerance and conflict.

The objective of this chapter is not only to address the causes of conflict but also to carry out a behavioural assessment that will be helpful to implement proper management measures to mitigate the problem.

To assess the attitude of local peoples towards elephants, we collected information from the affected villages. We provided questionnaires with options such as whether they fear, respect or hate elephants. A large percentage of the villagers stated that they fear elephants. Though the event of elephant migration started almost 30 years ago, the problem of large-scale destruction of agricultural crops and consequent human–elephant confrontation has occurred in the past 10 years. So the villagers are not accustomed to the nature of this problem. Until now, most of the

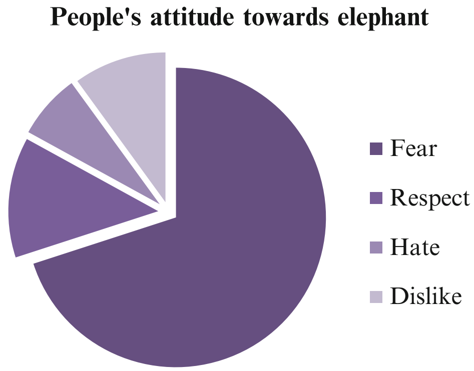
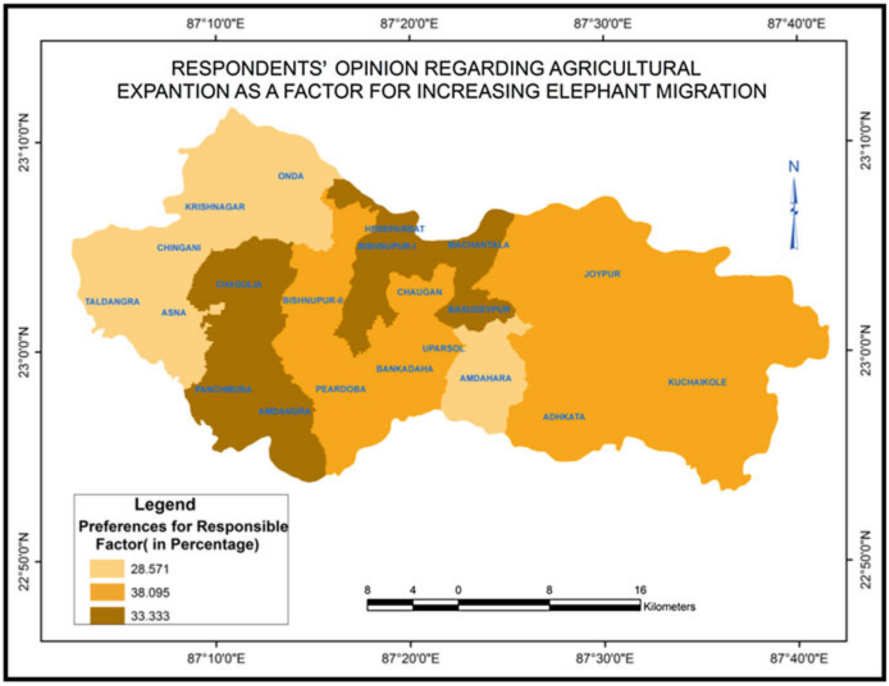


Fig. 7.1 People's attitude towards elephants

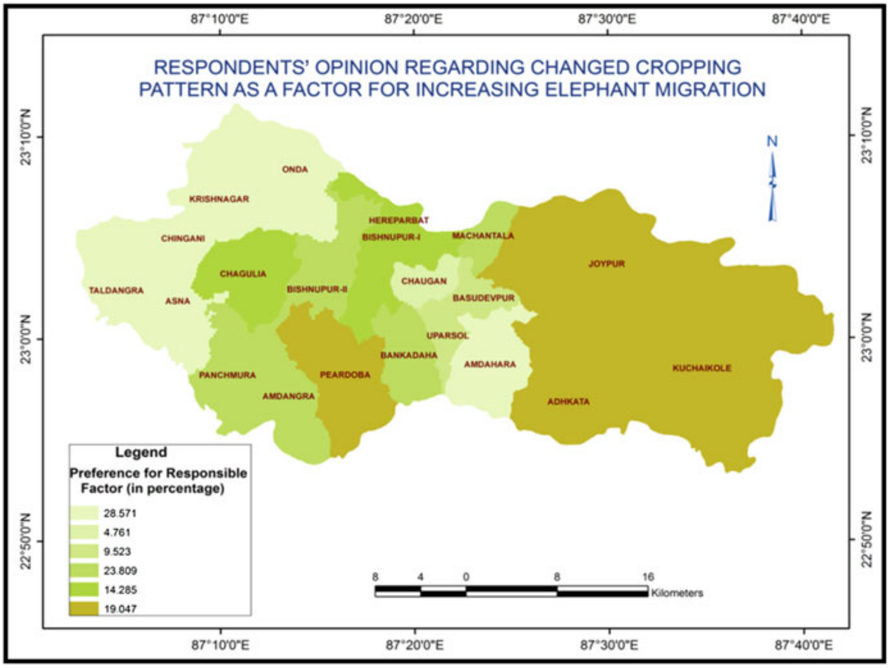
villagers were not well aware of the elephants' behaviour. Sometimes locals throw rocks from distant places or use bow and arrow to protect themselves. The majority of the respondents from the largely affected villages replied that they hate elephants. Yet still, some people glorify elephants and worship them. People are still tolerant of property losses, but the loss of human lives (average 7–9 persons in the district per year) is a matter of great intolerance. This means that with rational mitigation measures of the problem, the human–elephant relation should be revived (Fig. 7.1).

7.3 Community Perception Survey

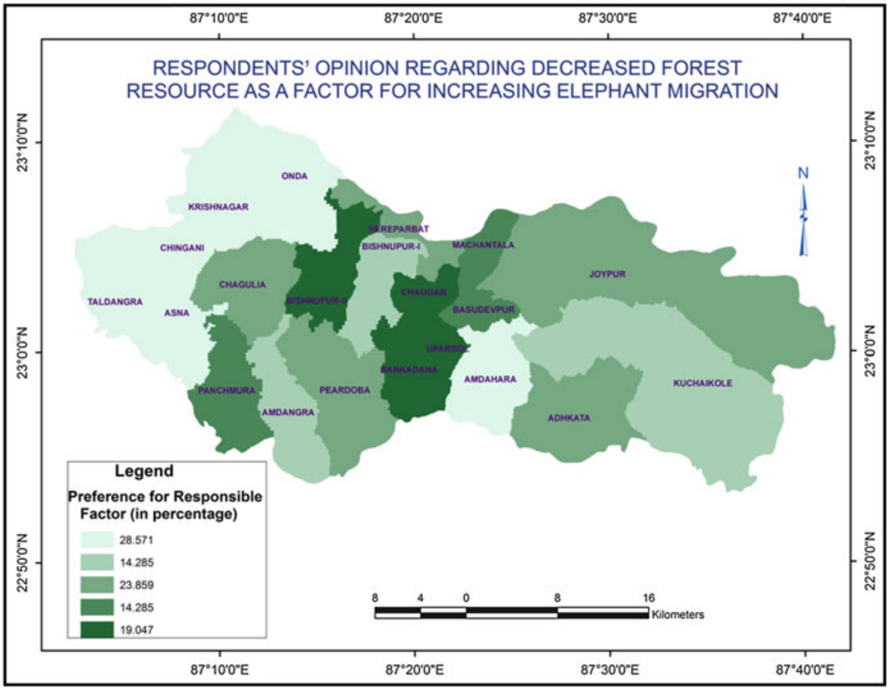
A community perception survey in the affected villages revealed some crucial facts. Through questionnaires we were able to find out the causes of increasing attacks against elephant by humans in the study area. On the basis of responses received from the villagers, we have prepared thematic maps (Maps 7.1–7.5). These maps will help the forest department to make policy decisions.



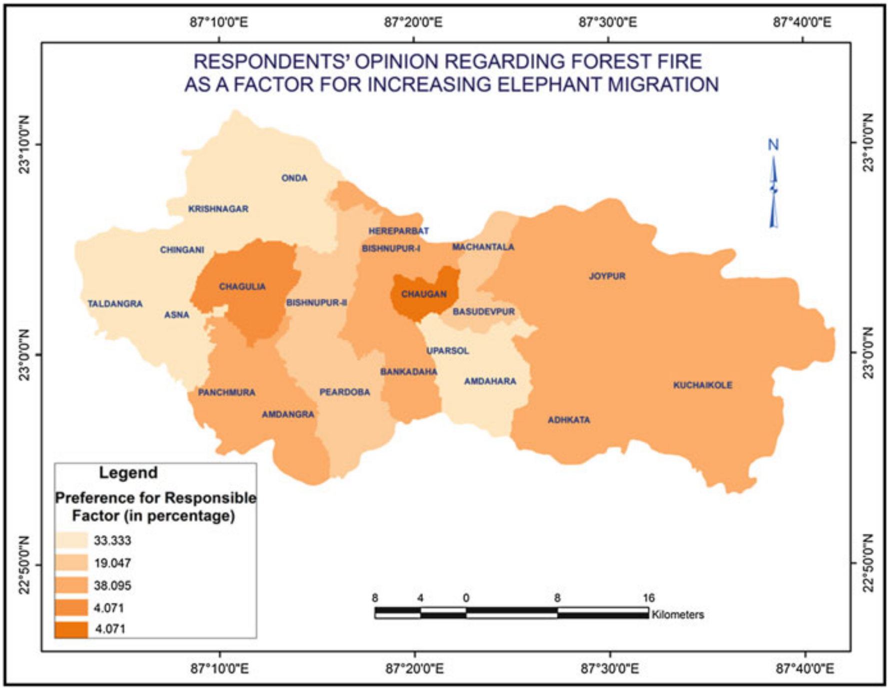
Map 7.1 Respondents' opinions regarding agricultural expansion as a factor for elephant migration



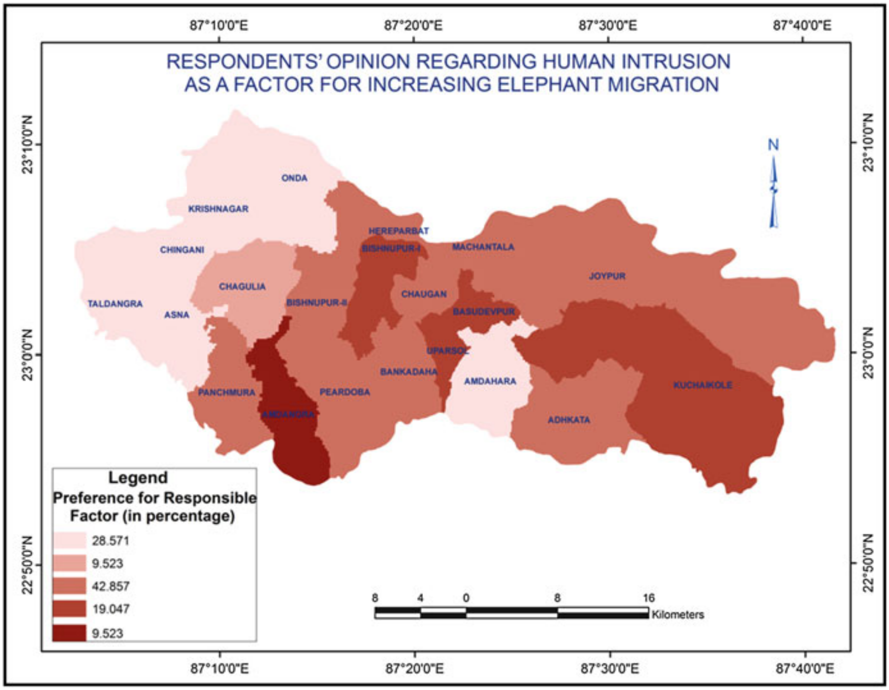
Map 7.2 Respondents' opinions regarding changed cropping pattern as a factor for elephant migration



Map 7.3 Respondents' opinions regarding decreased forest resources as a factor for elephant migration



Map 7.4 Respondents' opinions regarding forest fire as a factor for elephant migration



Map 7.5 Respondents' opinions regarding human intrusion as a factor for elephant migration

The level of awareness within the community is related to the location of nearby forest ranges or beat offices. Communities situated near the forest offices or having good contact with beat offices are aware of elephant migration routes, time of crop depredation, behaviour of elephants or management techniques.

Plate 7.1 People throwing stone to drive away elephant herd

The issue of elephant migration and consequent hazards are new to the people of this area. Even they have no idea about the ecological importance of this mega herbivore. The nature of elephant behaviour is also unknown to them. In some cases, people's behaviour towards elephants is very aggressive. Most cases of death or injury occur because of the unawareness of poor villagers. Moreover, the low level of education among villagers worsens the situation. They hesitate to approach the forest authorities or to undergo any complex official procedure for getting compensation even after loss of crops or life. The forest department supplies kerosene, petrol and/or firecrackers to drive elephants away from the locality or crop fields. But sometimes villagers are uninformed about this service. Thus, the level of awareness among the affected community has a significant bearing on the intensity of damage. In the study area, severely affected villages are situated in Bankadaha, Asna and Joypur ranges, where vegetables are largely cultivated and orchards have been heavily developed. The forest department also emphasis overcoming the situation. They conduct awareness programmes to inform people about the elephants' behaviour as well as how to handle an elephant herd if it enters their locality (Fig. 7.2).

“ মানব জাতির উন্নতির জন্য
বন্য প্রানীকে বাঁচতে দিন ”

আপনার এলাকায় বুনো হাতি বেরিয়ে পড়লে কি করবেন?

(১) বুনো হাতিদের থেকে দূরে থাকুন।

(২) রাতে ফসল রক্ষার জন্য চাষের জমির চারপাশে আগুন জ্বালিয়ে রাখুন।

(৩) বন বিভাগে সাহায্য নিয়ে স্বেচ্ছাসেবী বাহিনী গড়ে তুলুন।

(৪) হাতি তাড়াবার জন্য বনকর্মীদের সবর্তোভাবে সাহায্য করুন।

(৫) হাতিদের গতিবিধির উপর নজর রাখুন ও কাছের বনবিভাগ দপ্তরে ও থানায় খবর দিন।

(৬) হাতি গ্রামে এলে তাকে আগুন ও পটকার সাহায্য জঙ্গলের দিকে তাড়াবেন।জনবসতির দিকে তাড়াবেন না।

আপনার এলাকায় বুনো হাতি বেরিয়ে পড়লে কি করবেন না ?

- বুনো হাতি দেখার জন্য জঙ্গলে যাবেন না, তাতে বিপদ ও দুর্ঘটনা
- বাড়ির চারপাশে দৃষ্টি ব্যাহত হয় এমন উঁচু বেড়া বা কলাগাছ , বাঁশের ঝাড় লাগাবেন না।
- বুনোহাতির দলের দিকে ইঁট, পাথর, তীর ইত্যাদি ছুড়বেন না।তারা আহত হলে ক্ষিপ্ত হতে পারে।
- ঘরে দেশী মদ রাখবেন না, অথবা মত্ত অবস্থায় হাতির কাছে যাবেন না।মদের গন্ধ হাতিদের সহজেই আকৃষ্ট করে ফলে বিপদ হতে পারে।
- বনবিভাগের হাতি তাড়ানো দলের কাজে বাধা দিবেন না।তারা আপনাদের বিপদ ও ক্ষতির হাত থেকে রক্ষা করার কাজ করেন।
- হাতি তাড়াবার সময় হাতি চলার পথে জমায়েত হে কোন বাধা সৃষ্টি করবেন না।
- হাতিকে দেবতা ভেবে তাকে স্পর্শ করতে গেলে দুর্ঘটনা এমনকি মৃত্যু পর্যন্ত হতে পারে।তাই কাছে যাবেন না।

Fig. 7.2 Awareness notice issued by the forest department

7.4 Anthropogenic Causes of Damage by and Sufferings of Elephants

Our research work emphasises damages and death caused by elephants. The anthropogenic impact on the elephants in the form of injury or death has also been considered. With the increasing intensity of conflict between humans and elephants, the incidence of injury and death has increased. Killings, poisonings, captures and natural deaths of elephants have increased since 1987. But the reasons behind killings or injuries are different in the study area than in other locations, such as Africa, Sri Lanka, Sumatra, Thailand and other parts of India, where elephants are being killed for ivory. In the northern part of West Bengal, poaching of elephants for ivory does occur. But in South Bengal, killing or injury happens because of direct conflict caused by elephant attack. Sixty-six percent of mortalities have been found to be related to human–elephant conflicts. Sometimes the injured bull or calf gets detached

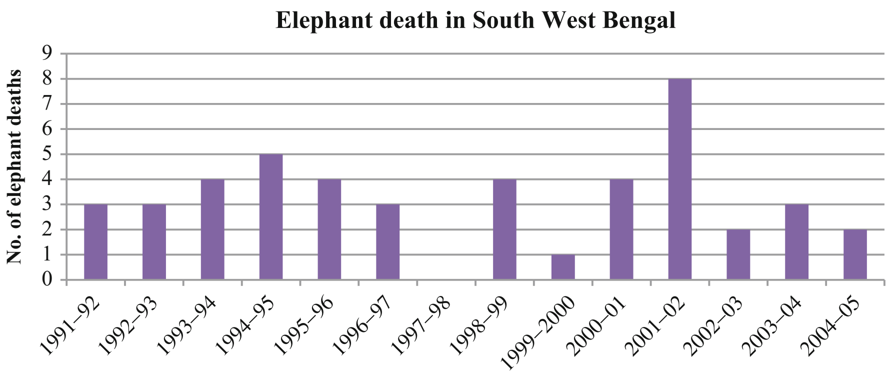


Fig. 7.3 Elephant deaths in southern West Bengal since 1991

from the herd. Information collected from the forest department shows that elephant death occurs from accidents while they are being chased away. But other causes, for instance, poison and capture, are also common. Though the number of affected elephants is lower in Panchet Forest Division, the elephant death or injury data in southern West Bengal are alarming (Fig. 7.3).

7.5 Views of Local People in Settling Human–Elephant Conflict

Conflict between humans and elephants is a key concern as it directly relates to economic loss, property damage or loss, injury to or death of humans as well as injury to or death of elephants. Thus, this problem embraces its economic, social, environmental and ecological issues. In the past, the villagers used to get involved and assist the forest department in driving away elephants from the settled areas. Today, though, most villagers have adopted a violent approach towards elephants mainly as a result of the continuous large-scale damage they face because of the elephants. The issue is not being properly addressed either by the forest department or by the concerned government ministry. As a result, locals have initiated some small-scale strategies to keep the elephants out of the crop areas. The most common among these methods are beating drums, scaring elephants with firecrackers or fire-balls, chasing them away with lit torches, using koonkie, shouting, and using bow and arrow or throwing stones (Fig. 7.4).

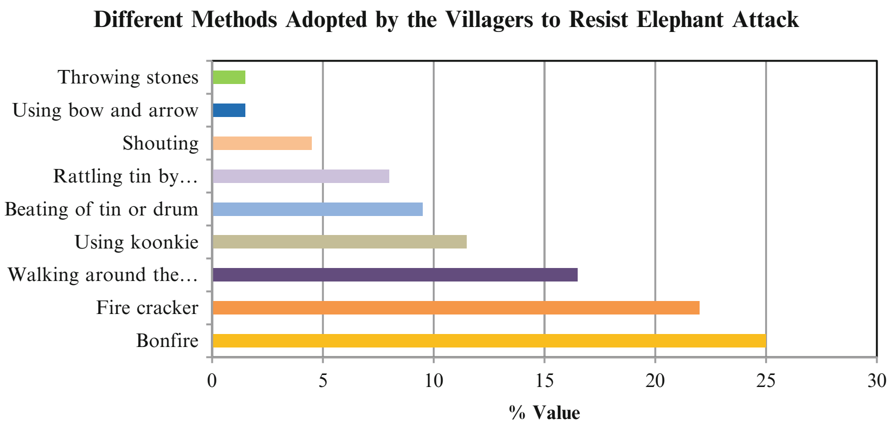


Fig. 7.4 Different methods adopted by villagers to resist elephant attack

However, all these attempts have a very limited effect. Elephants quickly become habituated to these methods and resume their crop-raiding activities. Because of their poor economic condition, the villagers cannot take the initiative to create effective barriers.

7.6 Locals' Evaluation of the Forest Department's Role and Response from the Forest Department

The local residents are not satisfied with the role government departments play in resolving human–elephant conflict because no long-term sustainable measures have been taken to combat the situation. Rather than adopting any long-term solution, government departments concentrate on giving compensation to the affected villagers. But the compensation given to offset the losses is insufficient. Sometimes villagers receive wages for helping forest officials chase elephants away, but the amount is very small. Thus, villagers are frustrated with the role of the forest department or government. They even voiced that in the event of elephant attack or crop raiding, the forest personnel are found to arrive late. Thus, local residents are compelled take the necessary steps to deal with elephants on their own. Moreover, the official procedure of receiving compensation is complex and time-consuming. It is not possible for villagers to visit government offices regularly, as such visits interfere with their regular work. The level of education among the community is also a barrier to the entire official works. Overall, an impression of dissatisfaction towards forest department personnel and their activities is found among the locals suffering from elephant-related issues.

The response from forest department personnel portrays a different picture. They stated that their plan for driving away herds with a *hullah party* has not always been successful because of the intervention of villagers. When they chase elephants to drive them away in a desired direction, the villagers—who have much more strength than *hullahs*—stand in front of them to intervene in their activity. Sometimes the villagers also chase them and mislead the herd. The herd splits into many unmanageable small groups. Ultimately, the herd returns to the place where the driving was started. Occasionally, it appears that some self-interested group of villagers deliberately mis-drives the herd to get wages from the forest department.

According to the forest department, the issue of human–elephant conflict has become frequent and more difficult to handle. Villagers challenge the administration and threaten the forest staff. They thus face the dual problems of combating elephants as well as villagers' fury (Kulandeival 2010). Villagers' expectations of the forest department do not match the forest department's plans and schemes. Villagers generally demand a permanent solution. The department also feels that implementation of a sustainable and rational plan is urgently needed to combat the situation.

Minutes of the meeting regarding elephant depredation in Bankura District held at Beliatore Forest Rest House on 7th September, 2013.

Chief Conservator of Forests, Central Circle informed that more than Rs.1,20,00,000/- was paid as compensation during 2012-13 to the victims in Bankura District. He also said that the assessment is

the migratory elephants have also gradually increased their home range upto Damodar River and some times, they cross the river and enter into Burdwan and Durgapur. The elephant started entering the Bankura District in the year 1997 onwards and the affected areas are Bishnupur, Joypur, Sonamukhi, Beliatore, Gangajalghati and Barjora Ranges. The elephants have also increased their time of stay gradually in this region and in Bankura District, migratory elephants stay for more than 7 months in a year. Last year, more than 60 elephants stayed back in South Bengal and only around 40 elephants went back to Dalma Forests in the month of June and came back to West Bengal in July through Karanjhore Bhulabeda corridor. Therefore, gradually the elephants are increasing their time period of stay and are

Chief Conservator of Forests, Central Circle said that more driving of elephants cause more damage as the elephants split into 4 to 5 groups and raid crops in different villages which is becoming difficult to manage due to shortage of staff. He informed that efforts are being made to strengthen the

Plate 7.2 Minutes of district forest office Bankura. *Source*: bankuraforest.nic.in

7.7 Changing Behaviour of Elephants

To address the problem of human–elephant conflict, one needs to assess elephant behaviour, as it is as important as human behaviour. Elephant behaviour should be considered before implementing any policy or strategy. Analysis of elephant behaviour is crucial in a human-modified landscape. Elephants face continuous pressure from chasing by forest personnel and locals. As a result, their behaviour has changed drastically. Specifically, the solitary bull, isolated from the herd, is more aggressive towards humans. The migratory herd is well aware about food availability. They move to those places where they can get alternative vegetables or other secondary growths. From an empirical survey, one can see that a high level of intervention in the forested area, the agricultural encroachment in the forest fringes, aggravates the human–elephant conflict. Though the number of elephant deaths is small in the study area, injury or change in behavioural patterns creates more problems. Most of the conflict happens in Bankadaha, Bishnupur and Joypur ranges, and so the injury report is also high from these ranges. Most respondents would prefer to change elephant behaviour. The following plate is self-explanatory and clearly depicts the situation.

Plate 7.3 Aggressive behaviour of elephant as a reaction of people attack

Chapter 8
Conclusion

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3_8

Abstract This is the concluding chapter of the book. It portrays different aspects of human suffering caused by conflict with elephants and suggests ways to combat the situation. Some thematic maps have been prepared depicting the villages affected by elephant attack. Maps of increased crop damage have been prepared and compare decadal data. Attempts of the forest department and the problems it faces are also depicted. The existing land use pattern is also responsible for the situation. Thus, we considered all these factors while applying any policy to improve the situation. Ultimately, people's support is essential for any strategy or plan to be successful. After analysing the typical situation of the study area, we proposed some mitigation and management measures. Some of the management measures have already been applied to similar cases at the national level. However, some significant proposals that are very case-specific should be useful at a local level only. The route of elephant migration and temporal route shift that we have prepared may be useful not only to the forest department but also to the affected communities. All the results of each chapter are written in the form of major findings in this concluding chapter, in an effort to draw some practicable management and peaceful coexistence between humans and elephants in the study area.

Keywords Damage map • Major findings • Management strategy • Mitigation measures

8.1 Introduction

The consequences of human–elephant conflict have become crucial for wildlife conservation. Nonetheless, they are also a major socio-economic and political issue and a big challenge to the nation too. Once the elephant was viewed with pride, was seen as a status symbol, had a cultural heritage and was worshipped by humans, but now it has become an object of conflict. The human–elephant relationship of respect has eroded into one of intolerance. The number of affected people and volume of damage have increased considerably. Forest departments have made several initiatives to address the problem. Payments ex gratia have been extended to the victims for injuries, death, crop loss, property loss and so forth, but this compensation scheme has not been successful because of procedural complexes within the system. At the same time, we have found that compensation schemes are not the right option to resolve the problem of human–elephant conflict. The construction of electrical fences or trenching along the forest margins has been built to restrict elephants within the forest area. But in the highly fragmented forest, it is not practicable to create and maintain such a fence. People need to enter the forest to collect fuelwood and non-timber forest products. It has also been found that people often break the fences and sell the wires. Thus, proper supervision is needed. Elephant calves may fall into the trenches and get stuck, which is dangerous. In such a situation, the herd becomes more violent and causes additional damage. Hence, people demand more sustainable and long-term solutions to the issue of human–elephant conflict.

Plate 8.1 Elephant calf trapped in man made tank

8.2 Mitigation Measures

Issues of elephant migration have become a regular phenomenon in Panchet Forest Division since 1987. The problem has three different dimensions: damage or loss of life or property of the villagers; damage or death of elephant population; and vulnerable situation of forest staff because of assault by the villagers and attack by elephants during the chasing of elephants. In their own way, villagers try to resist elephant attacks on their crops, and the forest department—with its limited strength—tries to combat the situation. The result is an increasing drain of public money for ex gratia payments, but the situation remains unchanged. The villagers and forest department have tried the following methods, described next: scaring and driving the herd away; crop guarding; throwing stones and using bows and arrows; wild elephant capture; chemical immobilisation; and habitat development.

8.2.1 Scaring and Driving the Herd Away

Elephants are driven away by scaring them. It is done by a specially trained *Hullah party* by forest department personnel and villagers. A *hullah* is made of a 3–4-m-long pole of iron or *sal* wood. The tip is wrapped with jute or cloth and finally tied with iron wire. Then it is soaked with kerosene or diesel. The *hullah party* leader then ignites the tip of the hullah and participants chase the elephant herd until they drive them away in the desired direction. During the chase, close proximity to the herd may be dangerous to the villagers too. Along with the *hullah,* they use firecrackers and fireballs supplied by the forest department. However, crop fields are trampled and damaged by the herd during the chase.

Plate 8.2 Hullah pati chasing elephant to drive elephant

8.2.2 Crop Guarding

Crop guarding is done by the farmers individually or collectively. They usually arrange to scare elephants from the huts made near the field. Noises made by the people in the fields may discourage elephants from raiding crops and thus damage could be minimised.

Plate 8.3 Crop guarding at night by the villagers

8.2.3 Throwing Stones or Arrows

Activities such as shouting and throwing stones or shooting arrows are rather reactive and confrontational (Fernando 2008b). These kinds of attacks on elephants make them more aggressive. All these traditional methods adopted by the villagers are only able to tackle the problem for the time being. Repetitive application of these traditional methods ultimately fails because either the elephants become habituated to these methods or they are not effective to protect against elephant attack. The constant failure of these traditional methods makes the villagers intolerant of elephants and more likely to use harmful and lethal methods. However, the forest department has taken some measures at the local level through capturing elephants, chemical immobilisation and habitat development.

Plate 8.4 People scaring elephant part to drive them back to the forest. *Source*: www.bankuraforest.in

8.2.4 Wild Elephant Capture

Capturing wild elephants is done by trained elephants, or *koonkie*. Wild elephants are chased by trained elephants with their guides, called *mahauts*, who capture them and drag them out of the forest. Dalma elephants were captured and driven back to their original habitat in 1987 with the help of trained elephants brought from North Bengal (Santra et al. 2007). Today this method has limited effects. When Dalma elephants initially started migrating to southern West Bengal, the number of elephants and herd size were small. Today, however, both the number of elephants in a herd and the number of herds have increased. Originally, there were 40–42 elephants in a herd, but now the number has increased to 70–80. So when the trained elephants chase the herd, the herd splits into two to three subgroups that move in different directions and become unmanageable to capture.

8.2.5 Chemical Immobilisation

This process of capture usually applies to rogue elephants or those who are creating problems, that is, problem elephants that cause severe damage in forest fringe settled areas. In this method an anaesthetic drug is administered to the problem elephant and the unconscious elephant is translocated to some other place. But this method is costly and requires more people to carry out.

8.2.6 Habitat Development

Habitat development is probably the most practical, rational method to address the issue of human–elephant conflict. Habitat improvement programs involve growing food plants that elephants like, planting fodder crops, creating water holes, salt licks and more. These activities can improve the quality of monospecies-dominated forest patches of the study areas, which serve as elephant habitats.

Creating a buffer zone with secondary vegetation like bamboo and grasses may be helpful to check the habitat of roaming elephants in the vicinity of the forest. Food crops preferred by elephants, such as paddy, maize, hybrid Napier and Bajra, are grown in various forest patches of Joypur and Bishnupur (Santra et al. 2007). The forest department planted elephant-preferred food plants and fodder on 200 ha of land. In addition, the forest department excavated several tanks within the forests to supply water for elephants within the forests. Most of the water tanks become dry during the summer season.

Habitat development and improvement in elephant-affected areas yielded effective results, but in most cases these improvement programmes are implemented on a local scale and in very few instances. It requires the co-operation of the local villagers to maintain and supervise the habitats created. Thus, the government should support these kinds of initiatives on a broader scale for proper management of the problem of habitat destruction.

Plate 8.5 Plantations by the forest department for habitat improvement

8.3 Managing Human–Elephant Conflict at the National Level

Elephants have co-existed with humans since time immemorial. With the advancement of civilization, however, this co-existence has turned into conflict. It is therefore a challenge for the nation to provide proper management plans so that the co-existence relationship rejuvenates. The largest herbivore needs living space, food and water. Scarcity of these needs within the forest area compels the elephants to go outside the forest in search of these needs, thus giving rise to conflict with humans. As a response, the government has created several programmes to overcome the problem of human–elephant conflict. Project Elephant is one such programme that focusses on the issue of elephant welfare.

8.3.1 Project Elephant

Project Elephant was launched by the government of India in 1992. It is sponsored by the Ministry of Environment and Forest (MoEF). The main aim of this project is to provide financial and technical support to the elephant range states of India for protection of elephants, their habitat and corridors and especially to address the issue of human–elephant conflict. It also promotes the welfare of captive elephants (Doyle et al. 2010).

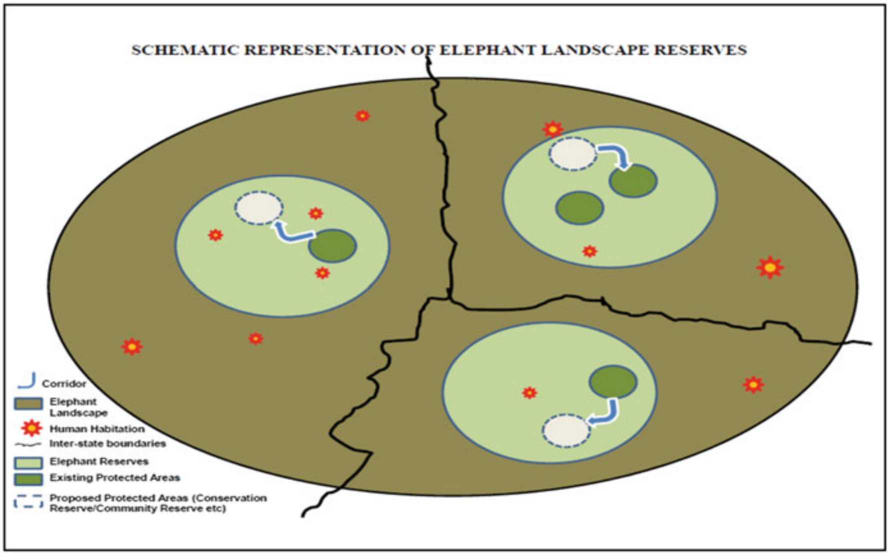


Fig. 8.1 Schematic representations of elephant landscape reserves

The prime objectives of Project Elephant are as follows:

- Ecological restoration of existing natural habitat and migratory routes of elephants
- Development of scientific conservation plan for elephant habitat
- Promotion of measures for mitigation of human–elephant conflict
- Measures to prevent poacher in elephant habitat zones
- Public awareness and education programme
- Eco-development
- Research on elephant management and veterinary care
- Technical and administrative assistance to the states to fulfil the above objectives

It is a central government–sponsored project and provides financial, technical and scientific assistance to states that have a large elephant population. As of this publication, there are 32 elephant reserves in India. For ease of work, a task force was formulated following the National Tiger Conservation Authority (NTCA) and named the National Elephant Conservation Authority (NECA); its role is to look after these identified elephant reserves of India. Emphasis was given on improving these habitats. For instance, in 8th Five Year Plan, Rs. 23 Crore was allotted, which was increased to Rs. 81.99 Crores in 11th Five Year Plan. In 12th Five Year Plan, this committee recommended to allocate Rs. 475 Crores for habitat development, elephant protection, corridor securement, monitoring, research, management and welfare of captive elephants (Fig. 8.1).

The task force has identified that the level of human–elephant conflict is very serious in West Bengal (Rangarajan et al. 2010). More than half of the expenditures was incurred mitigating human–elephant conflict and 15–20 % was allocated for ex gratia compensation for crop, life and property loss. Thus, to resolve the problem, development and improvement of habitat are more important for this area.

The task force has also recommended studying elephant behavioural ecology before implementing any long-term strategy or policy for the study area. Keeping in view the issues of human–elephant conflict in the face of population increases and expansion of settlement within or near the elephant habitat, they recommended a plan for the peaceful co-existence of humans and elephants sharing a common space.

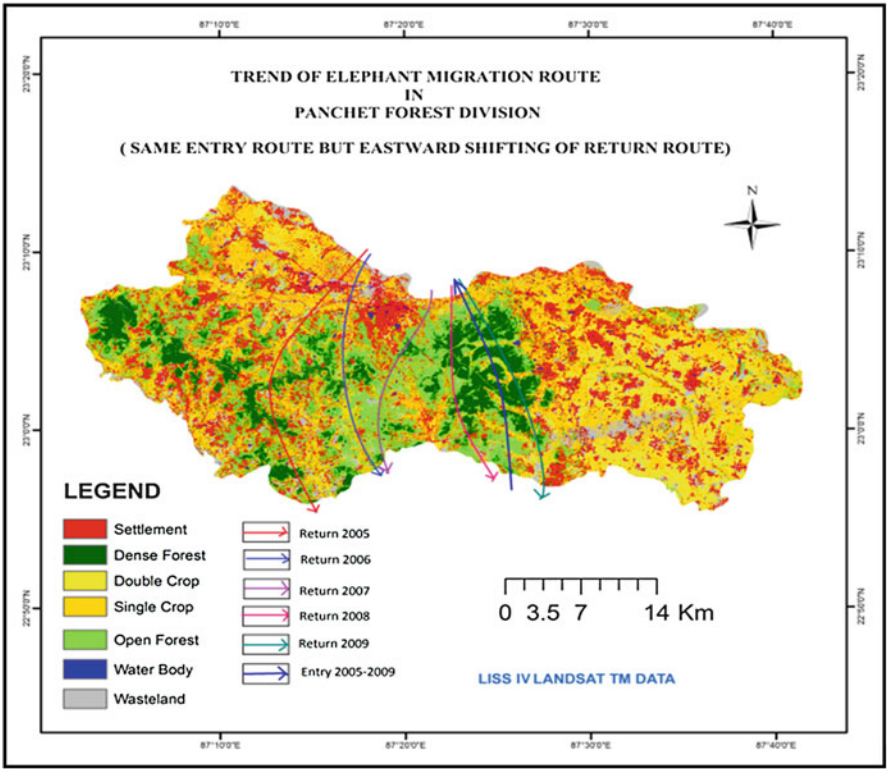
8.3.2 Community Involvement

To reduce the level of human–elephant conflict, it is essential to elicit people's support because any strategy or plan will not be successful without community support. Establishment and maintenance of barriers should be supervised by community members themselves. Regeneration of fodder crops or forest cover is only possible when the local community is involved with the programme. The local body, either the gram panchayat or gram sabha, may take the role to supervise these barriers. The survey indicated that a gap exists between the thoughts of the villagers and those of the forest department. The government has to take initiative in involving local people before implementing any strategic plan. Regular meetings, workshops and training programmes should be organized to make people aware of the behavioural patterns of elephants and different dimensions of human–elephant conflict.

8.3.3 Land Use Planning

Issues of human–elephant conflict have increased with changing land use. The problem is severe in the human-modified environment, where human settlement exists and the land has become fragmented. To manage the problem, we are developing regulatory mechanisms that reduce habitat loss and stop the fragmentation and degeneration of forest cover. Thus, habitat protection is urgently needed to readdress the situation. Several techniques can be applied for this purpose, as follows:

(a) Monitoring habitats using satellite imagery, one can easily see the temporal variation of vegetation cover and identify settlement growth by comparing satellite images of different periods.
(b) Corridors used by the elephants can be well demarcated on satellite images. Even shifting of corridors within a small area can be demarked. In the study area the shifting migration route is well demarked on the land use map. The cause of shifting can also be assessed.



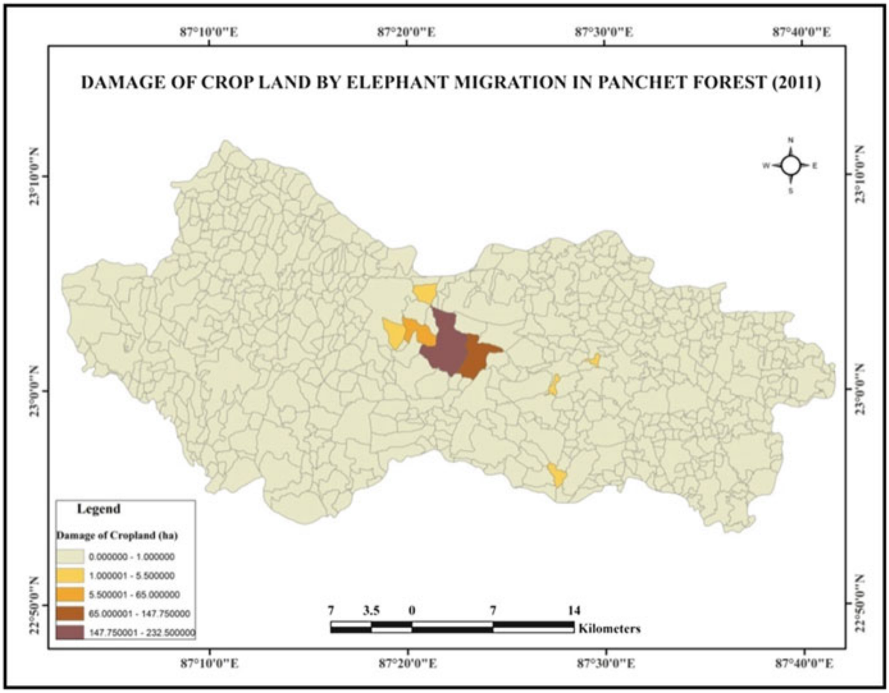
Map 8.1 Trend of elephant migration route, 2005–2009

(c) Plantation of chilli, capsicum, turmeric or arum as a biological border along village boundaries can be fruitful. The pungent smell of capsicum and chilli prevents elephants from entering the village. Turmeric is cultivated in some elephant-affected areas of Jharkhand. It has been successful to some extent. In some West Bengal locations, arum has been cultivated to restrict the movement of elephants.

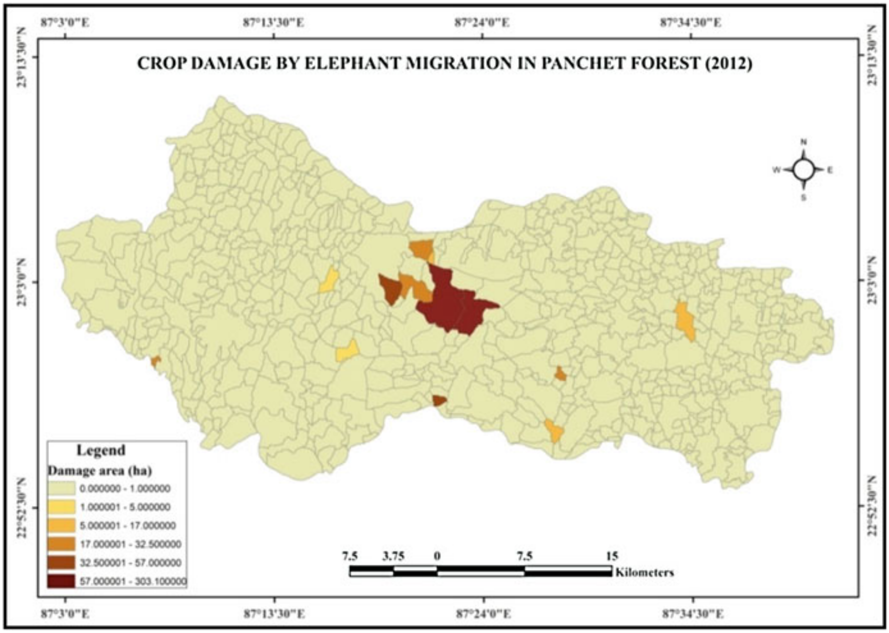
(d) Direct monitoring at the beat and range level will be very helpful to track the routes of elephants.

(e) Enforcement of law or legal application is needed in the places where the boundary is vague, disputed or encroached by human beings, which creates problem for management.

(f) A proper environmental impact assessment will be helpful to know the specific characteristics of land use planning in a conflict zone. It is necessary because every place has its own characteristics that should be taken into consideration before implementing any planning proposal.



Map 8.2 Damage map of Panchet Forest Division, 2011



Map 8.3 Damage map of Panchet Forest Division, 2012

The present study tries to cover almost all dimensions related to the human–elephant conflict. After analysing the answers to the questions raised at the beginning of this thesis, we are able to outline some results in the form of major findings.

8.4 Major Findings

1. Degradation and fragmentation of habitat have been caused by anthropogenic activity that includes agriculture, expansion of settlement, construction of road and railway lines, mining, encroachment of the forest fringe areas and establishment of poultry farms within the forest fringe areas.
2. The number of migratory elephants has increased since 1987. Initially, one herd used to come, but now three to four herds consisting of more than 70 elephants come into the study area.
3. The number of days the elephants stay in the study area is also increasing. Initially, it was only 1 or 2 months, but now it has increased to more than 6 months.
4. The number of residential elephants has also increased. These residential elephants are isolated from the herd. They create more problems throughout the year.
5. A temporal shifting of the entry and return routes of these migratory elephants has taken place. They have shifted their return routes towards the east, where the land use is dominated by agricultural lands.
6. A seasonal pattern of depredation is seen. During October–February, or during the harvesting season, depredation is frequent. The incidence of human–elephant conflict is severe during this time of the year.
7. The local communities primarily consist of marginal agriculturists. The level of education is very low among community members. A low level of awareness among local people has made the problem more complex.
8. Loss of life and crop has increased gradually.
9. There is a gap between the measures taken by the forest department and the local people's demand to combat the situation. Steps taken by the forest department in most cases are short term, but people demand a long-term solution.
10. Forest departments spend most of their grants paying ex gratia compensation to people who have suffered a loss. But people view the compensation as being insufficient to cover the loss.
11. Locals do not rely on the forest department to combat the situation because of the department's poor performance. Changing the locals' attitude towards forest department personnel in the field is another dimension of the problem.
12. Changing behaviour among both the migratory herd and residential solitary elephants has been found. Elephants have become more aggressive and attacking towards people and damage more crops and properties in the study area. At the same time, people's attitude towards elephants has also changed. A relationship originally built on respect has been transformed into one of fear and conflict.

8.5 Conclusion

Our research work is a humble submission to address the increasing tension between humans and elephants in Panchet Forest Division. We have tried to find the actual causes of migration of Dalma elephants to Panchet areas. Focus has been given to ecological and environmental causes along with socio-economic factors. The number of elephants coming into the study area and the length of their stay there have increased in the years since 1987. The population density of this area has also changed in these years. As a result, the area under settlement and agricultural land cover have also changed. The main cause of human–elephant conflict is the alteration and modification of land use patterns. Degraded areas or wastelands have been regenerated under the Social Forestry Programme. Successful implementation of social forestry not only increases the forest cover but also creates a corridor in between Dalma and southern West Bengal, which helps the migratory elephants take shelter in those patches. Initially, it was an infrequent event, but later on the migration became a regular event in the study area. Easy availability of food in the agricultural lands attracts elephants. Thus, the issue of human–elephant conflict has become a serious dimension in the study area. Each year forest departments have to compensate the losses with a huge amount of money given to the victims. But the severity of the problem remains unchanged. Local people, in their own way, are trying to handle the situation, while the forest department, with its limited infrastructure, is struggling to cope with the situation. Recently, the forest department has started to improve the quality of the habitat by planting fodder crops within and near the forest area. Other measures such as electrified fences, trenches in the forest boundaries, chemical immobilisation and capture are also being applied to control the situation. But co-operation between the local people or the stakeholders and the forest department is required with more realistic management practices to overcome the situation.

Appendix A

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3

Table 4.2 Patch analysis at Class Level and Landscape Level (Raster Layer)

		Number of patches		Patch density (#/100 ha)		Largest patch index (%)		Edge density (m/ha)		Mean patch area (ha)		Total core area (ha)	
		1990	2013	1990	2013	1990	2013	1990	2013	1990	2013	1990	2013
Class-level metrics	*Cropland*	19,231	13,346	8.5203	5.9242	6.7193	12.4409	60.1616	69.3658	1.967	4.1828	35458.124	36493.088
	Degraded forest	29,472	27,350	13.0576	12.1404	0.4124	0.3777	65.6871	56.8424	0.9297	0.8485	16278.79	6556.4325
	Dense forest	22,476	17,554	9.958	7.7921	5.4049	3.6628	97.3787	61.5471	2.1845	2.0765	21611.455	16631.955
	Openland	4168	15,371	1.8466	6.8231	0.1214	0.0117	7.0524	16.564	0.7775	0.2822	3240.7963	1946.565
	Settlement	22,123	11,636	9.8016	5.1651	0.0299	0.0389	21.7507	13.4207	0.225	0.302	4977.7117	3514.1625
	Water	8099	5911	3.5883	2.6238	0.0103	0.0079	9.919	6.55	0.3924	0.357	3177.8469	1571.04
		Number of patches		Patch density (#/100 ha)		Largest patch index (%)		Edge density (m/ha)		Mean patch area (ha)		Total core area (ha)	
		1990	2013	1990	2013	1990	2013	1990	2013	1990	2013	1990	2013
Landscape-level metrics		105,569	91,168	46.7724	40.4687	6.7193	12.4409	130.9747	112.145	1.1909	1.376	84744.723	66713.243

Core area percent of landscape		Core area mean		Mean Euclidean nearest-neighbour distance		Interspersion and juxtaposition index (%)		Connectance index	
1990	2013	1990	2013	1990	2013	1990	2013	1990	2013
15.7097	16.199	1.8438	2.7344	74.3135	55.7544	68.1364	71.9174	0.0116	0.0214
7.2123	2.9103	0.5523	0.2397	71.2557	61.6759	60.486	53.3374	0.0079	0.0087
9.575	7.3828	0.9615	0.9475	64.9644	58.6772	73.1705	79.6638	0.0135	0.0141
1.4358	0.8641	0.7775	0.1266	150.5473	82.3029	70.2979	87.8377	0.0192	0.0104
2.2054	1.5599	0.225	0.302	89.9724	89.6935	76.8328	86.5778	0.0073	0.013
1.4079	0.6974	0.3924	0.2658	140.2651	140.0425	77.5551	85.2131	0.009	0.0139

Core area mean		Mean Euclidean nearest-neighbour distance		Interspersion and juxtaposition index (%)		Connectance index		Patch richness (#)		Shannon's diversity index		Simpson's diversity index	
1990	2013	1990	2013	1990	2013	1990	2013	1990	2013	1990	2013	1990	2013
0.8027	0.7318	82.8203	72.3664	70.2171	73.5522	0.0097	0.0118	6	6	1.3757	1.3168	0.7066	0.681

References

Anandabazar Patrika. (2014a, March 5). Bishnupur. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014b, March 9). Barjora. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014c, May 24). Elephant at Kashipur. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014d, May 26). Ranibandh and Manbazar. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014e, May 28). Elephant at Labhpur. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014f, June 10). Bauxa. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014g, June 13). Jhargram. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014h, June 3). Malbazar. Retrieved from http://epaper.anandabazar.com/

Anandabazar Patrika. (2014i, June 27). Adra, Purulia. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Anandabazar Patrika. (2014j, June 28). Bishnupur. http://epaper.anandabazar.com/, http://www.anandabazar.com/searchresult/search-7.1090?q=elephant&short=desc&x=0&y=0

Andau, M., & Payne, J. (1992). Managing elephant depredation in plantations in Sabah. *IUCN/SSC Asian Elephant Specialist Group Newsletter, 8*, 19–24.

Anderson, T. M., Hopcraft, J. G. C., Eby, S., Ritchie, M., Grace, J. B., & Olff, H. (2010). Landscape-scale analyses suggest both nutrient and antipredator advantages to Serengeti herbivore hotspots. *Ecology, Ecological Society of America, 91*(5), 1519–1529.

Arivazhagan, C., & Ramakrishnan, B. (2010). Conservation perspective of Asian elephants (*Elephas maximus*) in Tamil Nadu, Southern India. *International Journal of Biotechnology, 1*, 15–22.

Asian Elephants Specialist Group. Newsletter, 1986: 1 to 1992: 8. *Gajah*.

Asian Elephants Specialist Group. Newsletter, 1992 9 to 2013 39. *Gajah*.

Balasubramaniam, M., Baskaran, N., Swaminathan, S., & Desai, A. A. (1993). Crop raiding by elephants in the Nilgiri Biosphere Reserve, India. In J. C. Daniel (Ed.), *Proceedings of the International Seminar on the Conservation of the Asian Elephant*. Bombay, India: Bombay Natural History Society.

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs in Environmental Science, DOI 10.1007/978-3-319-31162-3

Barnes, R. F. W., Azika, S., & Asamoah-Boateng, B. (1995). Timber, coca and crop-raiding elephants: A preliminary study from southern Ghana. *Pachyderm, 19*, 33–38.

Barnes, R. F. W., Barnes, K. L., & Kapela, B. (2008). The long-term impact of elephant browsing on baobab trees at Msembe Ruaha National Park, Tanzania. *African Journal of Ecology, 32*(3), 177–184.

Barua, P., & Bist, S. S. (1995). Changing patterns in the distribution and movement of wild elephants in North Bengal. In *A week with elephants* (pp. 66–84). Bombay, India: Bombay Natural History Society.

Bascompte, J., Possingham, H., & Roughgarden, J. (2002). Patchy populations in stochastic environments: Critical number of patches for persistence. *American Naturalist, 159*, 128–37.

Baskaran, N., & Desai, A. A. (1996). Ranging behavior of the Asian elephant (*Elephas maximus*) in the Nilgiri Biosphere reserve, South India. *Gajah, 15*, 41–57.

Baskaran N., Kannan, G., Anbarasan, U. & Sukumar, R. (2007a). *Conservation of the Elephant Population in the Anamalais–Nelliyampathis and Palani Hills (Project Elephant Range 9), Southern India.* Final report to USFWS, Asian Nature Conservation Foundation, Bangalore.

Baskaran, N., Kannan, G., & Sukumar, R. (2007b). *Southern India elephant Census 2007*. Final report to Karnataka Forest Department. Bangalore, India: Asian Elephant Research and Conservation Centre.

Baskaran, N., Varma, S., Sar, C. K., & Sukumar, R. (2011). Current status of Asian elephants in India. *Gajah, 35*, 47–54.

Bell, S. (2003). *The potential of applied landscape ecology to forest design planning*. Edinburgh, Scotland: The Forestry Commission.

Bender, D. J., Tischendorf, L., & Fahrig, L. (2003). Using patch isolation metrics to predict animal movement in binary landscapes. *Landscape Ecology, 18*(1), 17–39.

Bennett, A. F., & Saunders, D. A. (2010). Habitat fragmentation and landscape change. In N. S. Sodhi & P. R. Ehrlich (Eds.), *Conservation biology for all*. Oxford: Oxford University Press.

Bist, S. S. (2002a). An overview of elephant conservation in India. *The Indian Forester, 128*(2), 121–136.

Bist, S. S. (2002b). Conservation of elephants in NE India: Past, present and future. *Newsletter of the Rhino Foundation for Nature in NE India, 4*, 7–10.

Bist, S. S. (2003). An overview of the methods for enumeration of wild elephants in India. *Gajah, 22*, 67–70.

Bist, S. S. (2006). Elephant conservation in India—An overview. *Gajah, 25*, 27–35.

Blair, J. A. S., Boon, G. G., & Noor, N. M. (1979). Conservation or cultivation: The confrontation between the Asian elephant and land development in Peninsular Malaysia. *Abstract of Land Development Digest, 2*, 25–58.

Blair, A. S., & Noor, N. M. (1981). Conflict between the Malaysian elephant and agriculture. In M. Nordin, A. Latiff, M. C. Mahani, & S. C. Tan (Eds.), *Conservation inputs from life sciences. Proceedings of the International Symposium on Conservation Inputs from Life Sciences*. Malaysia: Universiti Kebangsaan.

Bureau of Applied Economics & Statistics (2005, November 8). *District statistical handbook*. Kolkata, India: Bureau of Applied Economics & Statistics, Government of West Bengal.

Champion, H. G., & Seth, S. K. (1968). *A revised survey of forest types of India*. New Delhi, India: Government of India publication.

Chen, J., Franklin, J. F., & Spies, T. A. (1992). Vegetation responses to edge environments in old growth Douglas-fir forests. *Ecological Applications, 2*(4), 387–96.

Choudhury, A. (1991). Status of wild elephants (*Elephas maximus*) in North Cachar. *Assam Journal of The Bombay Natural History Society, 88*(2), 215–22I.

Choudhury, A. et al. (2008). *Elephas maximus*. The IUCN Red List of Threatened Species 2008: e.T7140A12828813.

Chowdhury, S., Khalid, M. A., Roy, M., Singh, A. K., & Singh, R. R. (1997). *Management of elephant populations in West Bengal for mitigating man-elephant conflicts*. A consultancy report for West Bengal forestry project. Dehradun, India: Wildlife Institute of India.

Chowdhury, S., Shahi, S. P., & Daniel, J. C. (1985, November 6–9). *Report of the Asian Elephant Specialist Group—Central India Task Force, Bihar & Orissa* (pp. 1–80). Unpublished document presented in Asian Elephant Specialist Group Meeting, Bandipur.

Couvillion, B. R. (2005). *Thesis on spatial heterogeneity in forested landscapes: an examination of forest fragmentation and suburban sprawl in the Florida parishes of Louisiana.* BS Forest Management Louisiana State University.

Cox, C. B., & Moore, P. D. (2006). *Biogeography: An ecological and evolutionary approach* (7th ed., pp. 36–38). Hoboken, NJ: Blackwell.

Daniel, J. C. (ed.). (1993). *Proceedings of the International Seminar on the Conservation of the Asian Elephant*. Bombay Natural History Society. Bombay.

Daniel, J. C. (1998). *The Asian elephant: A natural history*. Dehra Dun, India: Natraj.

Daniel, J. C. (2009). *The Asian elephant: A natural history*. New Delhi: Natraj Publishers.

Daniel, J. C., Krishnamurthy, V., Desai, A. A., Sivaganesan, N., Datye, H. S., Kumar, R., et al. (1995). *Ecology of the Asian Elephant*. Final Report (1987–1992), Bombay, India: Bombay Natural History Society.

Daniel, J. C., Manakadan, R., Swaminathan, S., Ramesh Babu, M., Balasubramanian, G., Desai, A., & Mohan Raj, N. (2008). *The population, distribution, habitat and problems of the Asian elephant Elephas maximus in Andhra Pradesh, India*. Bombay Natural History Society and U.S. Fish and Wildlife Service.

Danquah, E., Oppong, S. K., & Sam, M. K. (2006). Aspects of elephant cropraiding behaviour in the Kakum Conservation Area, Ghana. *Nature et Faune, 21*(2), 15–19.

Das, B. S. (1984). *Changing profile of the frontier, Bengal 1751–1833*. Delhi: Mittal. (Bayley 1813).

Datye, H. S., & Bhagawat, A. M. (1993). Estimation of crop damage and the economic loss caused by elephants and its implications in the management of elephants. In J. C. Daniel & S. H. Datye (Eds.), *A week with elephants: Proceedings of the International Seminar on Asian elephants* (pp. 375–388). Bombay, India: Bombay Natural History Society.

Datye, H. S., & Bhagwat, A. M. (1995). Home range of elephants in fragmented habitats of central India. *Journal of the Bombay Natural History Society, 92*, 1–10.

Dawson, S., & Blackburn, T. M. (1991). Asian elephant threatened. *Nature, 352*, 274.

de Candolle, A. (1820). *Essai elementaire de geographie botanique Dictionnaire des Sciences Naturelles* (Vol. 18). Levrault: Strasbourg; cited in Cox, C. B., & Moore, P. D. (1973). *Biogeography: An ecological and evolutionary approach*. Oxford: Blackwell Scientific.

Degen, T., Devillez, F., & Jacquemart, A.-L. (2005). Gaps promote plant diversity in beech forests (Luzulo-Fagetum), North Vosges, France. *Annals of Forest Science, 62*(5), 429; cited in Morrison et al. (2006).

Dey, S. C. (1991). Depredation by wildlife in fringe areas in North Bengal with special reference to elephant damage. *Indian Forester, 117*(10), 901–908.

Dingle, H., & Drake V. A. (2007). *What is migration*? 57(2). www.biosciencemag.org. WWF IUCN/Species Survival Commission 2008, Strategic planning for species conservation: A Handbook 1.0, Gland, Switzerland.

Doyle, S., Groo, M., Sampson, C., Songer, M., Jones, M., & Leimgruber, P. (2010). Human–elephant conflict—What can we learn from the news? *Gajah, 32*, 14–20.

Dudley, J. P. (1993). *Community ecology of the Asiatic elephant*. Gainesville, FL: Department of Wildlife and Range Sciences, School of Forest Resources and Conservation, University of Florida.

Eisenberg, J. F. (1981). *The mammalian radiation: An analysis of trends in evolution, adaptation and behaviour*. London: The Athlone Press.

Environmental Law Centre, I. U. C. N. (1976). *Annual report*. Bonn: IUCN.

Farina, A. (2006). *Principles and methods in landscape ecology toward a science of landscape*. Dordrecht, The Netherlands: Springer.

Fernando, P., Kumar, M. A., Williams, C. & Wikramanayake, E. (2008a). *Review of human elephant conflict: Mitigation measures practiced in South Asia*. (AREAS Technical Support Document Submitted to World Bank), World Bank–WWF Alliance for Forest Conservation & Sustainable Use.

Fernando, P., Kumar, M. A., Williams, C., Wikramanayake, E., Aziz, T. & Singh, S. M. (2008b). *Review of human–elephant conflict mitigation measures practiced in South Asia* (p. 253).

Fernando, P., Wikramanayake, E. D., Janaka, H. K., Jayasinghe, L. K. A., Gunawardena, M., Kotagama, S. W., et al. (2008c). Ranging behavior of Asian elephant in Sri Lanka. *Mammalian Biology, 73*, 2–13.

Fernando, P., Wikramanayake, E., Weerakoon, D., Jayasinghe, L. K. A., Gunawardene, M., & Janaka, H. K. (2005). Perceptions and patterns of human–elephant conflict in old and new settlements in Sri Lanka: Insights for mitigation and management. *Biodiversity and Conservation, 14*, 2465–2481.

Forman, R. T. T. (1995a). *Land mosaics: The ecology of landscapes and regions*. Cambridge: Cambridge University Press.

Forman, R. T. T. (1995b). Some general principles of landscape and regional ecology. *Landscape Ecology, 10*(3), 133–142.

Forman, R. T. T., & Godron, M. (1986). *Landscape ecology*. New York: Wiley.

Gajah, 1992 9 to 2013 39. www.asesg.org/gajah.htm.

Gajah. (2010). *Securing the future for elephants in India*. The Report of the Elephant Task Force Ministry of Environment and Forests, Government of India.

Gascon, C., Lovejoy, T. E., Bierregaard, R. O., Malcolm, J. R., Stouffer, P. C., Vasconcelos, H. L., et al. (1999). Matrix habitat and species richness in tropical forest remnants. *Biological Conservation, 91*, 223–229.

The Gazette of India, Part II Section 3 Subsection (ii), March 29 2012. No. 596. Govt. of India.

Green, B. H., Simmons, E. A., & Woltjer, I. (1996) *Landscape conservation. Some steps towards developing a new conservation dimension*. A draft report of the IUCN-CESP Landscape Conservation Working Group. Department of Agriculture, Horticulture and Environment, Wye College, Ashford, England.

Gunderson, L. H., Holling, C. S., Pritchard, Jr., L., & Peterson, G. D. (2002). Resilience of large-scale resource systems. In L. H. Gunderson & L. Pritchard Jr. (Eds.), *Resilience and the behavior of large-scale systems* (pp. 3–20). Washington, DC: Island Press.

Hedges, S. (2006). *Asian elephants: Status and threats elephant range states meeting*. Kuala Lumpur, Malaysia.

Hoare, R. (1995). Options for the control of elephants in conflict with people. *Pachyderm, 19*, 54–63.

Hoare, R. (1999). Determinants of human–elephant conflict in a land-use mosaic. *Journal of Applied Ecology, 36*, 689–700.

Hoare, R. E. (2000). African elephants and human in conflict: The outlook for co-existence. *Oryx, 34*, 34–38.

Hoare, R. E., & Du Toit, J. T. (1999). Coexistence between people and elephants in African savannas. *Conservation Biology, 13*, 633–639.

Humboldt, A. von (1807). *Geography of Plants*. English translation by S. Romanowski, 2009, University of Chicago Press.

Jayawardene, J. (2003). Twenty-year study of elephant conservation amidst development in Sri Lanka's Mahaweli project. In J. Jayawardene (Ed.), *Proceedings of the symposium for human–elephant relationships and conflicts* (pp. 93–97). Sri Lanka: Biodiversity and Elephant Conservation Trust.

Johnsingh, A. J. T., & Panwar, H. S. (1992). Elephant conservation in India—Problems and prospects. In P. Wegge (Ed.), *Mammal conservation in developing countries: A new approach* (pp. 36–56). Oslo: Agriculture University of Norway.

Johnsingh, A. J. T., Prasad, S. N., & Goyal, S. P. (1990). Conservation status of the Chilla–Motichur corridor for elephant movement in Rajaji–Corbett National Park area, India. *Biological Conservation, 52*, 123–138.

Knickerbocker, T. J., & Waithaka, J. (2005). People and elephants in Shimba Hills, Kenya. In R. Woodroffe, S. Thirgood, & A. Rabinowitz (Eds.), *People and wild life: Conflict or coexistence* (pp. 224–238). Cambridge: Cambridge University Press.

Kulandeival, S. (2010). *A paradigm shift in the elephant depredation in South Bengal*. Retrieved from www.bankuraforest.in.

Kupfer, J. A. (1995). Landscape ecology and biogeography. *Progress in Physical Geography, 19*, 18–34.

Lahiri-Choudhury, D. K. (1980). An interim report on the status and distribution if elephants in northeast India. In J. C. Daniel (Ed.) *The status of the Asian elephant in the Indian subcontinent* (pp. 43–58). IUCN/SSC Report. Bombay, India: Bombay Natural History Society.

Lahiri-Choudhury, D. K. (1988). The Indian elephant in a changing world. In C. Borden (Ed.), *Cotemporary Indian tradition* (pp. 301–321). Washington, DC: Smithsonian Institution Press.

Lahiri-Choudhury, D. K. (Ed.). (1999). *The great Indian elephant book: An anthology of writings on elephants in the Raj*. New Delhi, India: Oxford University Press.

Laurance, W. F., Laurance, S. G., Ferreira, L. V., Rankin-de Merona, J. M., Gascon, C., & Lovejoy, T. E. (1997). Biomass collapse in Amazonian forest fragments. *Science, 278*, 1117–1118.

Lhamo, N. (2008). *Extent of human–elephant conflicts and the threat to elephant populations in southern Bhutan.* Thesis submitted in partial fulfillment of the requirement for the degree of master of science in mountain forestry, University of Natural Resources and Applied Life Sciences, Vienna, Austria.

Li, H. & Reynolds, J. F. (1995a). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Li, H., & Reynolds, J. F. (1995b). On definition and quantification of heterogeneity. *Oikos, 73*(2), 280–284.

Li, H. & Wu, J. (2007). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Linkie, M., Dinata, Y., Nofrianto, A., & Leader Williams, N. (2007). Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. *Animal Conservation*.

Linkie, M., Smith, R. J., & Leader-Williams, N. (2004). Mapping and predicting deforestation patterns in the lowlands of Sumatra. *Biodiversity and Conservation*.

Living Planet Report. (2006). Published in October 2006 by WWF–World Wide Fund For Nature (formerly World Wildlife Fund), Gland, Switzerland.

Logan, W., Brown, E. R., Longrie, D., Herb, G., & Corthell, R. A. (1985). Edges. Pages 115–127. In E. R. Brown, tech. ed. *Management of wildlife and fish habitats in forests of western Oregon and Washington*. USDA For. Serv. Publ. No. R6-F&WL-192-1985.

Mabry, K. E., & Barrett, G. W. (2002). Effects of corridors on home range sizes and interpatch movements of three small mammal species. *Landscape Ecology, 17*(7), 629–636. cited in Morrison. Michael L. Bruce G., Mannan R. William (2006)

MacArthur, R. H. (1972). *Geographical ecology*. New York: Harper & Row.

Malhotra, K. C. (1995). Biodiversity conservation and community development in south West Bengal. In H. Wood, M. Melises, & K. Warner (Eds.) *Biodiversity through Community Forestry* (pp. 36–53). PECCFT Report 12, Bangkok, Thailand: Regional Community Forestry Training Centre, Kesetsart University.

Malhotra, K. C., Debal, D., Dutta, M., Vasula, T. S., Yadav, G., & Adhikari, M. (1993, Summer). The role of non-timber forest products in village economics of south-west Bengal. In *Rural Development Forestry Network, Odi* (pp. 1–8). Network Paper 15d.

Malhotra, K. C., & Poffenberger, M. (1989, June 21–22). Forest regeneration through community protection. In *Proceedings of Working Group meeting on Forest Protection Communities, Calcutta, India*.

Marcot, B. G., Croft, L. K., Lehmkuhl, J. F., Naney, R. H., Niwa, C. G., Owen, W. R., et al. (1998). *Macroecology, paleoecology, and ecological integrity of terrestrial species and communities of the interior Columbia River Basin and portions of the Klamath and Great Basins (USDA Forest Service General Technical Report PNW-GTR-410)*. Portland, OR: Pacific Northwest Research Station, USDA Forest Service.

Martin, G. J. (2008). *Ethnobotany: A methods Manual* (People and plants conservation series). London: Earthscan.

Martin, P., & Bateson, P. P. G. (1993). *Measuring behaviour: An introductory guide*. Cambridge: Cambridge University Press.

Mavatur, A., Mudappa, D., & Shankar Raman, T. R. (2010). Asian elephant Elephas maximus habitat use and ranging in fragmented rainforest and plantations in the Anamalai Hills, India. *Tropical Conservation Science, 3*(2), 143–58.

McGarigal, K., & Marks, B. (1995). FRAGSTATS: Spatial analysis program for quantifying landscape structure. *USDA Forest Service Generation Technical Report*. PNWGTR351.

Menon, V., Tiwari, S. K., Easa, P. S., & Sukumar, R. (Eds.). (2005). *Right of passage: Elephant corridors of India* (Conservation reference series, Vol. 3). New Delhi, India: Wildlife Trust of India.

Milroy, A. J. W. (1923). Elephant catching in Assam. *Journal of the Bombay Natural History Society, 29*(3), 803–811.

Ministry of Environment and Forest (MoEF). (2012, March 29). The Gazette of India, Part II Section 3 Subsection (ii) March 29 2012. No. 596. Govt. of India.

Moeur, M. (1997). Spatial models of competition and gap dynamics in old-growth *Tsuga heterophylla/Thuja plicata* forests. *Forest Ecology and Management, 94*, 175–86; cited in Morrison et al. (2006).

Morgan, K. A., & Gates, J. E. (1982). Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. *Journal of Wildlife Management, 46*, 933–944.

Morrison, M. L., Marcot, B. G., & Mannan, R. W. (2006). *Wildlife–habitat relationships: Concepts and applications* (3rd ed.). Washington, DC: Island Press.

Nath, C. D., & Sukumar, R. (1998). *Elephant–human conflict in Kodagu, Southern India: Distribution patterns, people's perception and mitigation methods*. Bangalore, India: Asian Elephant Conservation Centre, Centre for Ecological Science, Indian Institute of Sciences.

Naveh, Z. (1987). Biocybernetic and thermodynamic perspectives of landscape functions and land use patterns. *Landscape Ecology, 1*, 75–83.

Nyhus, P. J., Osofsky, S. A., Ferraro, P., Madden, F., & Fischer, H. (2005). *Bearing the costs of human-wildlife conflict: The challenges of compensation schemes* (Conservation biology series, Vol. 9, p. 107). Cambridge: Press Syndicate of the University of Cambridge.

Nyhus, P., & Tilson, R. (2004). Agroforestry, elephants, and tigers: Balancing conservation theory and practice in human-dominated landscapes of Southeast Asia. *Agriculture, Ecosystems & Environment, 104*(1), 87–97.

Nyhus, P. J., Tilson, R., & Sumianto. (2000). Crop-raiding elephants and conservation implications at Way Kambas National Park, Sumatra, Indonesia. *Oryx, 34*(4), 262–274.

O'Malley, L. S. S. (1908). *Bengal District Gazetteers*. Calcutta, India: Bankura.

O'Malley, L. S. S. (1911a). *Bengal District Gazetteers.* Calcutta, India: Bankura.

O'Malley, L. S. S. (1911b). *Bengal District Gazetteers.* Calcutta, India: Midnapore.

O'Neill et al. (1988). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Olivier, R. (1978). Distribution and status of the Asian elephant. *Oryx, 14*, 379–424.

Paine, R. T. (1966). Food web complexity and species diversity. *American Naturalist, 100*, 65–75.

Palit, S. (1989). Present status of Forest Protection Committee; Forest regeneration through community protection: The West Bengal experience. In K. C. Malhotra & M. Poffenberger (Eds.), *Proceedings of the working group meeting of FPC, Calcutta, 21–22 June 1989* (pp. 5–8). Calcutta, India: West Bengal Forest Department.

Palit, S. (1991). Participatory management of forest in West Bengal. *Indian Forester,* 117(5).

Panda, C. (1996). *The decline of Bengal Zamindars*. New Delhi: Oxford University Press.

Phanthavong, B., & Santiapillai, C. (1992). Conservation of elephants in Laos. *IUCN/SSC Asian Elephant Specialist Group Newsletter, 8*, 25–33.

Pielou. (1977). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Poole, C. (1991). Even the Mekong. *BBC Wildlife, 9*(8), 523.

Power, M. E., et al. (1996). Challenges in the quest for keystones. *Bioscience, 46*, 609–620.

Prachi, M., & Jayant, K. (2013). Past, present and future of wild elephants in Maharashtra, India, Gajah 39. *Journal of Asian Elephant Specialist Group*.

Project Elephant Report (2009). West Bengal. http://www.envfor.nic.in/pc/pc.html.

Ramakrishnan, B., Sivaganesan, N., & Srivastava, R. (1997). Human interference and its impact on elephant corridors in South India. *Gajah, 18*, 1–20.

Rangarajan, M., Desai, A., Sukumar, R., Easa, P. S., Menon, V., Vincent, S., et al. (2010) *Securing the Future for Elephants in India*. The Report of the Elephant Task Force Ministry of Environment and Forests.

Ranney, J. W., Bruner, M. C., & Levenson, J. B. (1981). The importance of edge in the structure and dynamics of forest islands. In R. L. Burgess & D. M. Sharpe (Eds.), *Forest island dynamics in man-dominated landscapes* (pp. 67–94). New York: Springer; cited in McGarigal and Marks, 1995, FRAGSTATS manual. Report of the Elephant Task Force (Gajah). Securing the Future for Elephants in India. Ministry of Environment and Forests, Aug. 31, 2010.

Renolds (1988). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Risser, P. G., Karr, J. R., & Forman, R. T. T. (1984). *Landscape ecology. Directions and approaches*. Illinois Natural History Survey Special Publication number 2, Champaign.

Romme. (1982). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Rood, E. J. J. (2006). *The status and distribution of the Sumatran Elephant in Aceh, Indonesia*. WWF, Yayasan Gajah Sumatra, Amsterdam.

Root, K. V. (1998). Evaluating the effects of habitat quality, connectivity, and catastrophes on a threatened species. *Ecological Applications, 8*(3), 854–65.

Roy, M., Choudhury, S. P., Kamalakanth, P., Dutta, C., Kundu, S., Dasgupta, S., et al. (2010). Translocation of a wild elephant from southern West Bengal to northern West Bengal—An approach to reduce elephant–human conflict. *Gajah, 33*, 8–11.

Salter, R. E. (1989). Lao PDR forest resources and protected areas. *ESACP Environment News, 7*(3), 20–22.

Santiapillai, C. (1987). Translocation of elephants in Lampung, Sumatra. *IUCN/SSC Asian Elephant Specialist Group Newsletter, 2*, 15–20.

Santiapillai, C., Chambers, M. R., & Ishwaran, N. (1984). Aspects of the ecology of the Asian elephant Elephas maximus L. in the Ruhuna National Park, Sri Lanka. *Biological Consentation, 29*, 47–61.

Santiapillai, C., & Jackson, P. (1990). *The Asian elephant: An action plan for its conservation*. Gland, Switzerland: IUCN.

Santiapillai, C., & Ramono, W. S. (1993). Why do elephants raid crops in Sumatra? *Gajah, 11*, 54–55.

Santra, A. K., Samanta, A. K., & Pan, S. (2007). Measures adopted to combat migratory elephants in South West Bengal forests. *Gajah, 27*(2007), 42–47.

Sar, C. K., & Lahiri-Choudhury, D. K. (2006). Man-elephant conflict: The Keonjhar (Orissa) experience. *Journal of the Bombay Natural History Society, 103*, 286–293.

Sar, C. K., & Varma, S. (2004). *Asian elephants in Orissa*. Bangalore, India: Asian Nature Conservation Foundation.

Sarma, P. K., Talukdar, B. K., Baruah, J. K., Lahkar, B. P., & Hazarika, N. (2008). A geo-spatial assessment of habitat loss of Asian elephants in Golaghat District of Assam. *Gajah, 28*, 25–30.

Shahi, S. P. (1980). Report of the Asian elephant specialist group-central India task force. In J. C. Daniel (Ed.), *The status of the Asian elephant in the Indian sub-continent. IUCN/SSC Report*. Bombay, India: Bombay Natural History Society.

Shahi, S. P., & Chowdhury, S. (1986). *The status and distribution of elephants in Central India*. Report of the IUCN/SSC Asian Elephant Specialist Group.

Sitati, N. W., Walpole, M. J., & Leader-Williams, N. (2005). Factors affecting susceptibility of farms to crop raiding by African elephants: using a predictive model to mitigate conflict. *Journal of Applied Ecology, 42*, 1175–1182.

Silva, M., Harling, L. A., Field, S. A., & Teather, K. (2003). The effects of habitat fragmentation on amphibian species richness of Prince Edward Island. *Canadian Journal of Zoology, 81*(4), 563–73.

Singh, A. K. (2006). *Ecological Investigation of Human-Elephant Conflicts in South West Bengal*. Ph.D. thesis. Saurashtra University. p. 36.

Singh, A. K., Singh, R. R., & Chowdhury, S. (2002). Human–elephant conflicts in changed landscapes of South West Bengal, India. *Indian Forester, 128*(10), 1119–1131.

Sivaganesan, N. (1993). Status of feral elephant in Andamans. In J. C. Daniel (Ed.), *Proceedings of the International Seminar on the Conservation of the Asian Elephant*. Bombay, India: Bombay Natural History Society.

Sivaganesan, N., & Kumar, A. (1995). Status of feral elephants in Andamans. In J. C. Daniel & H. Datye (Eds.), *A week with elephants* (pp. 97–119). Bombay, India: Bombay Natural History Society.

Spellerberg, I. F., & Gaywood, M. J. (1993). *Linear features: Linear habitats and wildlife corridors*. Peterborough, Ontario, Canada: English Nature.

Stamps, J. A., Buechner, M., & Krishnan, V. V. (1987). The effects of edge permeability and habitat geometry on emigration from patches of habitat. *American Naturalist, 129*, 533–552.

State Forest Report West Bengal. (2006–2007). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

State Forest Report West Bengal. (2007–2008). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

State Forest Report West Bengal. (2008–2009). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

State Forest Report West Bengal. (2009–2010). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

State Forest Report West Bengal. (2010–2011). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

State Forest Report West Bengal. (2011–2012). Government of West Bengal, Directorate of Forests, Office of the Principal Chief Conservator of Forests, Kolkata, India.

Stati, N. W., Walpole, M. J., Smith, R. J., & Leader-Williams, N. (2003). Predicting spatial aspects of human–elephant conflict. *Journal of Applied Ecology, 40*, 667–677.

Strelke, W. K., & Dickson, J. G. (1980). Effect of forest clearcut edge on breeding birds in Texas. Journal of Wildlife Management, 44, 559–567.

Sukumar, R. (1989a). Ecology of the Asian elephant in southern India. I. Movement and habitat utilization patterns. *Journal of Tropical Ecology, 5*, 1–18.

Sukumar, R. (1989b). *The Asian elephant: Ecology and management*. Cambridge: Cambridge University Press.

Sukumar, R. (1990). Ecology of the Asian elephant in southern India, II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology, 6*, 33–53.

Sukumar, R. (1991a). The management of large mammals in relation of male strategies and conflict with people. *Conservation Biology, 55*, 93–102.

Sukumar, R. (1991b). *The Asian elephant: Ecology and management*. Cambridge: Cambridge University Press.

Sukumar, R. (2003). *The living elephants: Evolutionary, ecology, behavior, and conservation*. New York: Oxford University Press.

Sukumar, R. (2006). A brief review of the status, distribution and biology of wild Asian elephants *Elephas maximus*. *International Zoo Yearbook, 40*, 1–8. doi:10.1111/j.1748-1090.2006.00001.x.

Talukdar, B. K., & Barman, R. (2003). Man–elephant conflict in Assam, India: Is there any solution? *Gajah, 22*, 50–56. www.asesg.org/gajah.htm.

Tchamba, M. N. (1993). Number and migration patterns of savanna elephants (*Loxodonta africana africana*) in northern Cameroon. *Pachyderm, 16*, 66–71.

Tchamba, M. N. (1996). History and present status of the human/elephant conflict in the Waza-Logone region, Cameroon, West Africa. *Biological Conservation, 75*, 35–41.

Tchamba, M. N., Bauer, H., Hunia, A., De Iongh, H. H., & Planton, H. (1994). Some observations on the movements and home range of elephants in Waza National Park, Cameroon. *Mammalia, 58*, 527–533.

Temple, S. A., & Cary, J. R. (1986). Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology, 2*(4), 340–347.

The Report of the Elephant Task Force. (2010, August 31). *Gajah: Securing the future for elephants in India.* New Delhi: Ministry of Environment and Forests.

Thomas, J. W., Maser, C., & Rodiek, J. E. (1978). Edges—Their interspersion, resulting diversity, and its measurement. Pages 91–100. In R. M. Degraff, tech. coord. *Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States*. Gen Tech Rep PNW-64.

Thomas, J. W., Maser, C., & Rodiek, J. E. (1979). Edges. Pages 48–59 In J. W. Thomas, tech. (Ed.), *Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington*. USDA For. Serv. Handb. 553.

Thouless, C. R. (1994). Conflict between humans and elephants on private land in northern Kenya. *Oryx, 28*(2), 119–127.

Turner, M. G. (1989). Landscape ecology: The effect of pattern on process. *Annual Review of Ecology and Systematics, 20*, 171–97.

Turner, M. G. (2005). Landscape ecology: What is the state of the science? *Annual Review of Ecology, Evolution, and Systematics, 36*, 319–44.

Turner, M. G., Gardner, R. H., & O'Neill, R. V. (1995). Ecological dynamics at broad scales. *BioScience*, S–29.

Verner, J., & Boss, A. S. (1980). *California wildlife and their habitats: Western Sierra Nevada*. General Technical Report PSW-37. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station.

Wagner, H., Sydow, E. von. (1888). Wagners Methodischer Schul Atlas.Gotha: Parthes; cited in Cox and Moore (1931). *Biogeography, an ecological and evolutionary approach*, 7th edition, Blackwell.

Weltzin, J. F., Loik, M. E., Schwinning, S., Williams, D. G., Fay, P. A., Haddad, B. M., et al. (2003). Assessing the response of terrestrial ecosystems to potential changes in precipitation. *BioScience, 53*(10), 941–52; cited in Morrison et al. (2006).

Wiens, J. A. (1976). Population response to patchy environments. *Annual Review of Ecology and Systematics, 7*, 81–120; cited in Forman T. T. *Land mosaics, the ecology of landscapes and regions*, Cambridge University Press 1995.

Wines et al. (1993). Cited in Wu, J., Hobbs, R. J. (Eds.) *Key topics in landscape ecology*. Cambridge: Cambridge University Press.

Woodroffe, R., Thirgood, S., & Rabinowitz, A. (Eds.). (2005). *People and wild life: Conflict or coexistence?* Cambridge: Cambridge University Press.

Wu, J., Hobbs, R. J. (Eds.) Key topics in landscape ecology. Cambridge: Cambridge University Press.

Wu, J., & Loucks, O. L. (1995). From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. *Quarterly Review of Biology, 70*, 439–66.

www.bankura.in

www.elephant-news.com/

www.elephantconservation.org/

www.westbengalforest.gov.in/

Index

A
Agriculture
  land, nearness to, 72
  land use, 123
  natural forest clearance for, 7
  reduction of forest covers, 59

B
Behavioural study
  anthropogenic causes, of damage, 143
  community perception survey, 138
  elephants change, 147
  Forest Department roles and response, 145
  local people, in settling, 144
  local people's attitude, 137

C
Climate change, 8
Corridors, 36

D
Dalma elephants, 21
Dalma Wildlife Sanctuary (DWS)
  administrative arrangement, 29
  climate, 28
  legal status, 25, 30
  location, 27
  natural vegetation, 31–33
  physiography, 28
Disturbance model, 85, 89

E
Ecological biodiversity
  DWS
    administrative arrangement, 29–30
    climate, 28
    location, 27
    physiography, 28
  factors of forest fragmentation
    agriculture, 59
    forest cover and habitat, shrinkage of, 56–58
    land use and land cover change, 54–56
    mining and quarrying activities, 60
    roads and railways construction, 59–60
  landscape
    changing species association, 41–43
    composition and configuration, 34
    ecology and analysis, 30
    forest types and composition, 40
    heterogeneity, 34–39, 43–53
  PFD
    administrative structure, 22
    climate, 23
    geographical boundary, 21
    geology and physiography, 22
    natural vegetation, 23
  theory, 20
Elephant migration
  chemical immobilisation, 155
  crop guarding, 153
  dispersal
    biogeographical processes, 98
    conversion, 118
    crop calendar and appearance, 117

N. Das Chatterjee, *Man–Elephant Conflict*, SpringerBriefs
in Environmental Science, DOI 10.1007/978-3-319-31162-3

Elephant migration (*cont.*)
habitat requirements, 99
historical perspective, 99
routes and temporal shifts, 104–115
seasonal dependence, 115
volume and duration of stay, 101
habitat development, 156
herd away, 152
throwing stones or shooting arrows, 154
wild capture, 155
Elephants
food, nutrition and changing food habits, 65
habitat analysis, 64
home range, 63
migration (*see* Elephant migration)
shelter
agricultural land, 72
distance from road/noise source, 78
forest cover, vegetation succession and movement, 68
ground cover, 72
temporal observation, 66
water source, 79

F
Forest cover and habitat, shrinkage of, 56–58

G
Gap analysis model, 90

H
Habitat
disturbance model, 85, 89
gap analysis model, 90–93
heterogeneity, 85
vegetation composition and structure model, 86
Habitat suitability index (HSI) model, 93
Hullah party, 152
Human–animal conflict, 98
Human–elephant conflict
appropriate management options, 14
causes of, 4, 6–8
characteristics, 14
consequences, 6, 8
in India, 9–11
Panchet Forest Division, 13
research, 13
in Sri Lanka, 9
in West Bengal, 11
data and methods
collection, 17
detection study, 15
field-based information, 14
habitat–elephant relationship, 16
habitat intervention and consequences assessing, 16
nature of, 17
understanding migration behaviour, 16
wildlife habitat, appraisal of, 15
year-wise information, 15
forests and increase trends, structural characteristics, 13
literature, 6
local people, in settling, 144
Panchet Forest Division, 5
serious socio-economic and political issues, 5
temporal pattern, 14
zone
attacks, 130
community involvement, 158
consequences, 150
demographic characteristics, 121
forest ecosystem resources, 126–130
land use pattern, 122–126
land use planning, 158
life and assets damage, 131
livelihood pattern, forest fringe dwellers, 122
major findings, 161
manage, national level, 156
project elephant, 156
resistance, 132

J
Joint forest management (JFM) programmes, 42, 57, 127

K
Keystone species, 4

L
Landscape
changing species association
forest destruction, 41
phytocoenosis, 41
plant species, 41
sal-dominated forest, 42
composition and configuration, 34
ecology and analysis, definition, 30

forest types and composition, 40
heterogeneity, 34
composition metrics and percentage, 44
core metrics, 48
corridors, 36
edge metrics, 47
forest patch metrics, 44
metrics, 38
mosaic, 37
patch arrangement/connectivity metrics, 35, 49
patch shape metrics, 48
Land use and cover change, 54
Land use and cover map, 92
Largest patch index (LPI), 44

M
Mining and quarrying activities, 60
Myriad research, 11

N
Non-timber forest products (NTFPs), 4

P
Panchet Forest Division (PFD), 21, 125
administrative structure, 22
of Bankura district, 5, 13
climate, 23
definition, 21
geographical boundary, 21
geology and physiography, 22
land enclosed during 2007–2012, 57
landholding characteristics, 123
legal status, 25, 30
natural vegetation, 23, 25
rainfall distribution, 24
temperature distribution, 24
temperature variation, 73
Panchet Soil Conservation Division, 21
Patches, 35
arrangement/connectivity metrics, 49
shape metrics, 48
Permanent Settlement Act, 41
Project elephant, 156
Purbi Singhbhum district, 8

R
Roads and railways construction, 59–60

S
Social Forestry Project, 42
State Forest Report, for West Bengal, 8
Sumatran elephants, 6

T
Traditional methods, 11

V
Vegetation composition and structure model, 86

W
West Bengal
consequences in, 11
State Forest Department of, 10