APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN ASSESSING HABITAT, RESOURCE AVAILABILITY AND ITS MANAGEMENT IN TADOBA-ANDHARI TIGER RESERVE

A THESIS SUBMITTED FOR AWARD OF THE DEGREE

OF

DOCTOR OF PHILOSOPHY

IN

WILDLIFE MANAGEMENT

BY

YOGESH DUBEY

Wildlife Institute of India, Dehra Dun

TO

FOREST RESEARCH INSTITUTE (DEEMED UNIVERSITY)

P.O, NEW FOREST. DEHRA DUN- 248 006

February, 1999

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Vinod B. Mathur, D.Phil. (Oxon.)
Faculty of Wildlife Management

CERTIFICATE

*This is to certify that thesis entitled " **Application of Geographic Information System and Remote Sensing in Assessing Habitat, Resource Availability and its Management in Tadoba-Andhari Tiger Reserve** " submitted for the award of **DOCTOR OF PHILOSOPHY IN WILDLIFE MANAGEMENT** to Forest Research Institute (Deemed University), Dehradun (U.P), is a record of bonafide research work carried out by Shri Yogesh Dubey under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma and it fulfils all the requirements laid down in the ordinance of Forest Research Institute (Deemed University).*

VMathur

Dr. Vinod B. Mathur

Supervisor

Place:Dehra Dun

Date: 12 February, 1999

Post Box No. 18, Chandrabani, Dehradun - 248 001. India.
EPABX : 640112 to 640115; Fax : 0135-640117; Gram : WILDLIFE
E-Mail : wii@giasdl01.vsnl.net.in

TABLE OF CONTENTS

CONTENTS **PAGE.NO**

Acknowledgements

I am thankful to Shri. S. K. Mukherjee, Director, Wildlife Institute of India for granting permission and necessary funding for carrying out this study.

A very special thank to my supervisor Dr. V. B. Mathur for his guidance and support. I extend my deep gratitude to him for constantly encouraging me forward and for providing valuable comments on my work and closely monitoring its progress. Thank you very much Sir for all the discussions about fieldwork, the manuscript and practicalities of life.

I am grateful to Maharashtra State Forest Department for granting permission and logistic support to carry out the study. Mr. Mohan Karnat, Director, Tadoba Andhari Tiger Reserve is acknowledged for his constant support and friendliness.

I thank Shri B.M.S Rathore and Shir. Anil Bharadwaj for giving their critical comments on Chapter nine. Shri V. B. Sawarkar needs a special mention as all through he strongly supported the study and took great care of me.

I thank Dr. K. Sankar and his entire lab staff particularly Vinod Thakur who was of immense help in analyzing scats. I thank Dr. A.J.T.Johnsingh, Dr. Ravi Chellam, Dr. Y.V. Jhala and Shri Qamar Quereshi for their critical comments and help.

I owe my thanks to the entire Computer staff. I particularly thank Shri Rajesh Thapa, Shri. Panna Lal and Shri. Navneet Gupta who helped a lot in GIS analysis. My special thanks to Shri. M. S. Rana, Librarian and his wonderful team who helped me with finding books and related literature. I particularly thank Verma Ji for his readiness to help.

A special thanks to Narayan, Prakash, Sudhakar and Suresh, four of my field companions and assistants who made life not only simple but also eventful in field. I shared some of the most memorable moments of my life with them. I am thankful to Gayakwad and Vashishth at Tadoba who gave me good company. My friend Sirish who looked after my well being and kept on visiting me regularly from Nagpur and the great time we had together in Tadoba. I thank all the forest guards and foresters who worked with me for three years and I learned so much from them.

Back at the Institute I thank my friends, Rashid for giving me company through long dark nights with hot steaming tea, Meera for her non stop entertainment with all that humour and her instantly brewed stories, Tanushree for bugging me all the time and ensuring that I woke up on time every day and got back to work, Prachi for her constant inspiration and Kala who helped me with statistical analysis. I thank Antesh for his help in typing some part of bibliography. Anil, Reena and their little son Pacey for all those light moments I shared with them along with green label tea.

Finally, I thank my parents, who all these years constantly supported me and cheered me when things became rough.

10th February, 1999 Yogesh Dubey

LIST OF FIGURES

LIST OF TABLES

PAGE.NO

LIST OF PLATES

Chapter 1

PROJECT ORIGINS, OBJECTIVES AND ORGANIZATION OF THE THESIS

1.1. PROJECT ORIGIN

The Protected Area Network comprising National Parks (NPs) and Wildlife Sanctuaries (WLS) has grown steadily in India; from 10 National parks and 127 Sanctuaries covering an area of 25,000 km^2 in 1970 to 85 National Parks and 461 Sanctuaries covering an area of 1,50,814.08 km^2 (Panwar & Mathur, 1992; National Wildlife Database, 1998). Yet only few of them have been able to develop a systematic procedure for data collection and analysis on ecological and non ecological parameters, which would be of relevance for the effective management of these areas.

Protected area planning is a process that provides an established framework for consistent and systematic planning, development and administration of the park resources, programmes and facilities (Kesely, 1985). Detailed inventories and analysis are required to determine what recreational development are needed and how they fit the character of the site and what limitations are presented by the site resources (Raymon Sims, 1987). The planning process is inherently spatial in character so the use of Geographic Information System (GIS) technology greatly facilitates the process.

There have been many studies on wild ungulates in India in the last three decades (Schaller, 1972; Rice, 1984; Green, 1985; Haque, 1990; Mathur, 1991; Karanth & Sunquist, 1992; Sankar, 1994; Khan, 1994; Sathyakumar, 1994;

Sharma; 1995; Singh, 1995; Mishra, 1993; Shahar, 1990; Acharya, 1997; Raman, 1997,; Acharya, 1997; Raman, 1997; Pabla, 1998; Bhatnagar, 1998, Manjrekar, 1998), but most of these studies were species based. Not much emphasis has been given to community based studies on ungulates. Ungulates form an important part of the prey base for all large carnivores and the survival of endangered carnivore population has a direct correlation with the abundance of wild ungulates.

The present study attempts to determine the distribution and abundance pattern of ungulate species in Tadoba Andhari Tiger Reserve (TATR) and to assist in the development of a computerised wildlife database on spatial as well as non spatial attributes, which could be used for conservation monitoring and evaluation as well as to help in resource management planning. With the increasing pressure on forests it has become important to focus the research effort which could eventually lead to a better management of our PAs. Such community based studies along with information on biotic and abiotic factors would provide a better picture of the ecological status of the PA and in this case a newly formed Tiger Reserve. To achieve the overall conservation goals this alone would also not be sufficient. We need to develop user friendly and efficient tools for easy analysis of data to enhance the decision making process (Giles & Fujita, 1989). Geographical Information System (GIS) and Remote Sensing are two main tools currently in focus. They have wide application in assisting the management of forests and wildlife. A database from field observations can be created in the GIS domain. Resource planning requires information on the physical attributes of the PA (soil, slope, aspect, climate), socio economic aspects of land use in the protected area (grazing customs, firewood collection patterns and location of villages) (Yonzon *et al*, 1991). Because the GIS contains spatially and geographically referenced information, any combination of data at any scale can be viewed. GIS provides the ability to produce output at all stages of planning. Because resources are never static and the conceptual plan is in constant state of change, it is important to be able to update and repeat analysis. GIS database facilitates the necessary updation and repeat analysis at any stage and for any number of times.

The overall approach of the study is to revive the use of existing forest compartment system for gathering baseline ecological information. These compartments would serve as 'Ecological bench-marks' for monitoring and evaluation (Mathur, 1991). The compartment is the smallest sub-division of a forest and is defined as territorial unit of a forest permanently demarcated for the purpose of administration, description and record keeping. These compartments can not only be shown on maps but can also be easily located on ground and therefore can be surveyed in different seasons and years. The data so generated would help in establishing a park level computerised wildlife database. This in collation with GIS technology will be used in management planning and monitoring process (Pabla, 1998).

Monitoring is an important requisite for managing living resources. Monitoring helps in understanding the ecological interrelationship between various components of ecosystem (Mathur, 1992). Monitoring of resources in a protected area is therefore becoming an important management activity. There is an urgent need to develop a simple, efficient and ecologically sound monitoring programmes for the PAs.

The field work for this study was initiated in January, 1994 and continued upto June, 1997. Laboratory investigations and analysis of spatial database was taken up subsequently. The writing up of the thesis continued upto January, 1999.

1.2. OBJECTIVES

This study has the following objectives:

1) To study the population structure, distribution and abundance of various ungulate species of Tadoba- Andhari Tiger Reserve.

2) To study the habitat utilization patterns and preferences of ungulates and their relation with the habitat.

3) To study the food habit and prey selection by tiger.

4) To study the forest resource dependency and utilization pattern by local communities.

5) To generate a spatial database in GIS domain which would facilitate management decision making.

6) To demonstrate the utility of remote sensing and GIS in wildlife conservation studies.

1.4. Organisation Of Thesis

The thesis is organised in ten chapters. The first chapter deals with the project origin and objectives of the present study. The second chapter contains a detailed description of study area. Chapter three gives an account of spatial database created in Geographic Information System domain. Chapter four is on vegetation mapping, structure and classification. This chapter also deals with the utility of remotely sensed data in deriving the land cover and land use map and discusses results of vegetation sampling. Chapter five is on the animal densities, distribution and habitat utilization. This chapter also deals with habitat - herbivore relationships. Chapter six is on predation ecology of Tiger. Chapter seven contains the results obtained from the study on unique habitats. Chapter eight deals with forest fires and their risk modelling. Chapter nine is on people and their resource dependency on forest and patterns of resource utilization. Chapter ten contains the general discussion and conclusion of the study. References and Appendices are cited after chapter ten.

Chapter 2

THE STUDY AREA

2.1. INTRODUCTION

Tadoba Andhari Tiger Reserve (TATR) is situated in the civil district of Chandrapur, Maharashtra State (Plate 2.1). This area of Maharashtra is known as Vidharbh region. The area lies between 20°-04'.53"N to 28°-25'.51"N latitude to 79°-13'.13"E to 79°-33'.34"E longitude. The TATR covers four tehsils namely Chandrapur, Bhadrawati, Chimur and Warora.

2.2. CONSTITUTION

Tadoba National Park, which forms a part of TATR is named after picturesque Tadoba lake (made famous by legendary Gond Chief Taruwas) was established in 1955 vide section 3(i) of Madhya Pradesh National Parks Act, 1955. This was the first national park of Maharashtra. Prior to it, Tadoba was a shooting block up to 1935 when it was declared as a sanctuary. In the year 1986, the Government of Maharashtra declared the Andhari Wildlife Sanctuary which consists of famous shooting blocks of Kolsa, Karwa and Moharli. Andhari Wildlife Sanctuary along with Tadoba National Park form the composite area of Tadoba Andhari Tiger Reserve which was established in Feb, 1994.

Extent of the total area of the TATR is 619.76 km^2, out of which Tadoba National Park comprises of 116.54 km^2 and the remaining 503.22 km^2 belongs to Andhari Wildlife Sanctuary, (Plate 2.2). The total area is divided into 179 forest

Plate 2.1 Map of India Showing Location of Study Area

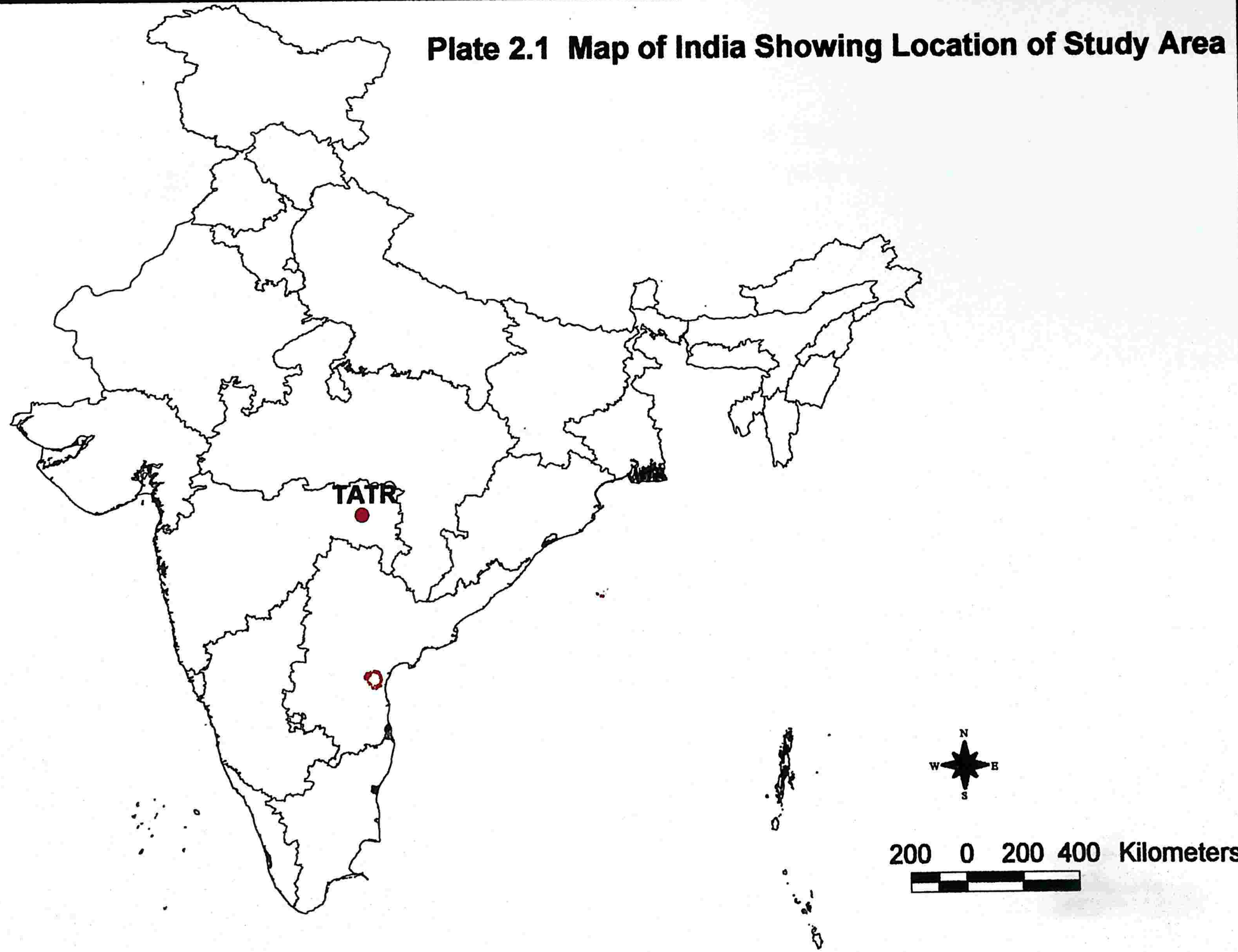
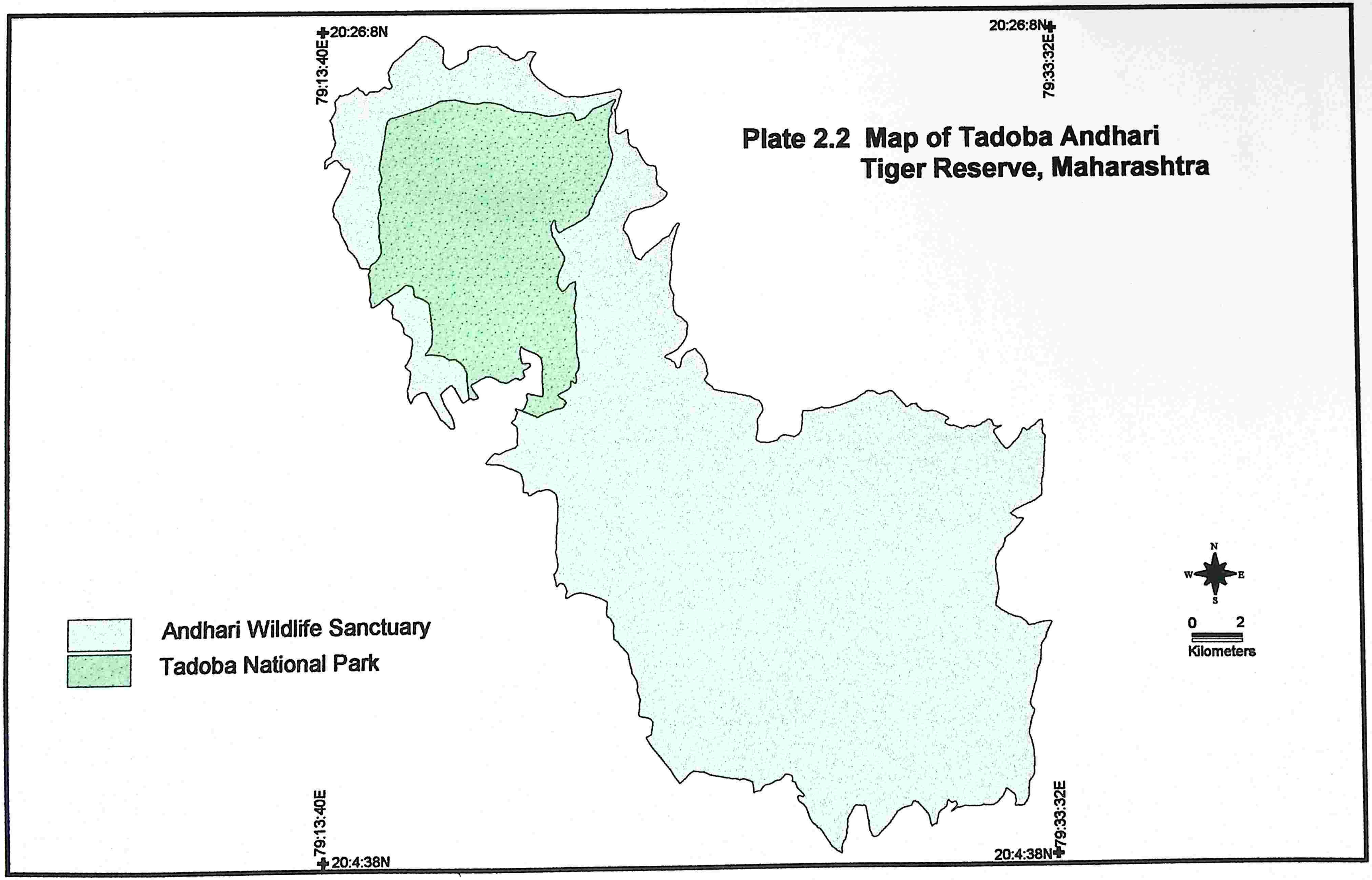


Plate 2.2 Map of Tadoba Andhari Tiger Reserve, Maharashtra



compartments.

2.3. GEOLOGY, ROCK AND SOIL

Vindhyan sand stones occur in almost all the areas which consists of sand stone, shales and lime stone. The shale is intercalated with limestone. The prominent rocks are the fine grained vitreous sandstone with a uniform or splashed pink colour, brownish sand stone, purplish shale and quartzite. The soil in the greater part is sandy with stretches of yellow brown and black loam. True black cotton soil is found in the plains except where forests are heavily degraded. On the slopes the soil layer is thin and vegetation is sparse. The top of the hillocks are mostly barren and covered with exposed rocks.

2.4. TERRAIN

The area is mostly undulating and hilly in north. The southern part of the reserve is mostly plain. The Chimur hills start from the east of Chimur and run southwards with gradually diminishing height. In the basin of the hills lie Tadoba lake which is of 120 ha spread. Elevation ranges from lowest of 212 metres. m.s.l to 360 m m.s.l.

2.5. CLIMATE

The area has a sub-tropical climate with three distinct seasons- summer, monsoon and winter. Climate is characterised by hot summers, well distributed rainfall during south-west monsoon and a general dryness. Winters are from December to February. This is followed by summers from March to June. The monsoon arrives in first week of July and continues till September. However, cyclonic rains are received during the remaining part of the year.

2.5.1. TEMPERATURE AND HUMIDITY

Climatically, this area is hot and dry. The summers are extremely hot. The maximum recorded temperature is 49.2°C. Figure. 2.1 shows the trends in temperature. The air is generally dry except during the south-west monsoon season when the humidity exceeds 70 percent. The summer months are the driest when the relative humidity in the afternoon is between 20 - 25 percent.

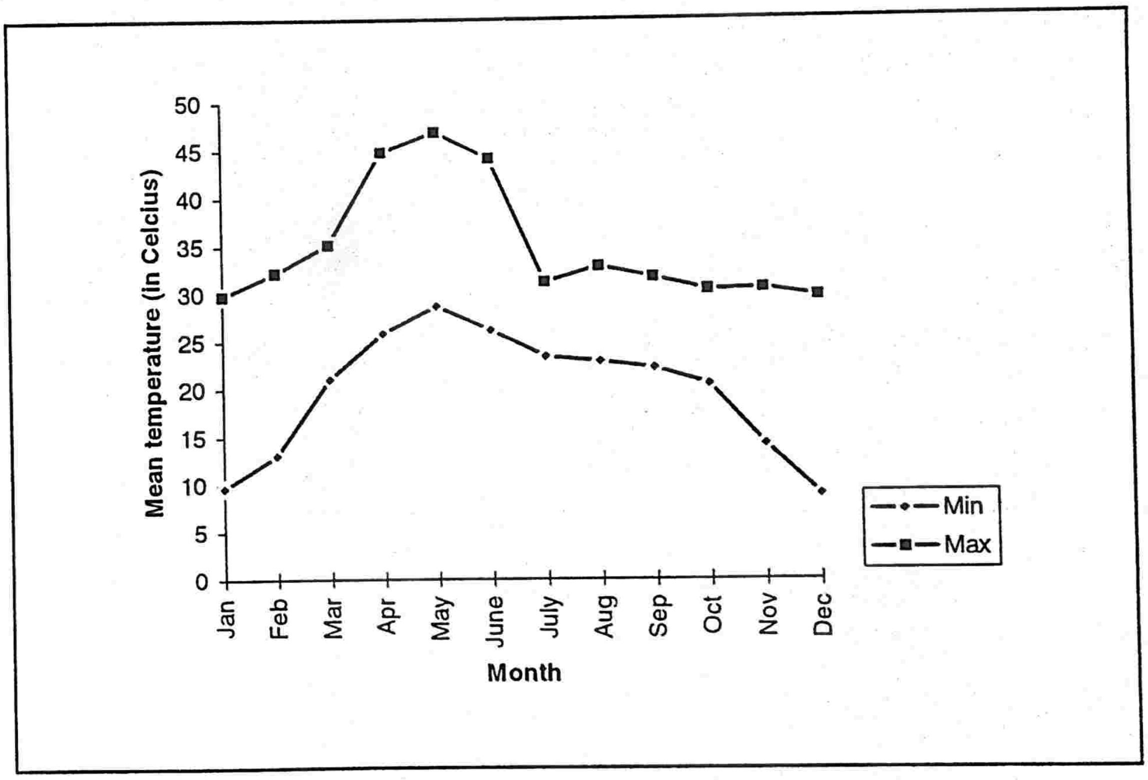


Figure 2.1 Variation in mean maximum and mean minimum temperature in TATR (1994 - 1997)

2.5.2. RAINFALL PATTERN AND DISTRIBUTION

The rainy season is sultry and humid and falls between July and October. The south west monsoon brings nearly 90% of the total annual precipitation. Most of the rainfall occurs in the month of July through October. Trends in rainfall patterns are shown in Figure. 2.2. Figure 2.3 shows the trend in mean number of wet days in TATR.

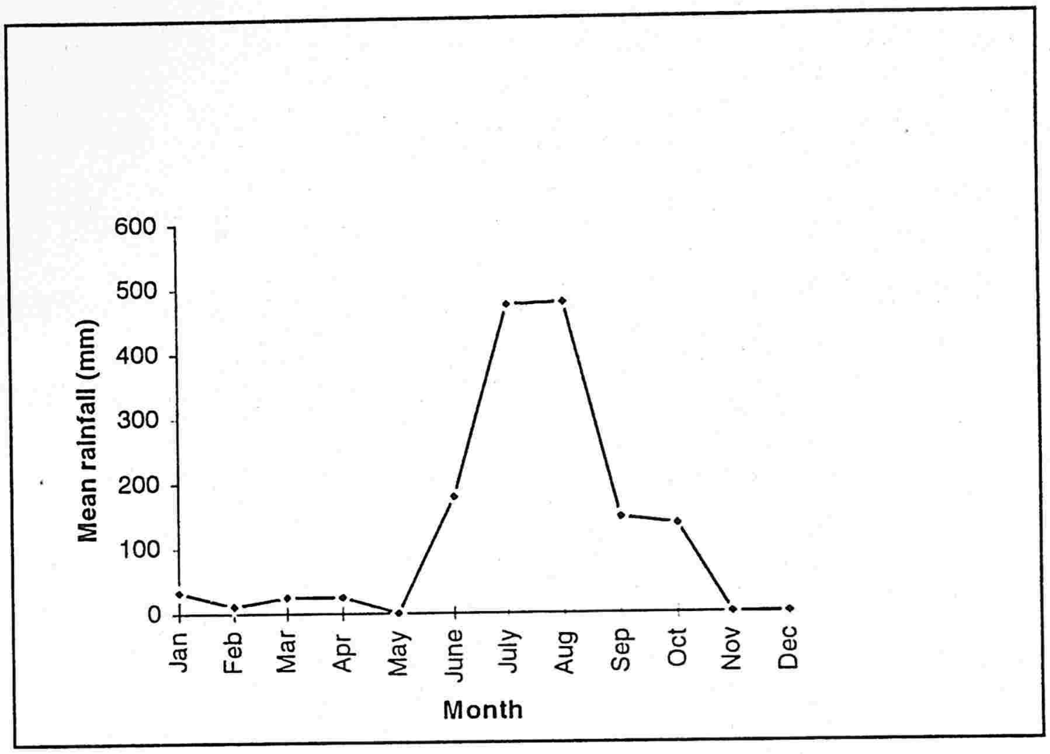


Figure 2.2 Variation in mean monthly rainfall in TATR (1994 -1997)

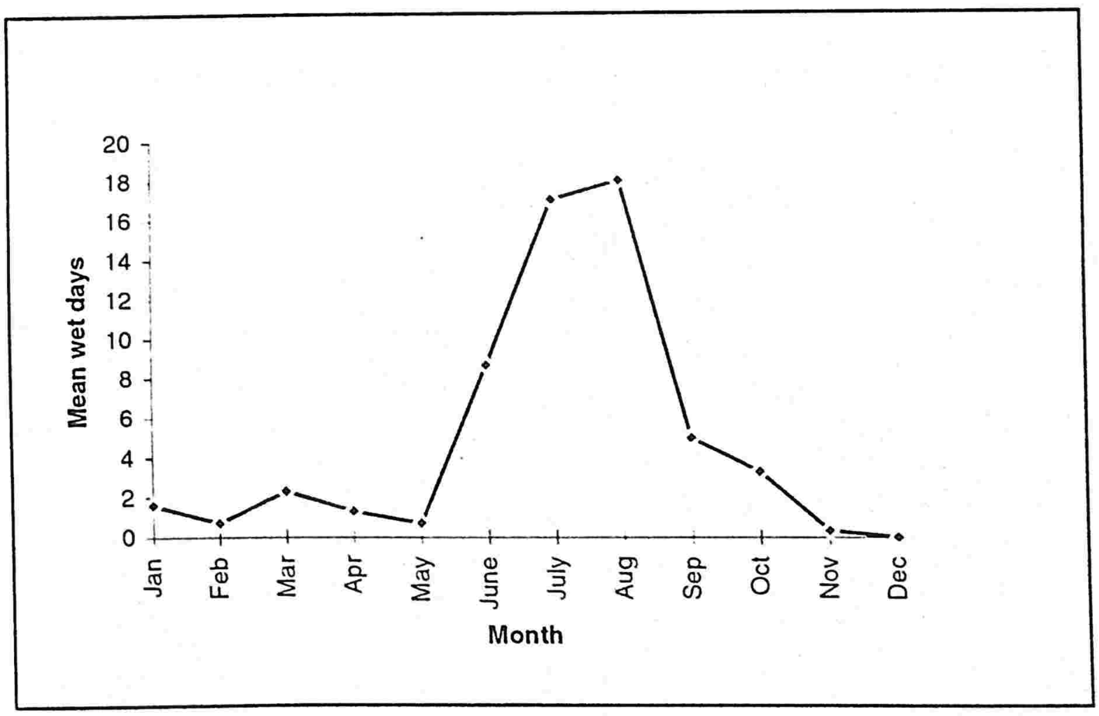


Figure 2.3 Variation in mean number of wet days in TATR (1994-1997)

2.6. FLORA

Tadoba Andhari Tiger Reserve has Southern tropical dry deciduous forest - 5A/16 (Champion & Seth 1968). Fairly large area is dominated by Teak (*Tectona grandis*). The main associates of Teak are Bija (*Pterocarpus marsupium*), Dhaora (*Anogeissus latifolia*), Ain (*Terminalia tomentosa*), Mahua (*Bassia latifolia*), Tendu (*Dyospyros melanoxylon*), Salai (*Boswellia serrata*), Sehna (*Lagerstromia parviflora*) etc. Bamboo (*Dendrocalamus strictus*) forms the middle storey in almost all the communities and in certain cases understorey also.

2.7. FAUNA

Tiger (*Panthera tigris*) is the keystone species and major management inputs are focussed towards its conservation. A total of 42 mammals have been check listed in the study area during the course of field work. Other carnivores include Leopard (*Panthera pardus*), striped hynae (*Hynae hynae*), Wild dog (*Cuon alpinus*), Jungle cat (*Felis chaus*), Desert cat (*Felis sylvestris ornata*). Rusty spotted cat (*Priobailurus rubiginosa*) was reported for the first time during this study. Jackal (*Canis aureus*) and a wolf (*Canis lupus*) occur in the western fringe of the reserve. Sloth bear (*Melursus ursinus*) also occurs in fairly large numbers. Major herbivores in Tadoba are Gaur (*Bos gaurus*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), Barking deer (*Muntiacus muntjac*), Nilgai (*Boselaphus tragocamelus*), Chowsinga (*Tetracerus quadricornis*), Wild pig (*Sus scrofa*), and Langur (*Presbytes entellus*).

2.8. PEOPLE

There are six villages inside the TATR which lie in the Andhari Sanctuary. The area is dominated by Gonds and Mana tribes. Gonds have a rich history in the area. Once the rulers of the Southern Vidharba area they were pushed into forest by repeated invasions by Marathas.

Gonds and Manas mainly survive on the products derived from the forest. Trees like Mahua (*Bassia latifolia*) and Tendu (*Dyospyros melanoxylon*) are considered to be lifeline by these people as they provide food for them. Lifestyles have definitely changed over the years and so is the landuse pattern which in turn has affected the forested landscape. The main sources of livelihood are minor forest produce, agriculture and labour works, if available.

2.9. VISITORS

TATR receives three kinds of visitors. First are the tourist who come to visit the reserve to see wildlife. Their number is about 72,000 per annum and most of them visit in Oct-Nov and April-May-June. Second, are travellers who pass through Reserve and use it as thoroughfare for going to Chimur-Nagpur from Chandrapur and vice-versa. Strict regulations are imposed on the traffic. Thoroughfare is allowed only from six in the morning to six in the evening. Heavy vehicles like goods carrier are not allowed. Three State transport corporation buses ply between Chandrapur and Tadoba for tourists who come from far off places. Two buses ply form Chimur to Chandrapore for local people to facilitate their movement to near by townships. Third category of visitors are the pilgrims.

They camp inside the reserve in large congregations and use resources from the forest like fuel wood etc. Chances of forest being subjected to fires during their visitation becomes very high. Tadoba deo " the tribal deity" is worshipped in the months of April and Dec-Jan.

2.10. HISTORY OF PAST MANAGEMENT, PRESENT PRACTICES & RESEARCH

2.10.1. General

There are no human settlements in Tadoba National Park (TNP) but there are six villages inside Andhari Wildlife Sanctuary (AWS). There are ten villages on the periphery of the sanctuary where protected forest has been included in the sanctuary.

The above mentioned six villages are totally dependent on the forests. There are 54 villages within 5 km radius of TATR which are also dependent on forest resources for fuel wood, small timber and cattle grazing. AWS came into existence in 1986 and soon after that regular forestry operations were stopped inside the (PA). The employment opportunities from forestry activities outside the PA are insufficient to provide regular means of livelihood. As a result the economic condition of these people is poor.

2.10.2. Timber Operations Including Bamboo And Firewood Harvest

As per Champion's classification the forest type in the park and the sanctuary is Southern Tropical Dry Deciduous (sub group 5a/ca/1B) having Teak as dominant species. The forests of the area are composed of mixed species represented in their various stages of growth. Bamboo (*Dendrocalamus strictus*) dominates over a considerable extent of area. Till 1887, the forests were worked unsystematically. Gradually restrictions were imposed on the removal of timber, green fuel and bamboo but the forest produce like grass, dry fuel and minor forest produce were allowed to be removed from forest. Systematic fire protection works were introduced in 1873. There were no specific compartments numbers till that time.

A systematic working of the forest was started in 1927. A detailed stock mapping was carried out during 1925-26. Again during the revision of the working plan by Karat Singh, the stock mapping was carried out for the whole area. However, the area of TNP was excluded from the working plans (1927-28 to 1991-92) of Chandrapur division. The area of AWS was kept for working under the working plan till 1986 when sanctuary area was merged with TNP forest division. The area was worked under the Improvement Working Circle, Coppice with Reserve Working Circle and Bamboo Working Circle. With the amendment of Indian Wildlife (Protection) Act, 1972 in 1991, there was a total ban on the removal of any forest produce from the area.

2.10.3. RESEARCH

Tadoba though being one of the oldest National Park of the Maharashtra State has not given much emphasis to research. Not much has been done either by the forest department or any other Institution except for inventorising the flora and fauna. Mathur, 1991 studied the animal-habitat interactions as part of doctoral study, which formed the precursor to this study.

Chapter 3

GEOGRAPHICAL INFORMATION SYSTEMS DATABASE

3.1. INTRODUCTION

Databases are an important way of organizing and analysing large amount of information. The Geographic Information System (GIS) is described as " An organized collection of computer hardware, software, geographic data designed to efficiently capture, store, update and analyze all forms of geographically referenced data " (Anon. 1993).

Computers are quite powerful tool which facilitate the decision making process. Feedback and feed forward information can be used iteratively to improve the planning process (Giles & Fujita, 1989). Natural resource planners require information on geophysical attributes, socio economic aspects of land use in and around protected area and the animal communities. The most pressing problem faced by the management is the lack of reliable information, lack of funds and insufficient staff to process whatever information is available (Yonzon *et al* , 1991). For effective planning and in order to over come these problems, tools are required for analyzing and updating spatial information quickly and efficiently.

Geographic Information System (GIS) utilize computer based techniques for collating, displaying and overlaying multiple data layers. GIS has been widely used to model the habitat of a wide range of species (Tomlin *et al*, 1987; Young *et. al* 1987; Hodgson *et al* 1988; Agee *et al*, 1989 and Skidmore *et al*, 1996). The GIS thus allows optimum site location for various developments including optimizing, linear feature developments such as creation of roads and trails. The GIS analysis is dynamic and can be used in predictive way. Spatial data layers and large amount of attribute data can not only be linked together but also be used to generate scenarios which are easy to visualize and understand.

In order to achieve a better understanding of the process in which natural systems operate, the application of GIS technology in conjunction with remote sensing is getting wide acceptability (Natrajan, 1992, Dabral 1992, Legg 1995, Palihawadana 1995, Legg &Jewell 1995).

3.2. METHODS

The methodology mainly involved the input of spatial data concerning various map layers and associated attribute data. Attribute data was analyzed along with spatial data layers to produce result oriented derived thematic maps. The main sources of spatial data were the Survey of India (SOI), 1:50,000 toposheets, satellite imagery (IRS IB, LISS-II) geocoded False Color Composites, Global Positioning System (GPS) data, field data collected during study period and ancillary data taken from forest department records.

The spatial data layers like road, drainage, settlements, contours, boundaries were taken from SOI toposheets. One of the most important data layer on vegetation was derived from Satellite image (details described in chapter 4). This data was obtained from National Remote Sensing Agency (NRSA), Hyderabad. The data related to fire, grazing, human impact zones and water availability was generated through field study and in certain cases data was extracted from old records to determine the trends.

All the maps were digitized in Geographic Resource Analysis Support System (GRASS 4.0), UNIX based Work Station using calcomp digitizer. The attribute data was stored in Foxbase software and analysis was performed using SPSS + software. For analysis of spatial data GRASS 4.0, GRASS 4.1 and ARC/INFO were used. The entire geophysical database was ported on Sun Sparc 2 Work Station for spatial analysis.

3.3. RESULTS AND DISCUSSION

1. Map of legal status: Plate 3.1 shows the different areas along with their legal status as per the Indian Forest Act, 1927. The areas are shown as Reserve Forest (RF), Protected Forest (PF) and Non - forest enclaves (E). The extent of RF, PF and non - forest enclaves is 580 km^2, 20 km^2 and 17 km^2. This gives the total area of TATR as 617 km^2.

2. Administrative Map: Plates 3.2, 3.3 and 3.4 show the various administative units like range, round and beats. These maps can be effectively used for overlaying with other maps for meeting administrative needs.

3. Compartment Map: Plate 3.5 shows various compartments including settlements inside the TATR. As all management in TATR is based on compartments, all the derived maps have to be read with reference to the compartment map. Overlaying of the compartment layer over all other maps would have made derived maps complicated because of the small scale on which they were produced. Hence, a compartment map on acetate sheet is being provided in the thesis, which can be overlaid over any map for quick referencing and better understanding.

Plate 3.1 Legal Status Map of TATR

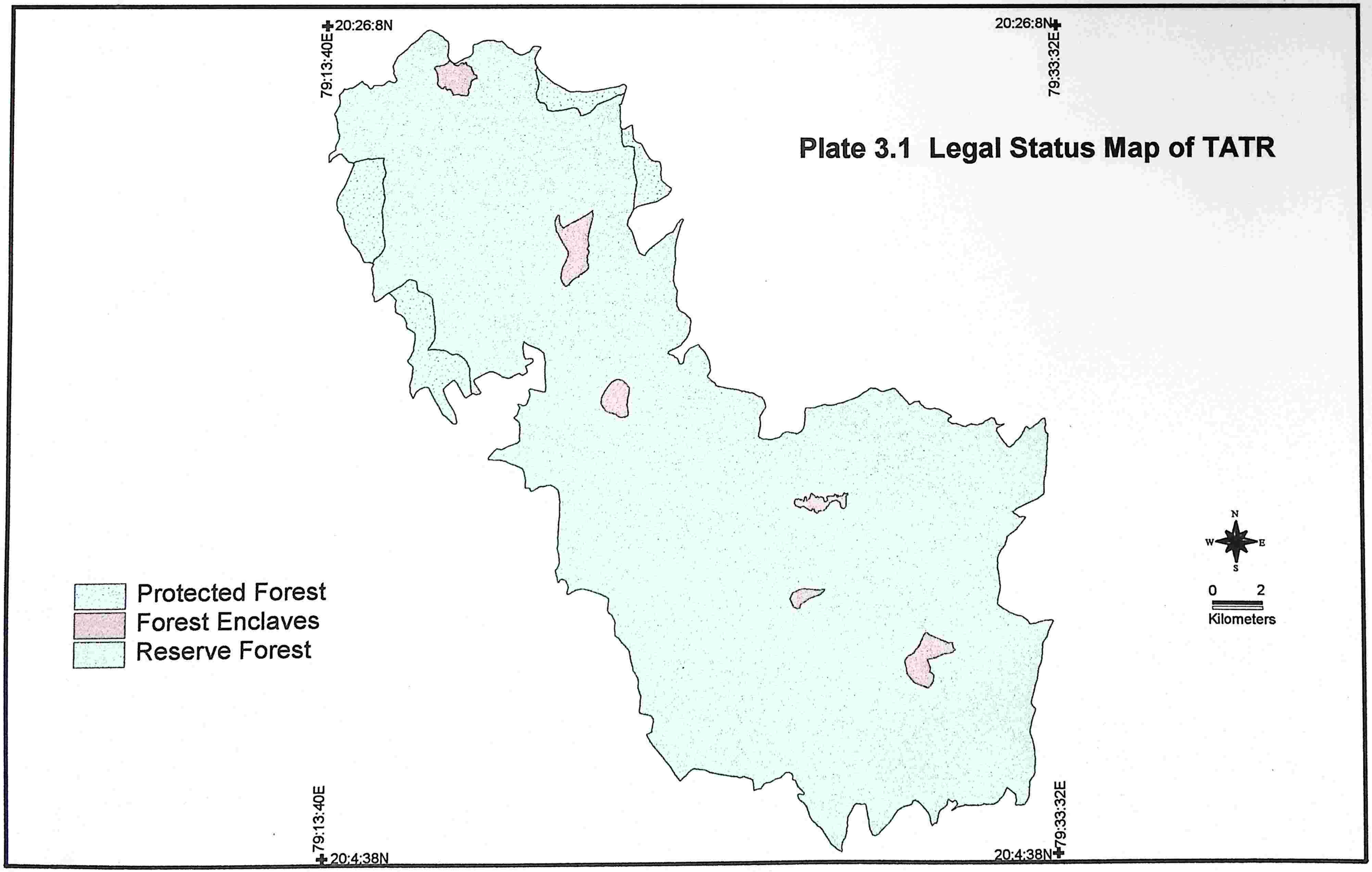


Plate 3.3 Round Map of TATR

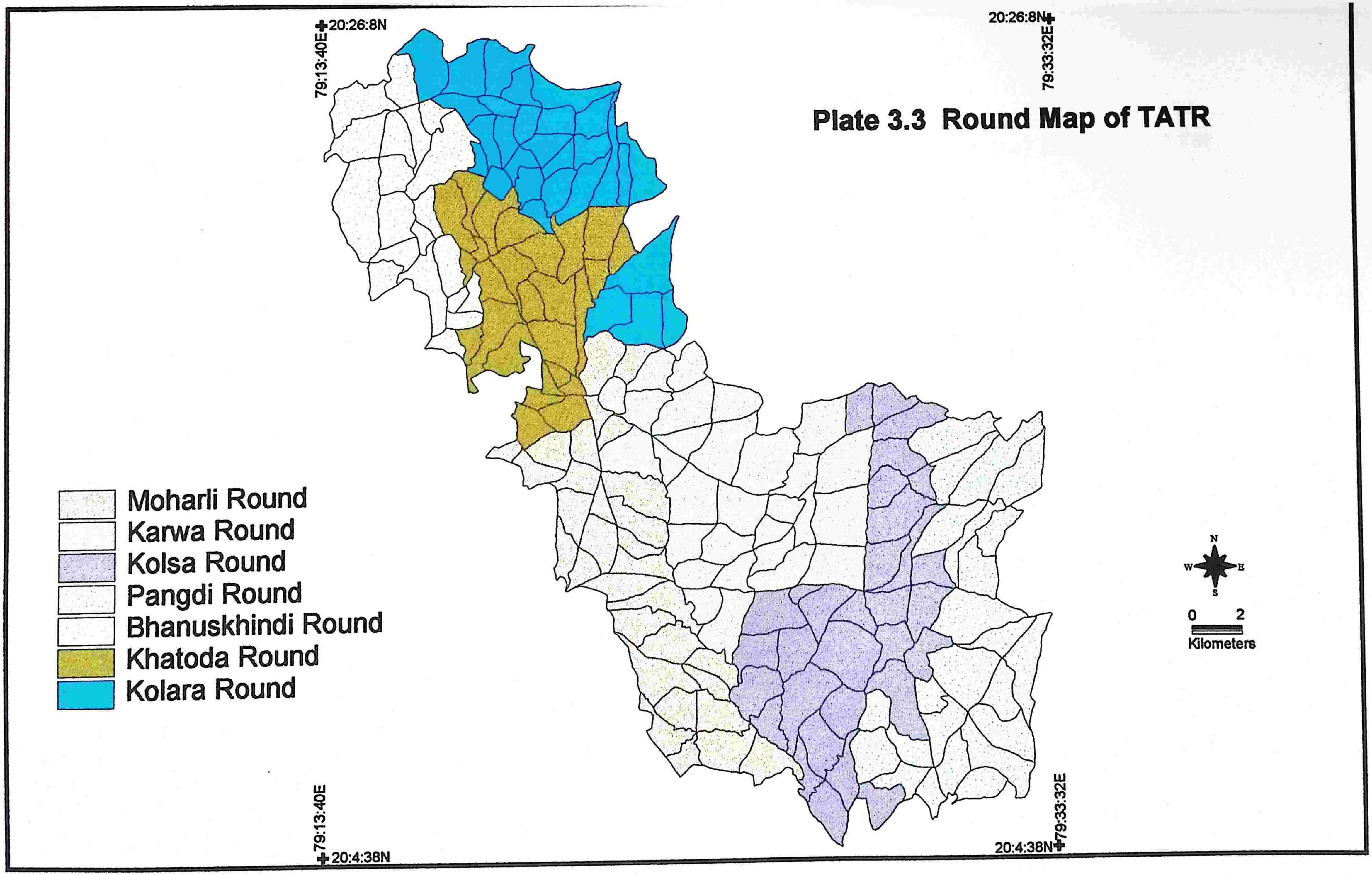


Plate 3.4 Beat Map of TATR

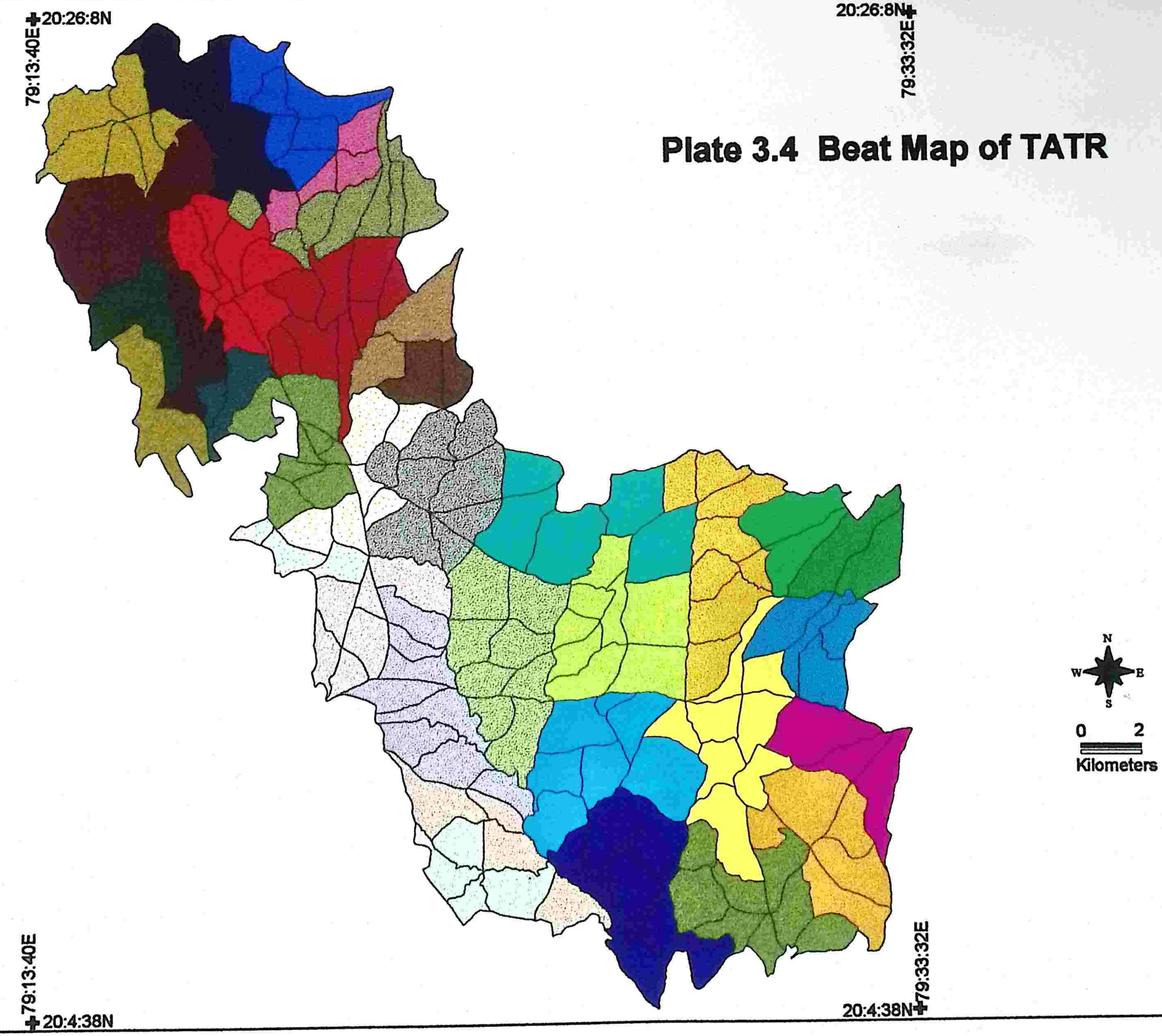
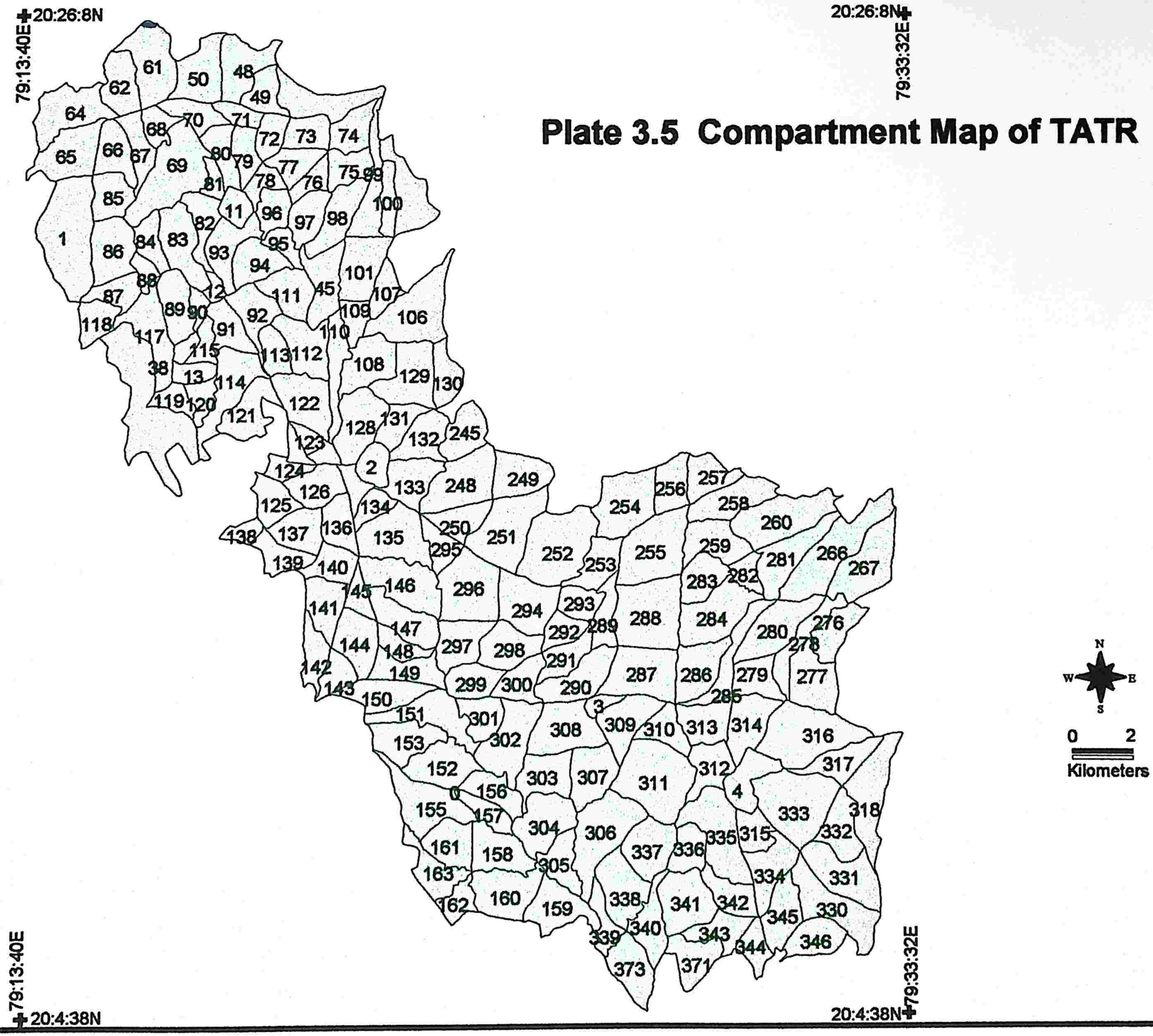


Plate 3.5 Compartment Map of TATR



4. Topographic map: Plate 3.6 shows the distribution of altitude classes in the reserve as per the SOI toposheets at an contour interval of 20m. The total area of the reserve has been divided in two elevation classes.

5. Digital Terrain Model (DTM): DTM's are generated through routing algorithm which is inbuilt in software. It does so by calculating neighbourhood attributes i.e., attributes which can be calculated by using height information from neighbouring points (Desmet and Govers, 1996). DTM's have been widely used by land managers and hydrologists for various things like determining flow paths (Lea, 1992), calculating upslope areas (Jenson and Domingue, 1988), drainage network detection (Mark, 1984) and identifying and delineating catchment areas (O' Callaghan and Mark , 1984). The DTM was prepared at 20m contour interval. These DTM's can also be used to prepare interpretive models for visitors and can be useful in planning other developments like construction of roads and trails inside the reserve. Plate 3.7 shows the Digital Terrain Model of TATR.

6. Drainage: Plate 3.8 presents all primary, secondary and tertiary drainage lines. Drainage maps can be very useful in planning soil and moisture conservation works which is a major management thrust area in most of the National Parks and Sanctuaries.

7. Road Map: Plate 3.9 shows the road network of the reserve. Roads were digitized from SOI 1:50,000 scale toposheets and Forest Department maps on the same scale. Roads are an integral part of any protected area management system as they are used for tourism and patrolling activities. It is important to

Plate 3.6 Topographic Map of TATR

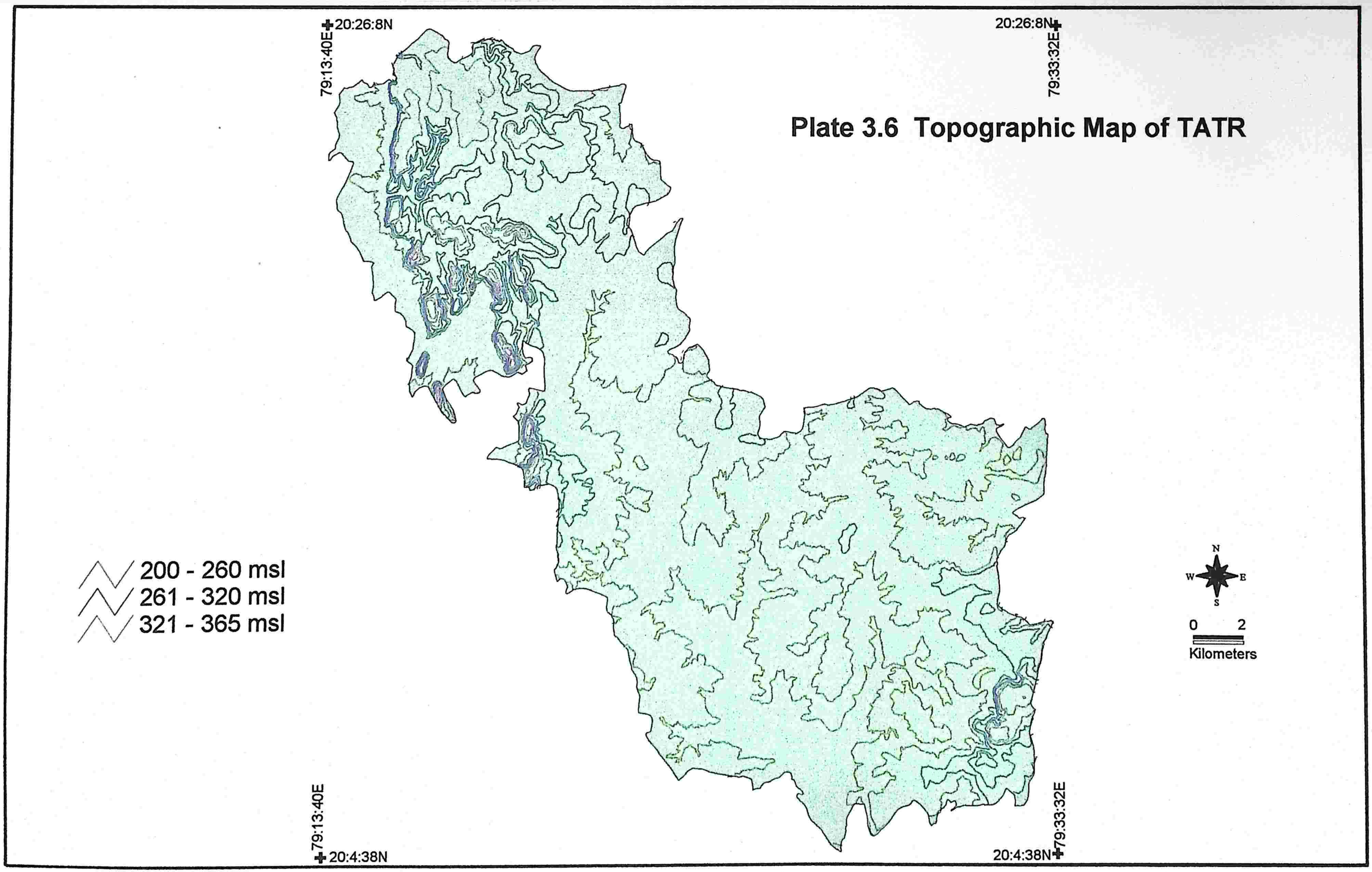


Plate 3.7 Digital Elevation Model of TATR

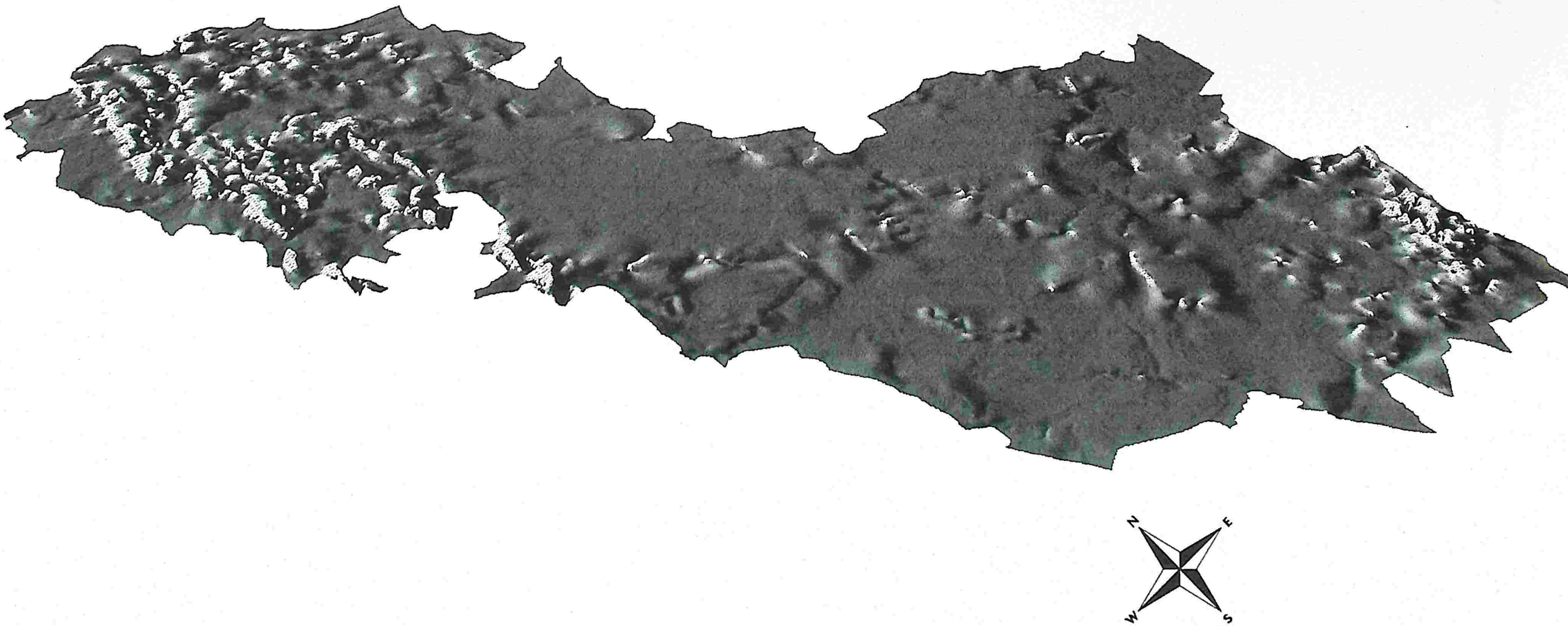


Plate 3.8 Drainage Map of TATR

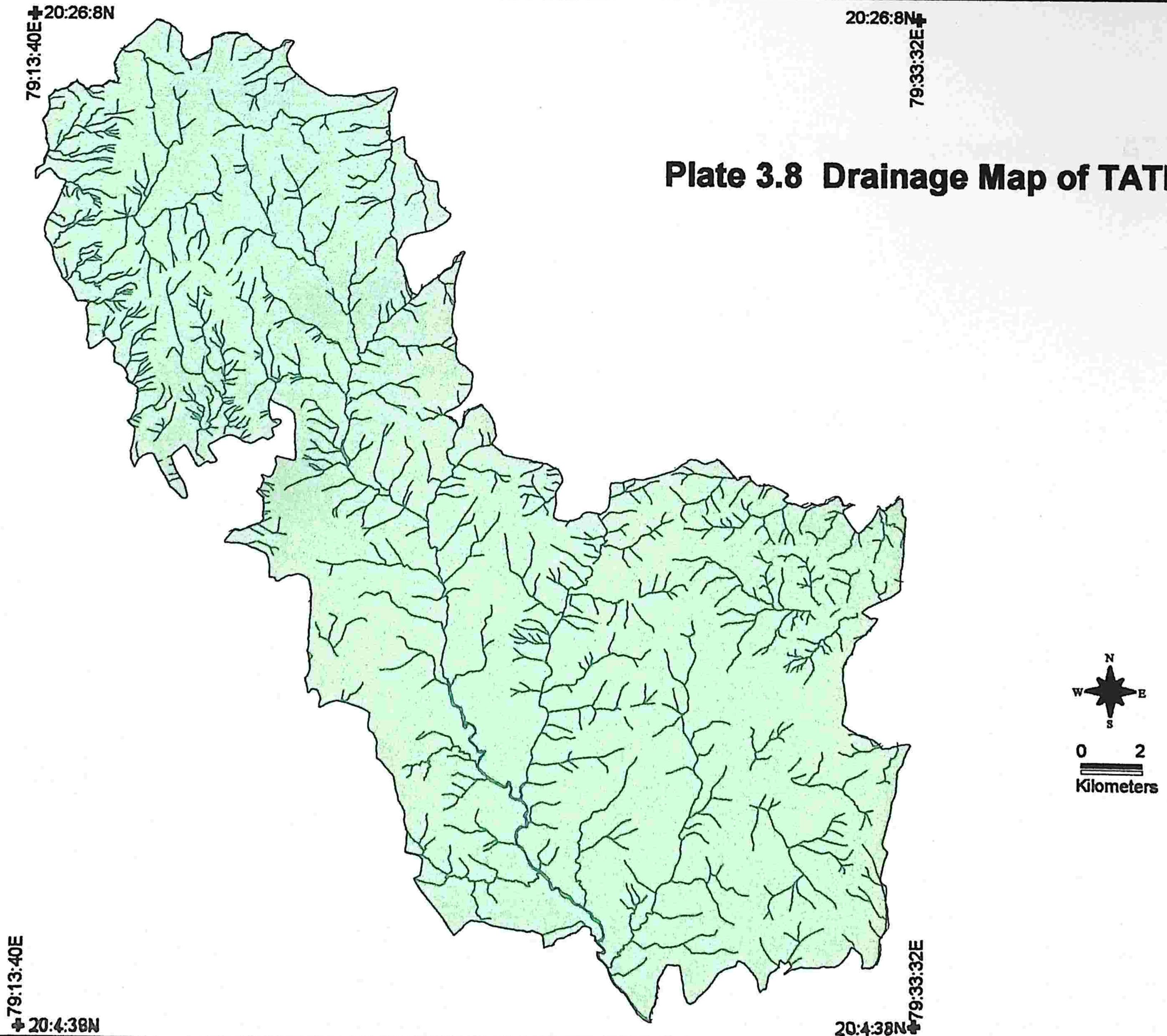


Plate 3.9 Road Network of TATR

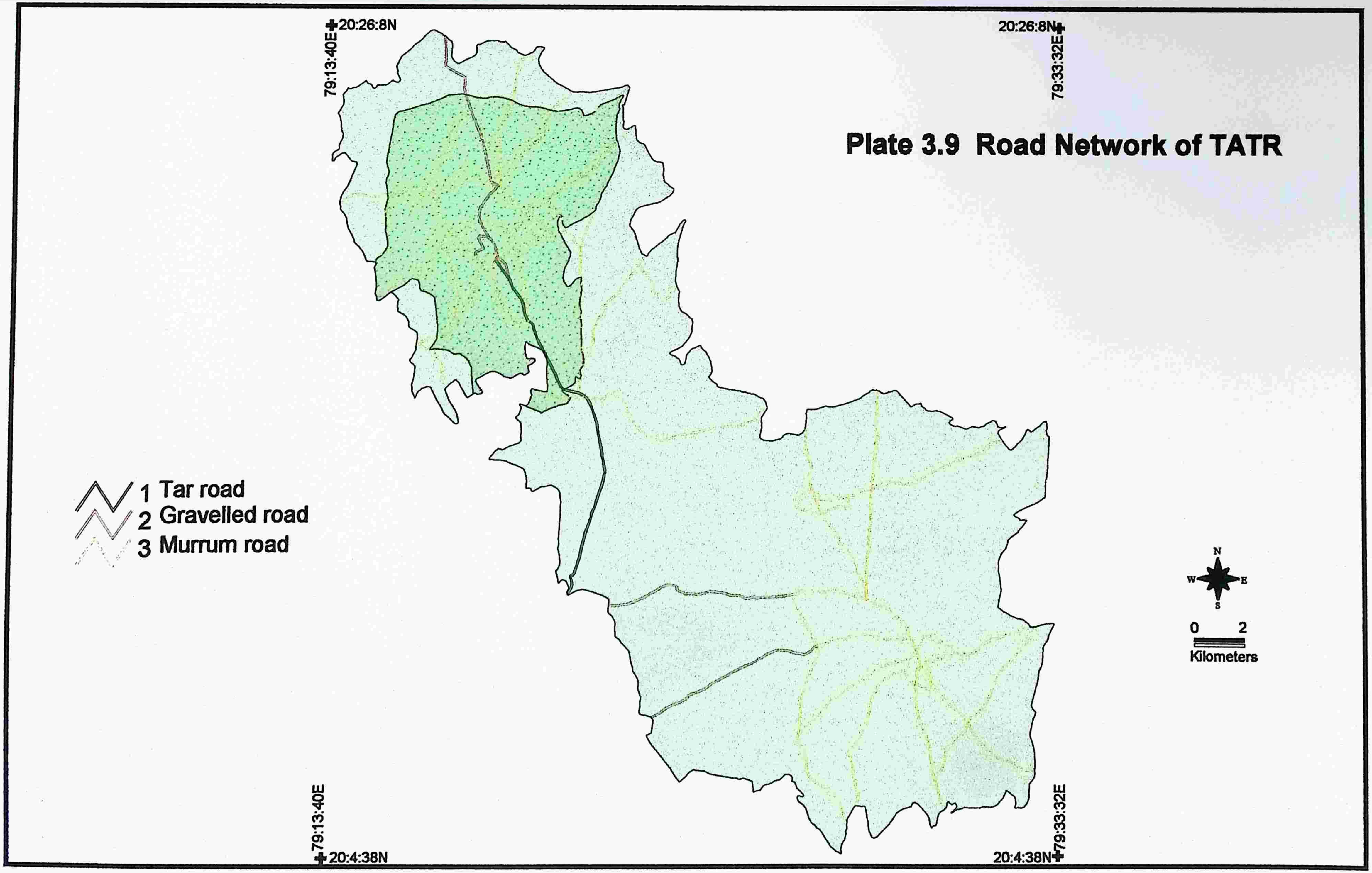


Plate 3.10 Artificial Waterhole Distribution Map of TATR

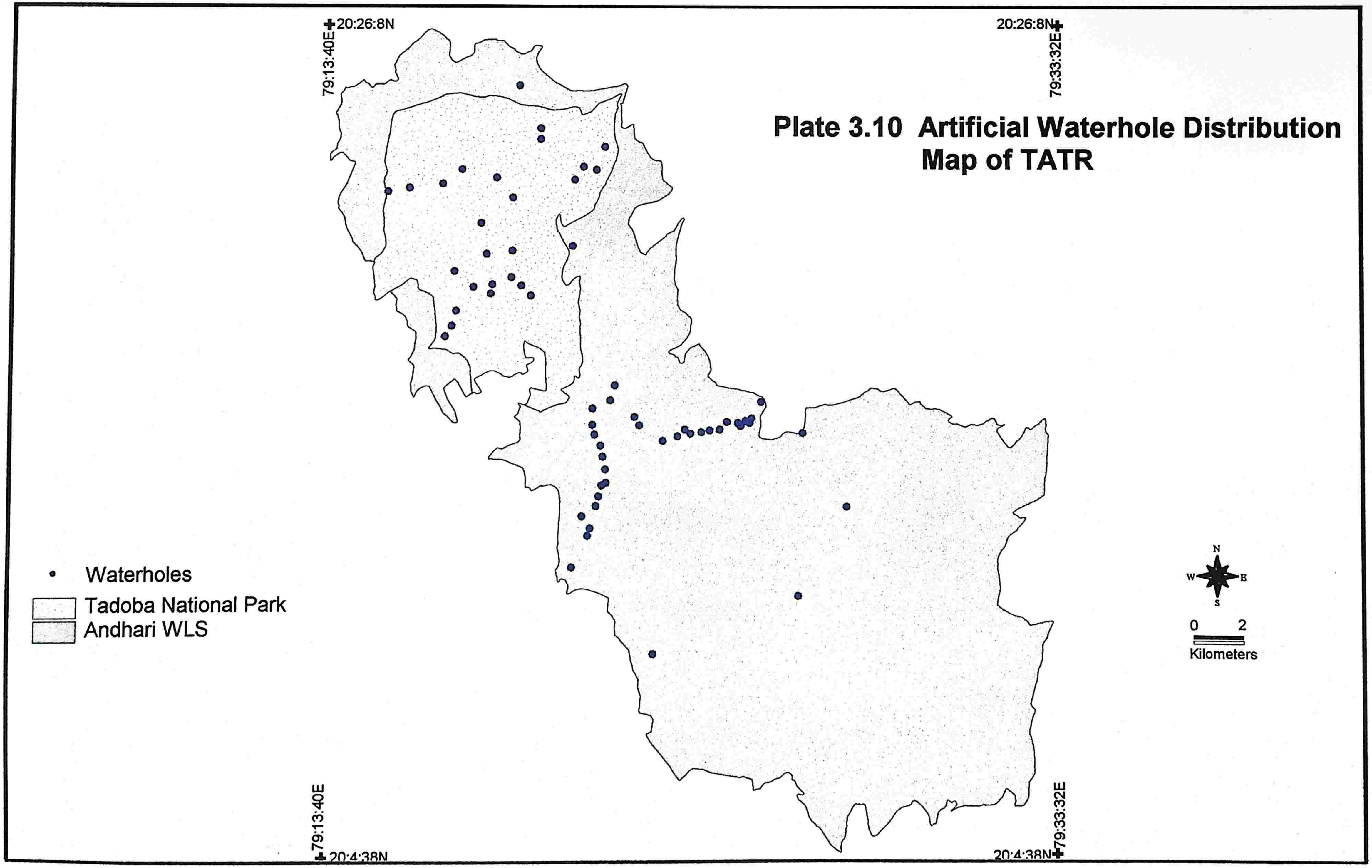
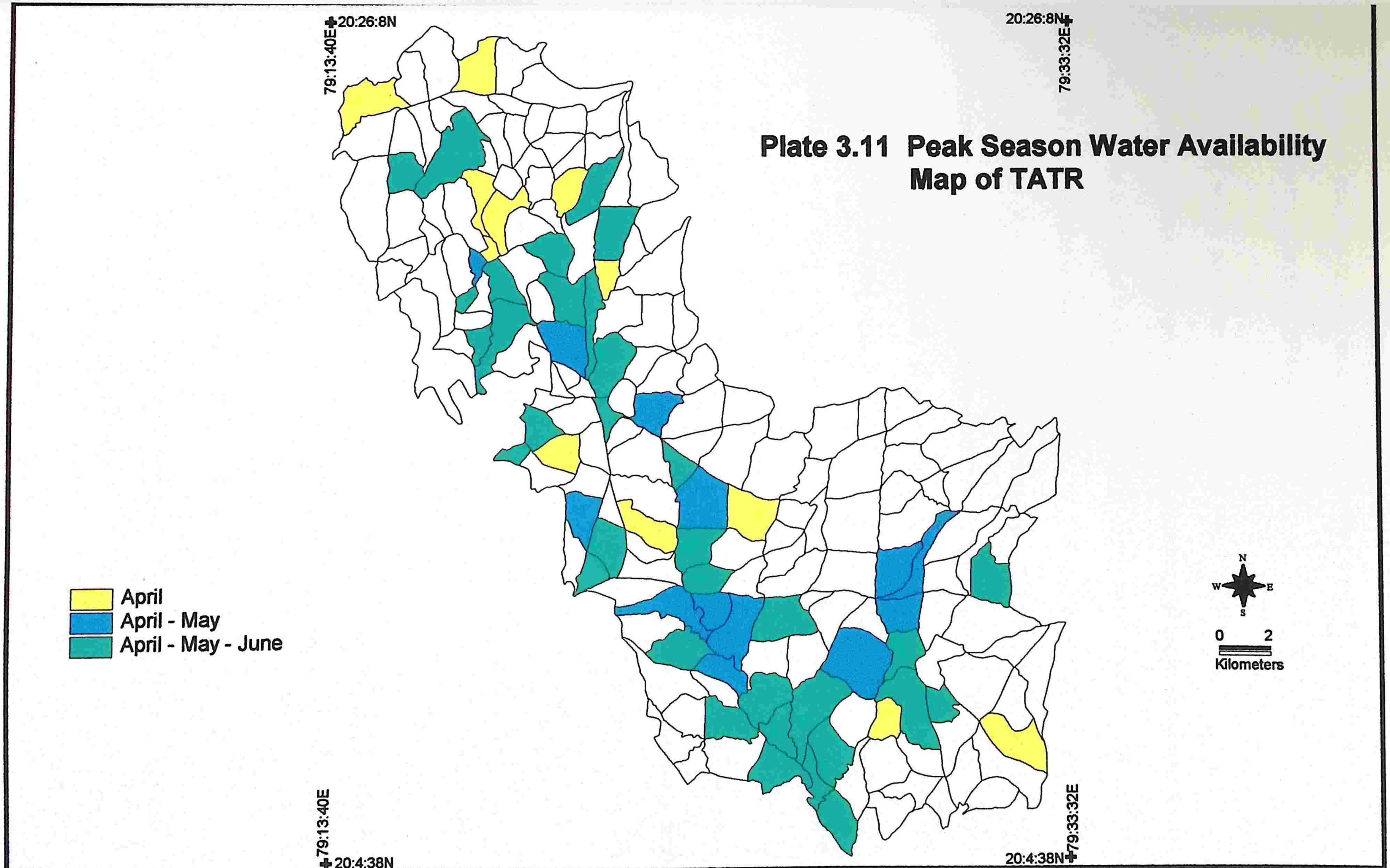


Plate 3.11 Peak Season Water Availability Map of TATR



be able to plan out tourism and patrolling strategies properly and for this, road forms the primary layer for analysis.

8. Map of water sources: Water sources are an important asset in any dry deciduous ecosystem. Animals move large distances in search of water in lean season and are forced to move to the regions with open water areas (Jarman, 1972 ; Jarman and Jarman, 1973 ; Western, 1975 ; Fryxell and Sinclair, 1988 ; Williamson, Williamson and Ngwamotsoko, 1988; Rautenstrauch and Krausman, 1989). It is therefore important for management to have a clear picture of water availability in the protected area so that animals can be prevented from moving outside the PA boundary, where they become prone to poaching and other threats. Water resource management is therefore a priority work in dry seasons in most of the protected areas. In extremely dry years even the permanent water-holes and streams dry up resulting in large number of animal mortality (Anon. 1961 ; Owaga, 1975 ; Williamson and Mbano, 1988). The water sources are also frequented by predators, as apart from meeting their water requirement they also need to cool their bodies and the chances of successful predation also increases as large number of herbivores tend to congregate in such areas (Bourliere 1963; Ayeni, 1975; Elliot, Cowan and Holling, 1977). To map the distribution of water in the reserve initially all artificial water holes were mapped using Global Positioning System (GPS). Plate 3.10 shows the distribution of artificial water holes. Subsequently, compartment wise survey was done so as to cover all compartments of TATR and data on water availability was collected for two years i.e., from January 1996 to December 1997. This data was spatially analysed to generate the water scarcity map , (Plate 3.11).

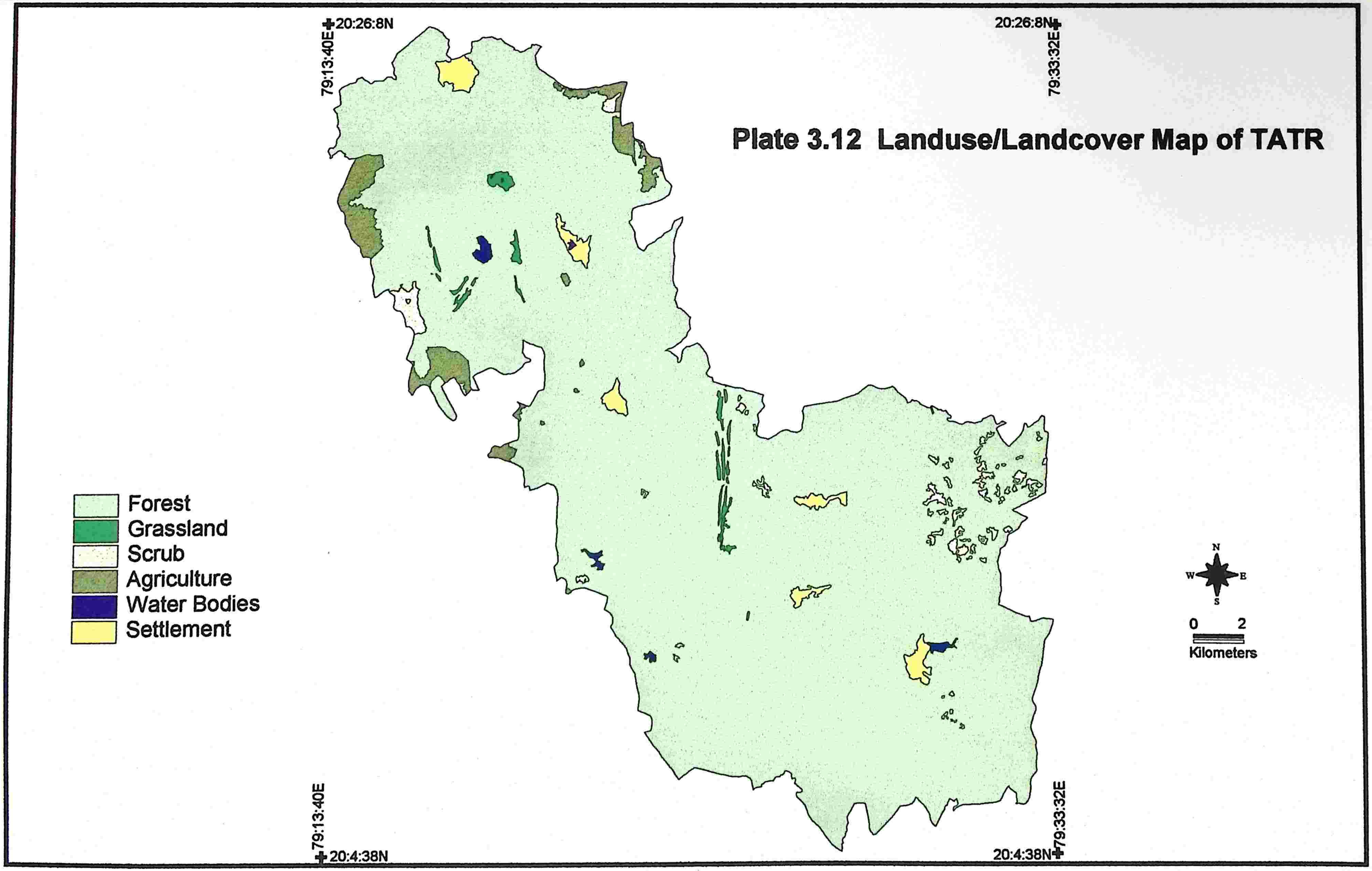
9. Land-use/Land cover Map: Plate 3.12 was produced by visual interpretation of the satellite imageries for the month of November 1994. Detailed description is given in Chapter 4.

10. Grassland Distribution Map: Plate 3.13 shows the distribution of grasslands. There are two types of grasslands (i) low lying grasslands and (ii) grasslands on plateau. These grasslands are very small in size but nonetheless offer great deal of support to wildlife in terms of forage and cover. Grasslands form 0.6 % of the total geographic area of TATR.

11. Bamboo Distribution Map: Bamboo being understorey was difficult to delineate from the satellite imagery. A survey was under taken for this purpose and bamboo density was ocularly estimated in different vegetation types. Plate 3.14 shows that areas under Very dense, dense, medium and sparse bamboo distribution come to 46%, 24%, 12% and 13% respectively. The total area under bamboo comes to 95%.

12. Salt lick Distribution Map: Saltlicks are places where animals ingest the soil which is rich in salts to replenish their salt deficiency. Large number of ungulates and birds are known to visit saltlicks (Jarman 1972). Saltlicks are found naturally as well are created artificially by putting salt bricks in different areas, normally close to the water sources. To select sites to create artificial saltlicks it is important to know the spatial distribution of natural ones and then accordingly decide the new areas. Compartment wise survey was undertaken for this and all natural salt licks as well as artificial ones were recorded. Data was also collected on the use of these salt licks by wild animals, based on direct and indirect evidences for one year (1996 - 1997). This data was later

Plate 3.12 Landuse/Landcover Map of TATR



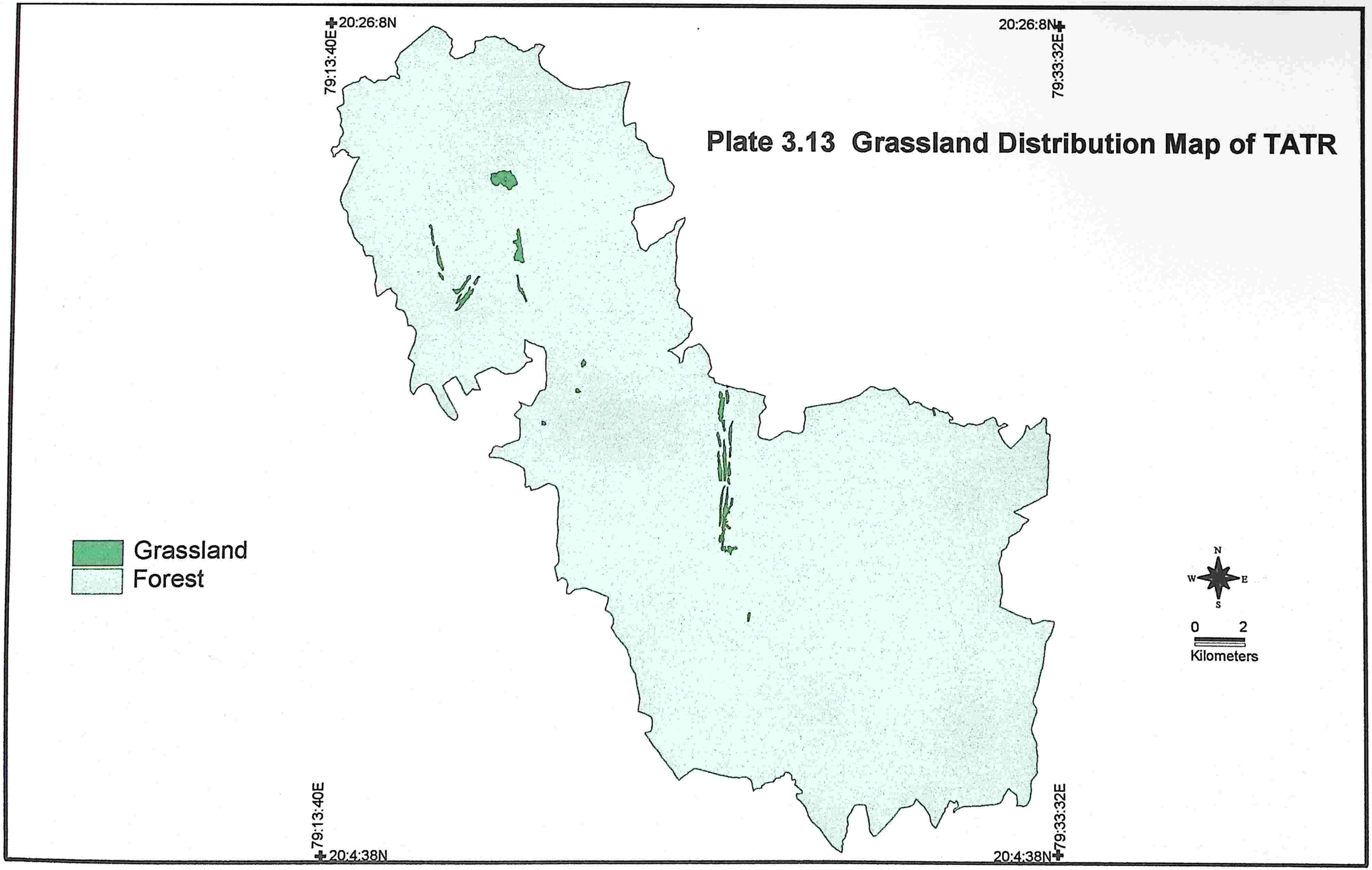


Plate 3.13 Grassland Distribution Map of TATR

Plate 3.14 Bamboo Distribution Map of TATR

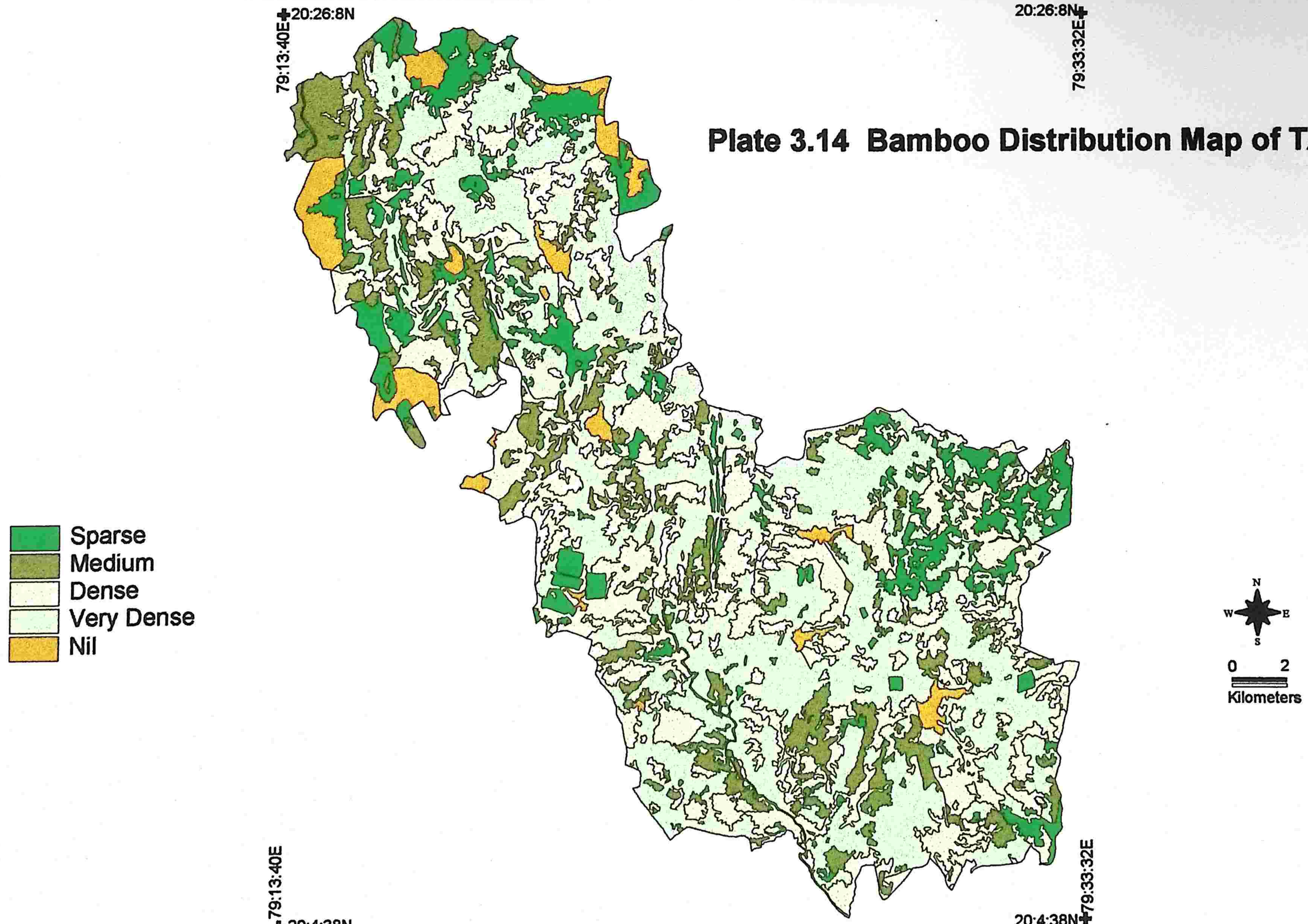
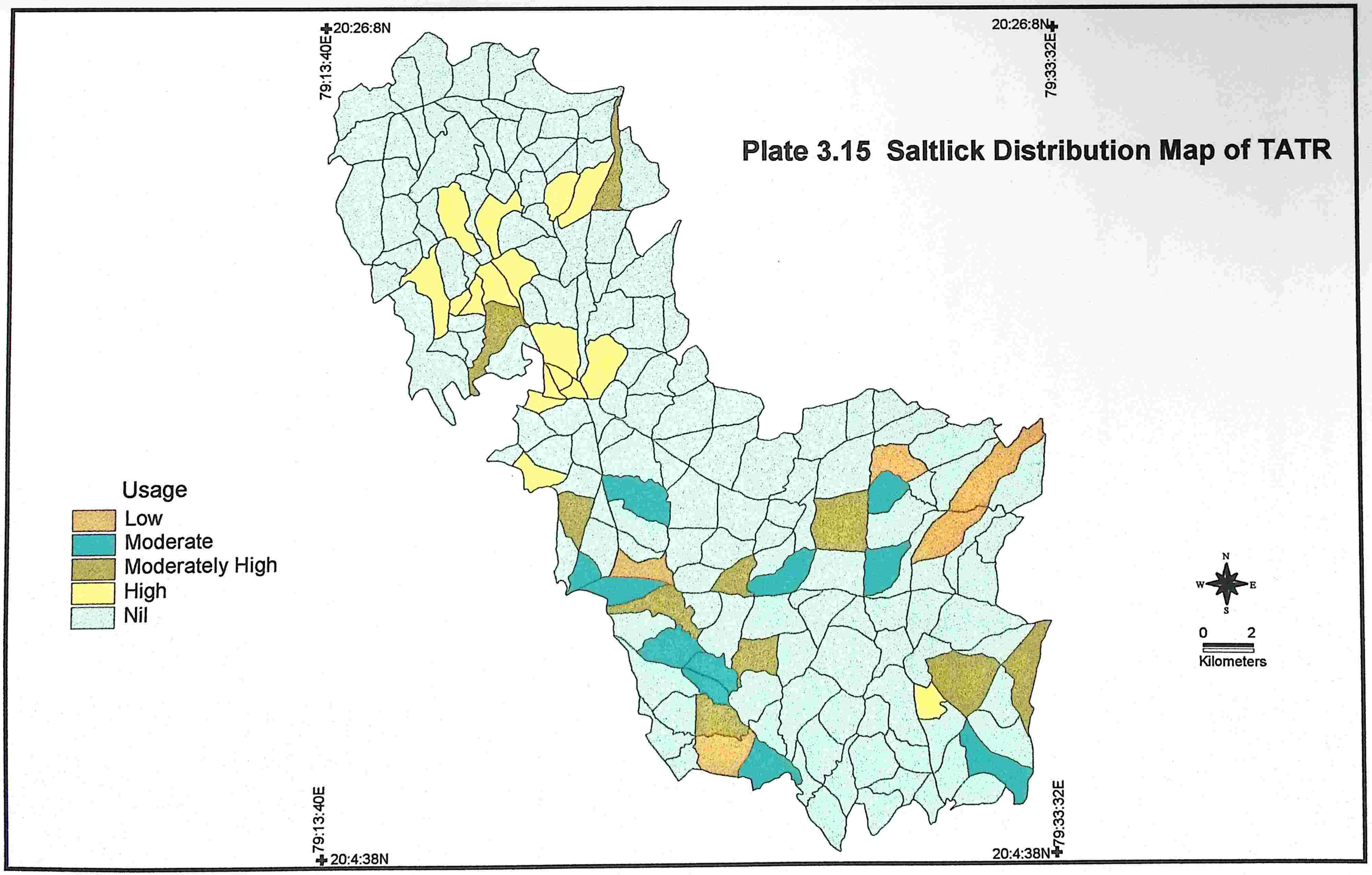


Plate 3.15 Saltlick Distribution Map of TATR



summarized into four usage categories viz. Low, Moderate, Moderately high and High. Plate 3.15 shows the distribution of these salt licks as well as their usage.

13. Livestock Grazing Map: Data on livestock grazing was collected partly by field study and partly through the information provided by game guards of the respective beats, based on their perception and field observations. Plate 3.16 gives the areas having low, medium and high grazing pressure by domestic livestock. This map was created through the data collected from each compartment during routine work by recording all observations on encounter of livestock dung and livestock. The areas under low, medium and high grazing, as per the map are 5%, 4% and 14% respectively. It is evident that 77% of TATR area is free from any kind of grazing.

14. Human Disturbance Map: Despite the best efforts by protected area management it is virtually impossible to eliminate the adverse impacts of human habitations on PA resources. Observations of lopping signs and direct encounter of people in the forest were recorded compartment wise and later same information was mapped to visualize the spatial pattern and extent of anthropogenic intrusion inside the protected area. Plate 3.17 shows the areas disturbed by human presence for various reasons like fire wood collection, MFP collection etc.

15. Fauna Distribution and Abundance Maps: These maps (Plate 5.1 to 5.7, Chapter 5) show the distribution and abundance of various ungulate species found in TATR. The distribution map of each species is presented alongwith the abundance ratings, viz. Low, Medium and High.

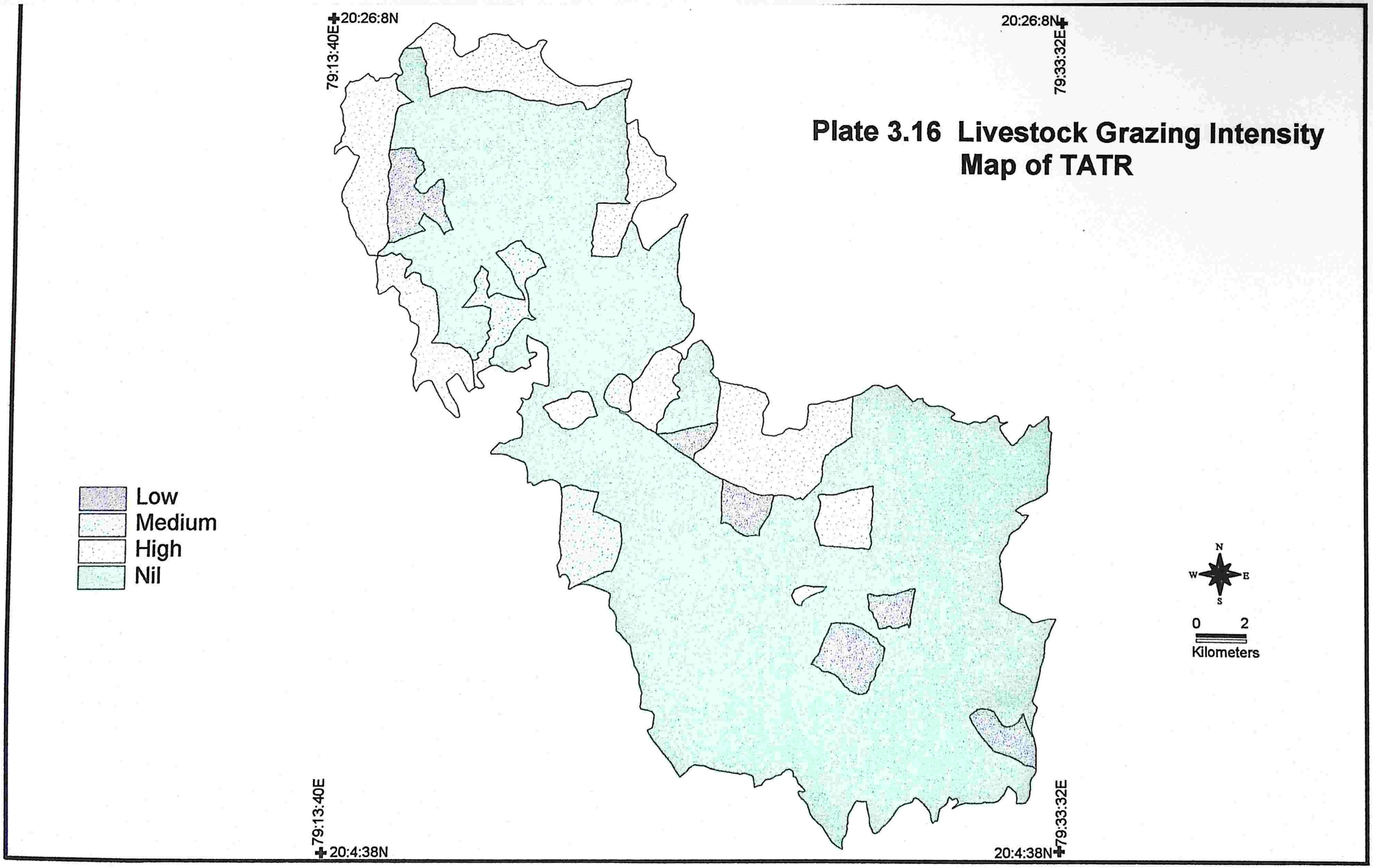


Plate 3.16 Livestock Grazing Intensity Map of TATR

Plate 3.17 Anthropogenic Disturbance Map of TATR

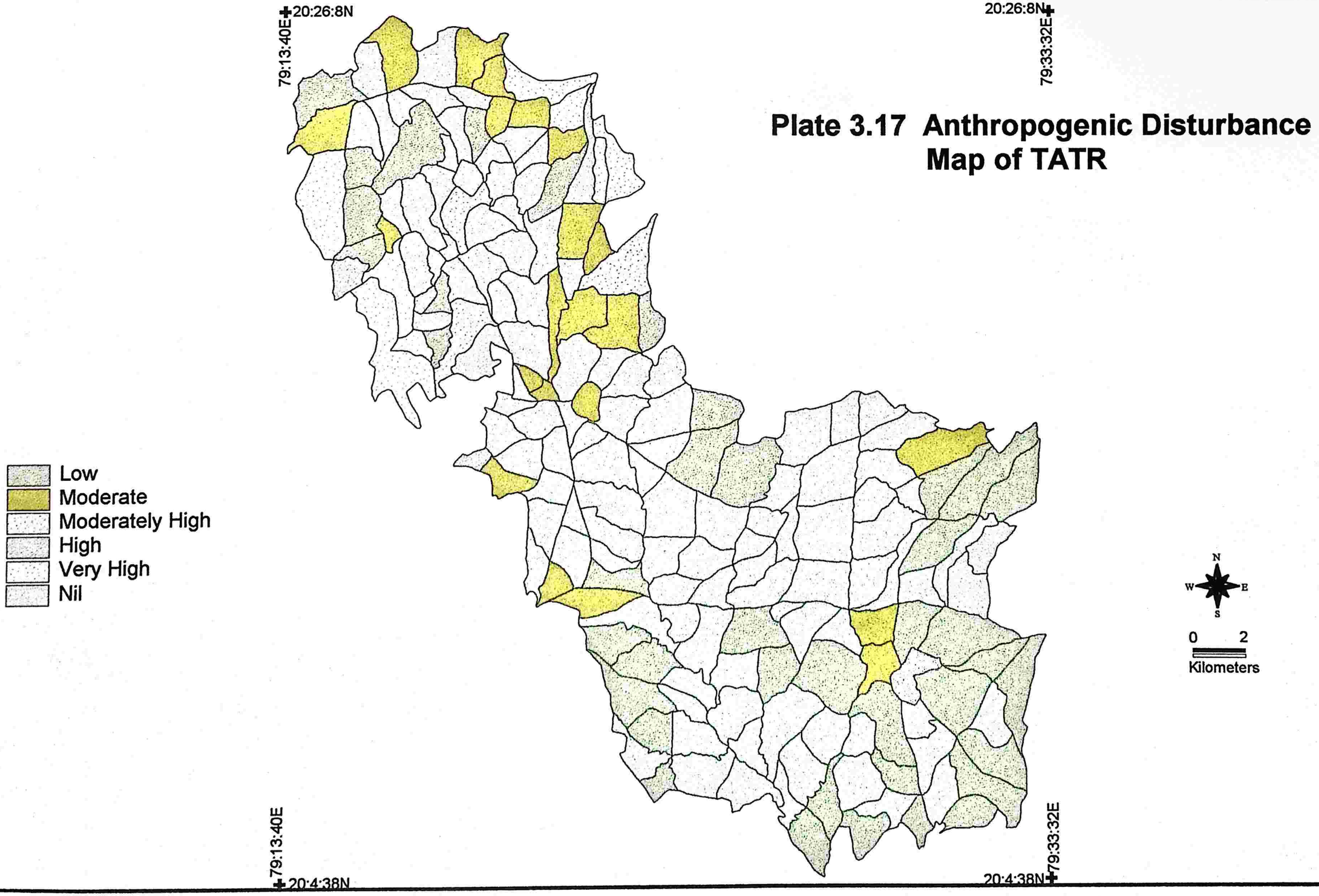
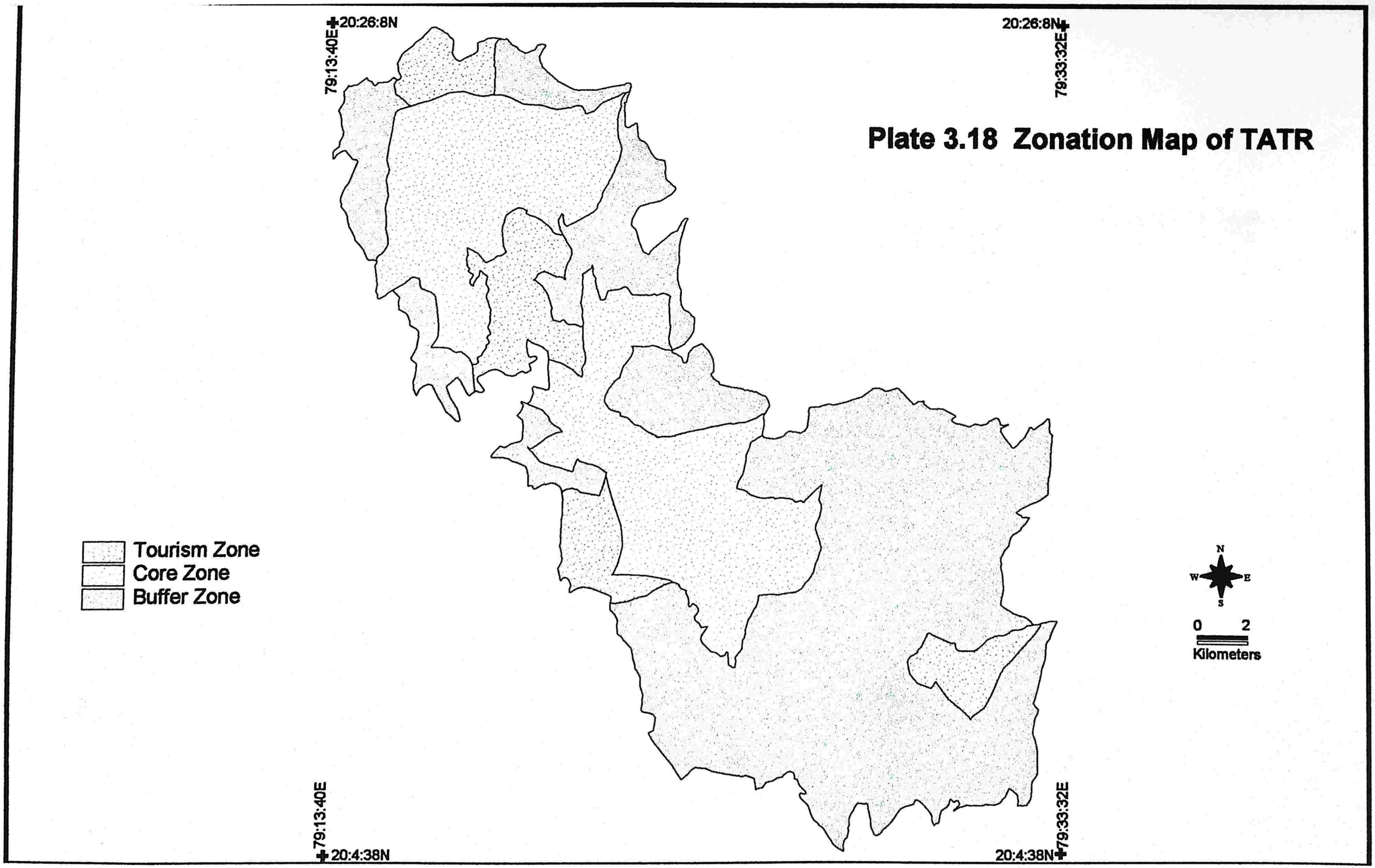


Plate 3.18 Zonation Map of TATR



3.4. TOURISM

Tadoba-Andhari Tiger Reserve (TATR) has a long history of recreational and cultural use by visitors as it is located at a distance of 44 km, north-east of Chandrapur town - a Railway Station on the Grand Trunk route of Central Railway. Forests of the PA are important sites for natural heritage and are of interest to visitors because of rich wildlife such as Tiger, Gaur, Sloth bear, Leopard, Crocodile, Python etc., alongwith avifauna and scenic beauty of the Tadoba Lake.

TATR has gained reputation as one of the important wildlife destination in the country. Moreover, at Tadoba there is a temple called Tadoba Deo for which hundreds of people especially tribal, come to Tadoba every year. There is another well known Ramdegi temple near Ramdegi village, which is visited by people every year especially on the occasion of Mahashivratri.

This park in 1905, was a shooting block for large carnivore and other game, for which special permits were issued from time to time. Since 1931, shooting of all types of game including big cats was totally prohibited and the area was declared a Sanctuary in 1935. Subsequently along with "Kanha" in M.P it was declared as a "National Park" in 1955.

The mean tourist influx in Tadoba is about 71,213 per year, which comes out to about 260 per day during tourist season of November to June. Considering the area of 116.5 km^2 of the park and road length of about 40 km available for excursion, the present number is already very high. Inside the park there is a network of about 123 km of motorable fair weather roads. A 'Circular

Road' about 5 km in length completely encircles the lake. It was one of the favourite roads of the visitors for observing wildlife specially deer, tiger and crocodile till it was closed for reducing disturbance to animals coming to drink water.

There are three watch - towers constructed along the edge of the lake at three vantage points where animals often come out for drinking water and for rest. Thus, animals sighting is high at the edge of the lake. On the other hand, fruit trees are being preserved intensively and attempts to increase their numbers along the lake have also been carried out. As a result, Jamun is abundant near the lake side which also attracts the visitors. There are more watch tower constructed inside the reserve to facilitate the wildlife viewing by visitors (Plate 3.19). Tourists use many of the hides and machans inside the PA.

3.4.1. Tourist types of TATR

1) Dedicated nature tourists.
2) Nature tourists.
3) Casual nature tourists.
4) Pilgrims and religious tourists.

Data collected on types of visitors coming to TATR was categorised in five categories (Table 3.1). It is interesting to note that around 38.34 % people falling in other's category are the people who use reserve road connecting the townships of Chandrapur and Chimur.

Table 3.1 Visitor types and their percentage visiting TATR

VISITOR CATEGORY	PERCENT OF TOTAL
Wildlife tourist	43.92 %
Pilgrims	10.88 %
Students	6.6 %
Trainees	0.30 %
Others	38.34 %

It is interesting to note the dramatic increase in the tourist numbers (Figure. 3.1) visiting TATR from 1995 onwards. The reason for this could be attributed to the fact that this area was declared a Tiger Reserve recently. Monthly trends clearly show a visitation peak in the month of May followed by January (Figure. 3.2). This is because in the month of May water sources are limited which compels the animal to stay near to water sources. This makes the chances of sighting animals very easy.

3.4.2. Vehicles

Tourist coming to TATR use a wide range of vehicles to approach the area Table 3.2. Around 10,000 vehicles come to TATR every year which comes to an average of 29 vehicles every day. Figure 3.3 shows the trends in vehicle numbers between 1984 to 1996 and Figure 3.4 shows the trends in vehicles numbers in different months. It has been observed that there has been a dramatic increase in numbers from 1995 onwards. Month of January and December receive maximum vehicles.

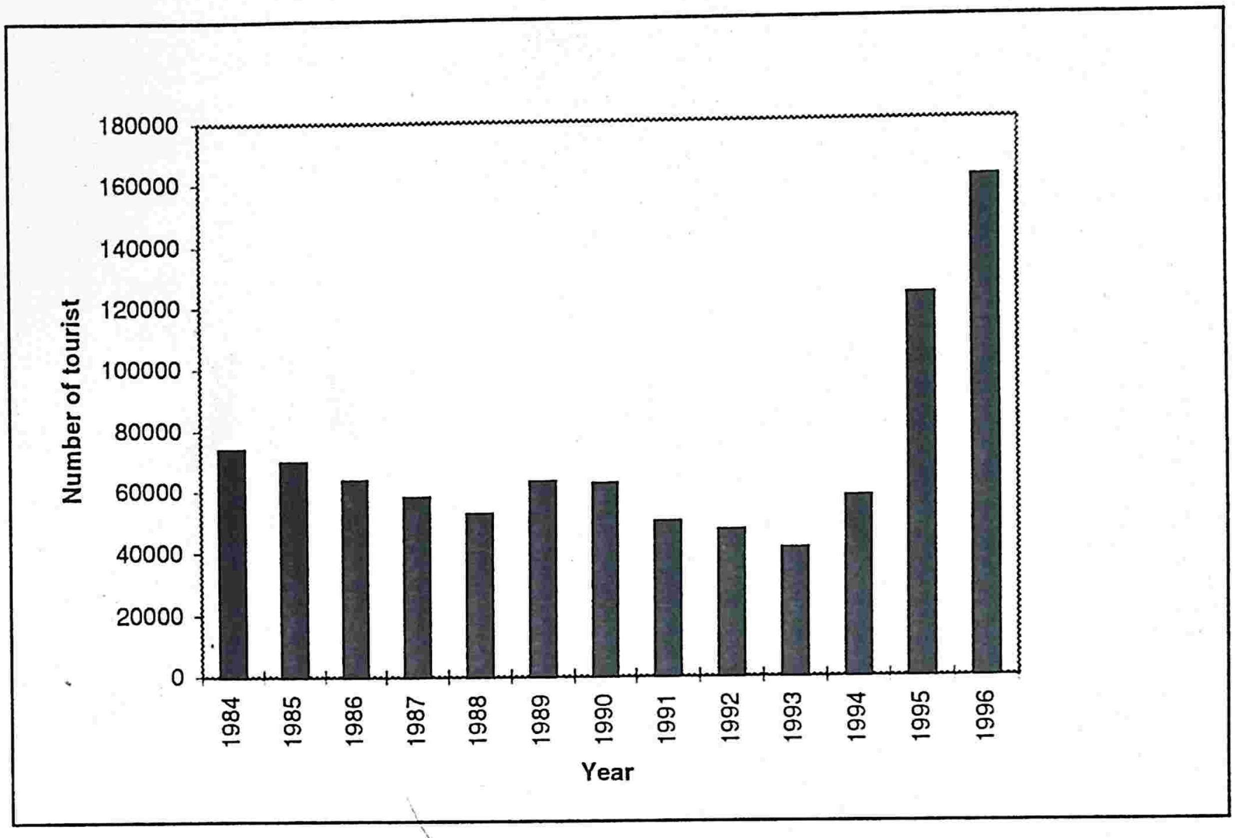


Figure. 3.1 Tourist influx in TATR from 1984 to 1996

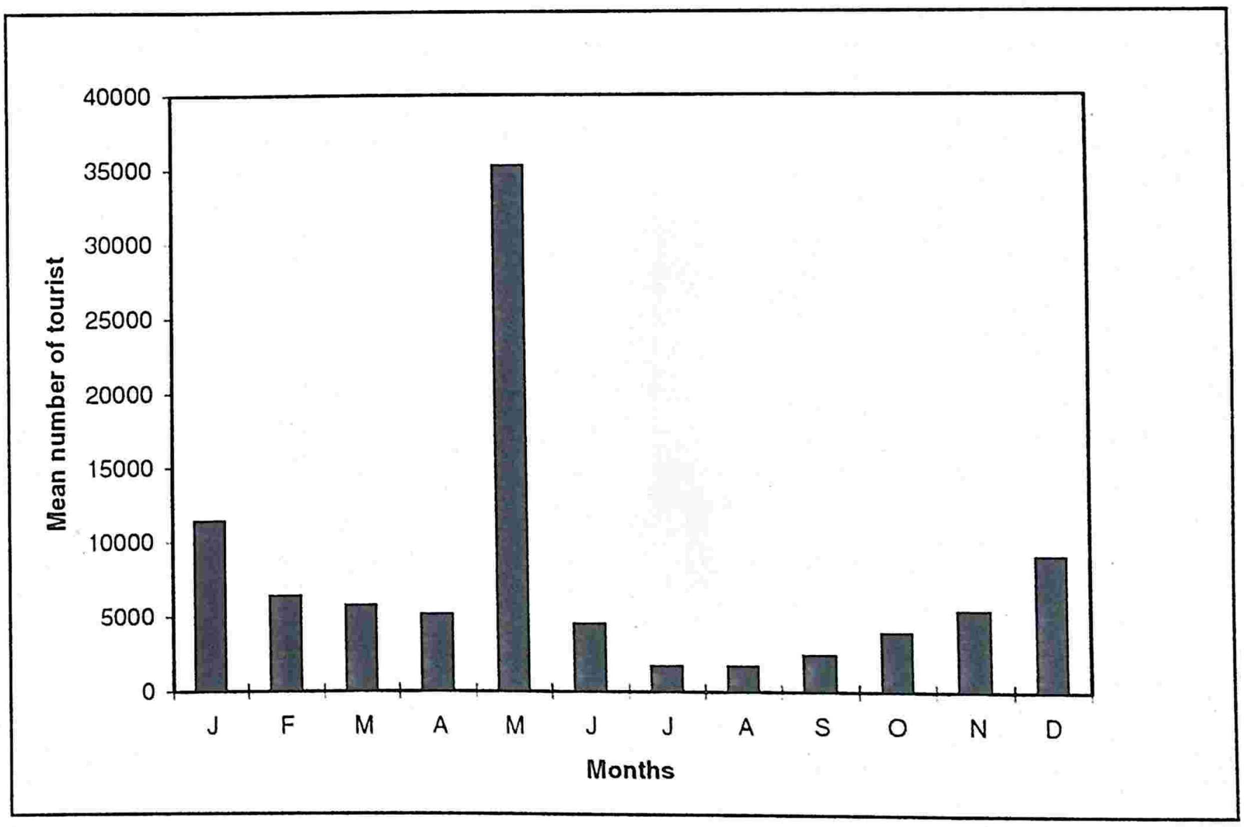


Figure. 3.2 Monthly influx of tourist in TATR

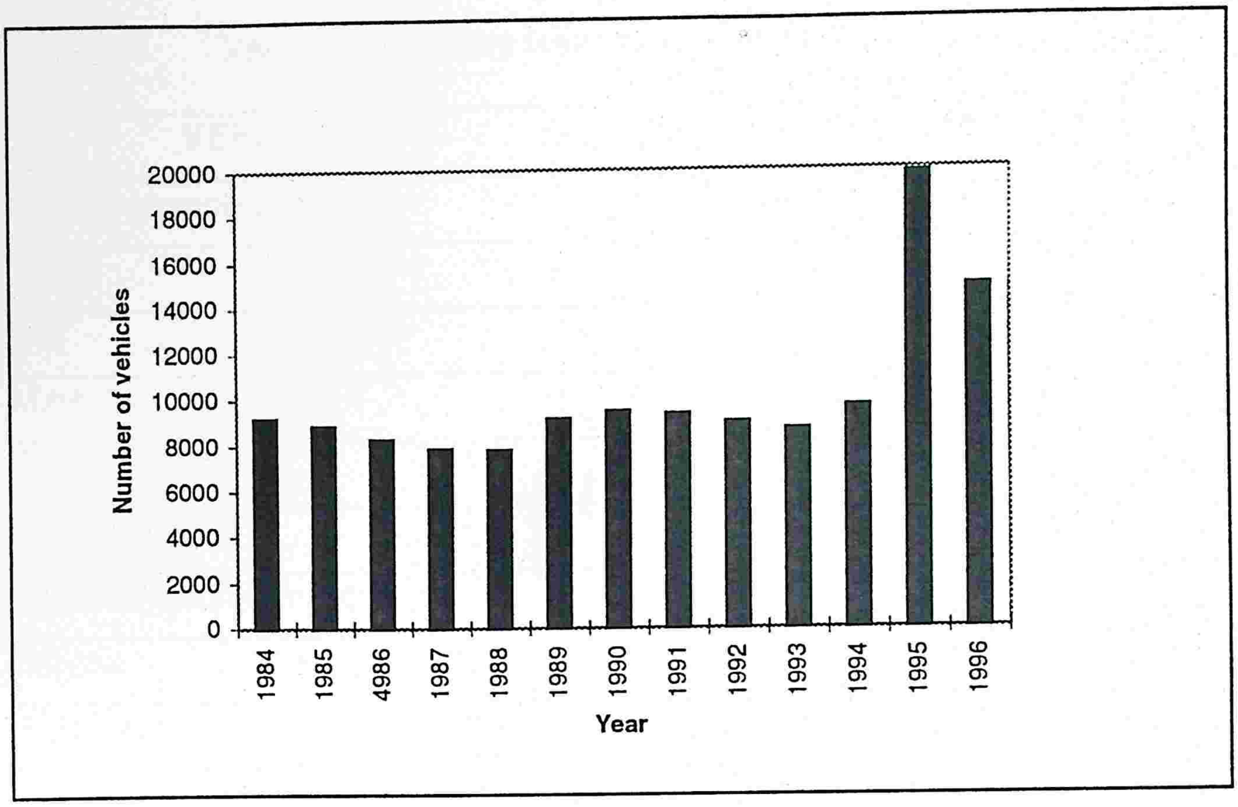


Figure. 3.3 Vehicle influx in TATR from 1984 to 1996

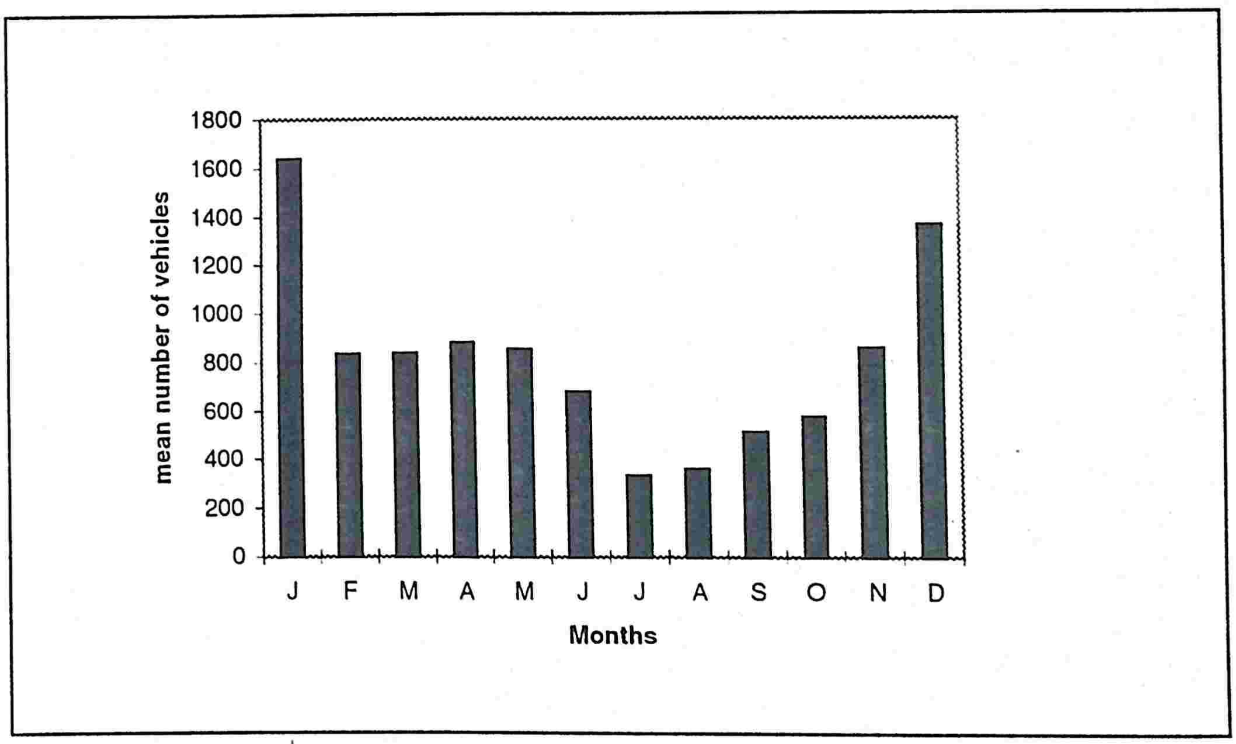


Figure. 3.4 Vehicle influx in TATR in different months

Table 3.2. Vehicles used by tourist to visit TATR

VEHICLE TYPE	PERCENT (%)
State transport bus	21.57
Jeep	18.25
Car	10.66
Minibus	2.26
Truck	2.47
Luxury coach	0.53
Scooter/Mobike/Autorickshaw	16.08
Bicycle	21.00
Bullock cart	7.2

The main area of interest for tourists is the Tadoba lake. Earlier, there were six gates through which the tourists could come to Tadoba. Now two of these gates are closed and only four approach roads are open to the tourists. These are Nawegaon, Khatoda, Kolara , Jhari and Dewada (Plate 3.19). The vehicles range from Bullock carts to State Transport (Table 3.2).

There is a major problem linked with the traditional festival, which the tribals celebrate every year in the month of January. During this period, the Government has exempted the local tribals from the entrance fees. These tribals come to Tadoba and cook their food near the lake. This causes huge distrubance to animals apart from creating grabage dumps. The situation becomes further complicated because of the fact that Tadoba National Park forms the core zone and the lake is situated in the centre of the core zone.

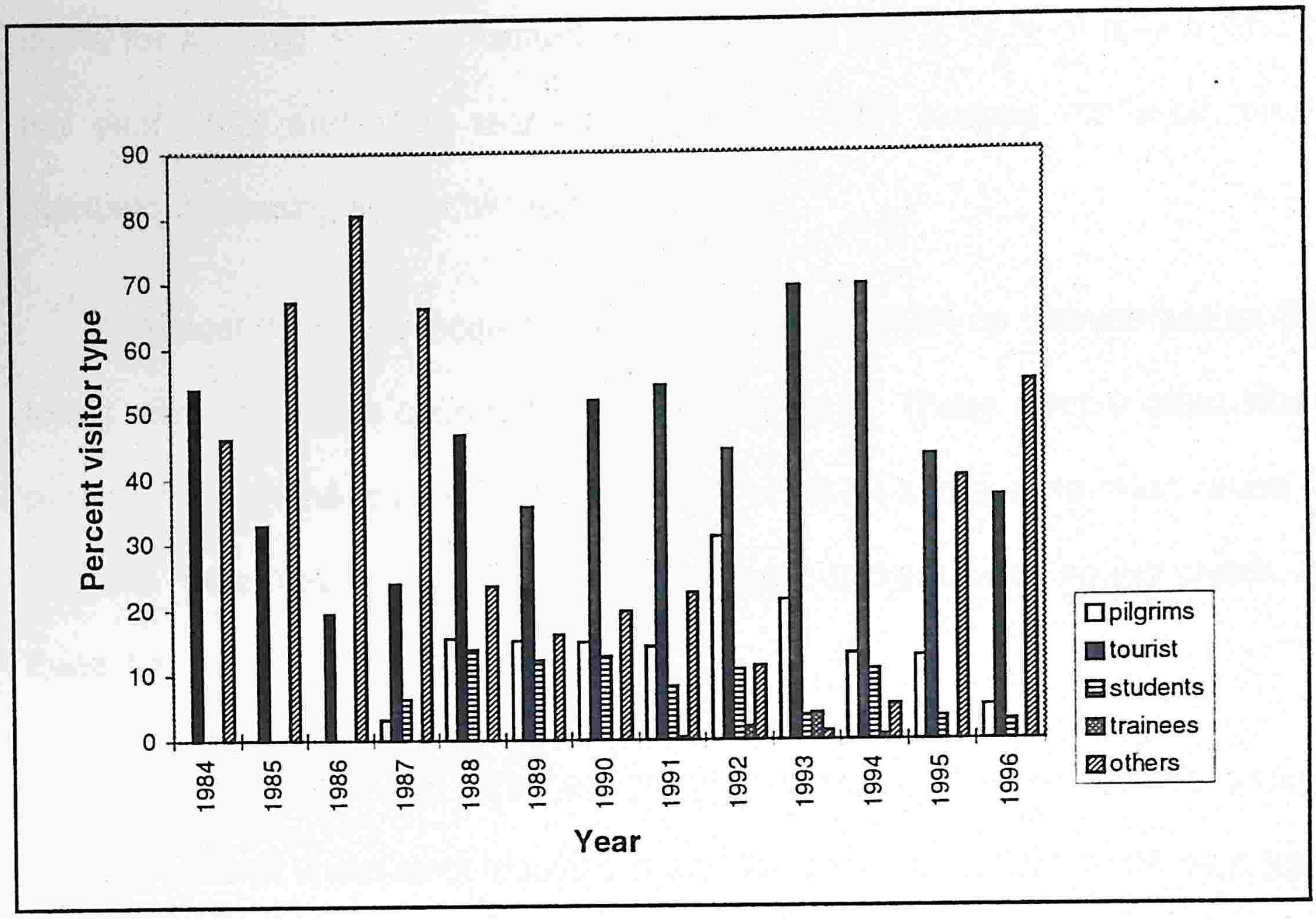


Figure. 3.5. Visitor categories (in %) in TATR from 1984 to 1996

3.5. DISCUSSION

Tourism has received a major boost since 1995 and this is evident from the results. Tourist numbers in 1995 and 1996 almost doubled to what they were till 1994. The major reason for this is that the area was brought under the fold of Project Tiger Reserves. The other reason being the easy sighting of the most charismatic large cat which has started attracting large number of people. Tadoba is also the only popular recreational site for the people of Chandrapur and hence most of the tourist pressure is local in nature.

Pilgrims form only about 10 % of total tourists and are generally tribal. They cause less disturbance in the park compared to other day visitors, who come for a picnic. Pilgrims formed only 12.84 % and 5.15 % of total tourist in the year 1995 and 1996 respectively.(Figure. 3.5) despite the total tourist numbers increasing almost two fold.

Almost 38 % are those people who use the TATR as throughfare as the forest road of reserve connects two state highways. These people often when passing through the reserve violate the rules of TATR and are the main cause of concern. Strict regulation needs to be practised to keep a complete check on these people.

Nature camps and other educational groups coming to reserve should also be covered under strict regulations and the zone of activity should be clearly defined for them. They should not be allowed to conduct their activities outside these zones. Trekking inside the forest by these groups should also be strictly regulated as it is a tiger country. In dry season, concentration of tourist activity close to water sources should also be strictly regulated. There should be strict enforcement of time regulations as to the hours for which the roads can remain open for excursions and educational activities. Anybody found violating these norms should be penalised. In dry season, roads which pass by the perennial water sources should be monitored properly and if the water sources are found to be heavily used by carnivores then in that case they should be closed for tourism. Road network was overlaid on Tiger sighting map (Plate 3.20) and it was found that one road passes through high density tiger occurrence area and tigers are known to intensively use the water sources in that area. Excess tourists and nature and education camps cause manifold disturbance in summers, when temperatures are exceedingly high. Application of GIS offers an

Plate 3.19 Tourism Map of TATR

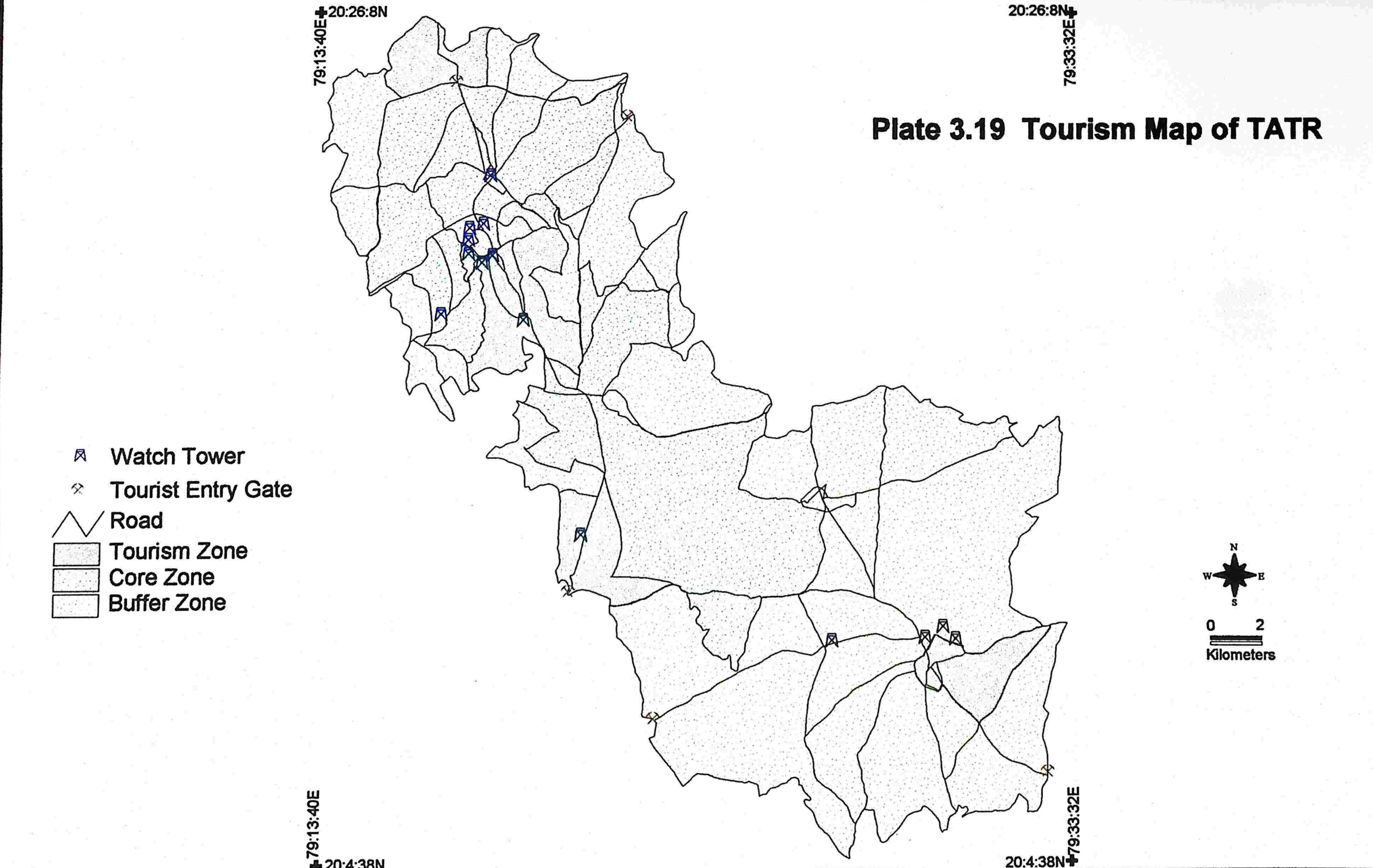
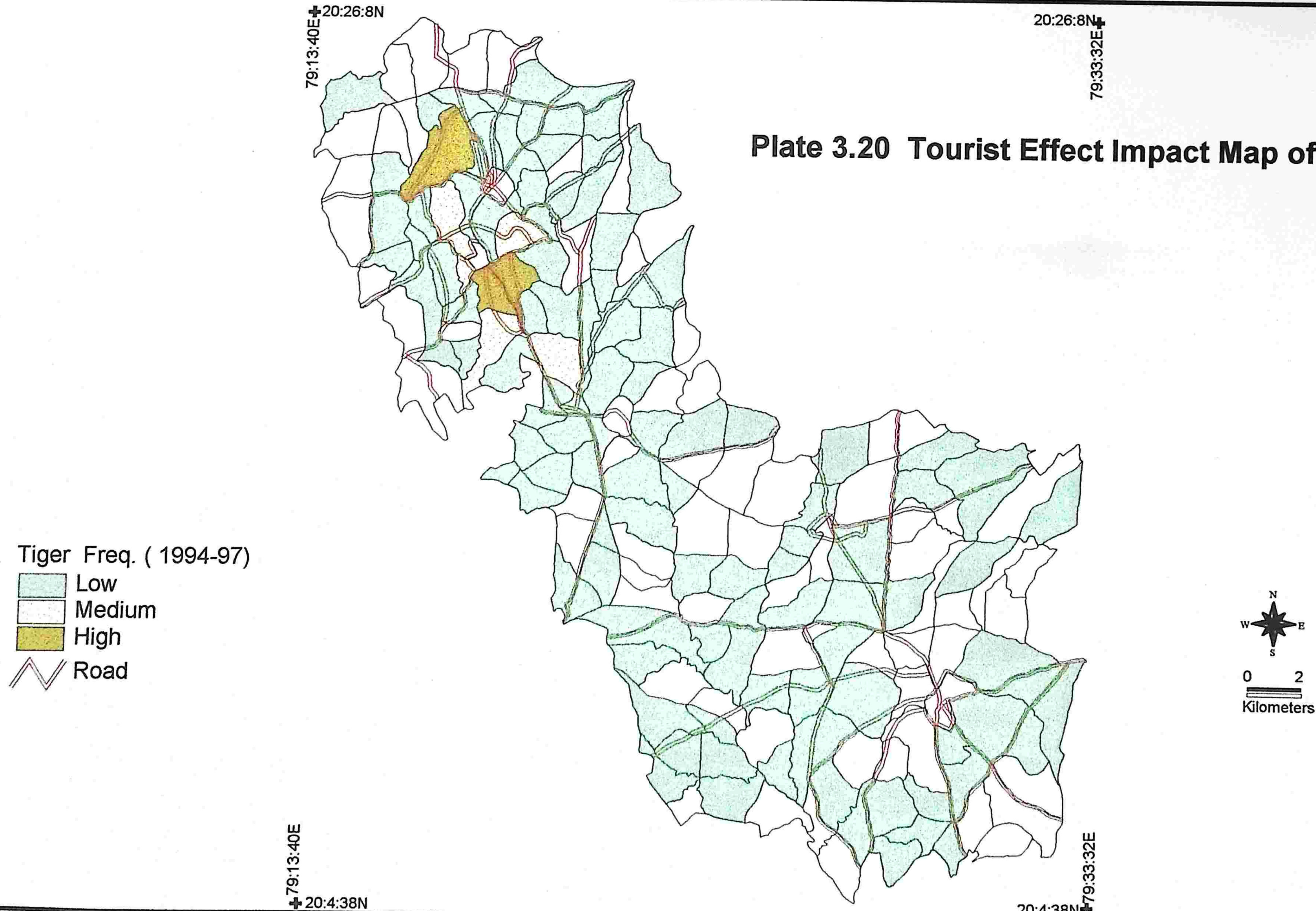


Plate 3.20 Tourist Effect Impact Map of TATR



excellent opportunity to collate such information and display multiple data layers and visualise the effect of one variable over other and hence improve planning. Regulating tourism spatially with the aid of GIS is a new concept and has not been brought in practice perhaps any where in the country, but nonetheless it offers an increasingly important support system to properly and effectively control the movement of vehicles and tourism inside the reserve.

As can be observed from Table 3.2 all kinds of vehicles are being used by visitors to reach the reserve. There should be a regulation on the use of two and three wheelers as they are not safe. Only four wheelers should be given access to move on reserve roads.

Tourism as an industry has gained lot of impetus from all sectors of society. Wildlife tourism has an old history, when in past people used to go to the forest for game hunting. With the enforcement of Wildlife Protection Act, 1972, hunting virtually came to an end, but peoples fascination for wildlife continued to flourish in the form of wildlife tourism. Wildlife tourism has a bright future in a country like India which still has lots of wildlife diversity to offer to the tourist. Nicely planned tourism packages can help protected areas in generating goodwill among common masses and spreading conservation awareness beside bringing additional income to local communities .

Chapter 4

VEGETATION MAPPING, STRUCTURE AND CLASSIFICATION

4.1. INTRODUCTION

Vegetation studies are an integral part of any wildlife ecology study as plants form part of habitat and contribute most in providing food, cover and breeding sites to most of the animals, directly or indirectly. The study of plant communities, their geographic distribution in the landscape and their relationship with various environmental variables is important in shaping out management strategies.

Vegetation science is about 300 years old (Muller Dombois & Ellenberg, 1974). Vegetation studies are important to determine the presence, abundance and distribution of plant species. With the rapid changes occurring in natural landscapes, it has become increasingly important to inventorise, map and monitor the spatial distribution of vegetation.

Forests are one of the important resources on earth for the sustenance of wildlife and human beings (Lal, 1989). Reliable and precise information of these resources is required for careful planning. To assess the availability of resource we need to use a technology which can give this information with precision. Remote Sensing technology has given an impetus to resource mapping and monitoring (Lillisand & Kiefer, 1979; Curran, 1985). Space borne techniques are now widely used in vegetation mapping and distribution (Lakshmi *et al*, 1998).

Many studies have been conducted using remote sensing techniques in India and else where and results have suggested that satellite data can give fairly accurate assessment of land cover without any personal and professional bias (Lal 1989; Gulati and Bist, 1991; Prasad *et al*, 1998; Nair & Menon, 1998).

Remote sensing data has been in use since the sixth decade. Various satellites like Landsat series(1-5), Spot series (1-2), IRS Series (1-2) etc. provide data in visible to middle infrared range. ERS-1 provides data in microwave region which is not affected by climatic variables like rains, clouds etc. Indian remote sensing satellites have given an opportunity to planners to map and monitor the changes in resources at a very low cost. Present series of IRS LISS-II gives a resolution of 36.5m. The manifold utility of IRS data has been successfully demonstrated through a number of studies conducted in forestry, flood zone mapping, soil mapping, waste land mapping and management and urban planning(Karake, 1992; Lakshmi & Dutt, 1998; Prasad, 1998).

Geographic Information System (GIS) gives a linkage between spatial and non-spatial data. This computer aided technology assists in overlaying several thematic layers and enhances the capability at the user end to see through different layers. GIS technology is being used for several applications in resource management, landscape analysis, fire risk modelling etc. (Lillesand & Keifer 1987; Burrough, 1990).

In this chapter I have tried to establish a linkage between remotely sensed data and ground data collected by sampling and have integrated it using Geographical Information System (GIS) to generate a clear picture of the availability of different vegetation types and their spatial extent and distribution.

4.2. VEGETATION MAPPING METHODS

4.2.1. Satellite Data Used

False Colour Composites **(FCC)** of **IRS- LISS-II** imagery for the month of November 1994 were used with the following details.

Satellite	: IRS IB
Sensor	: LISS-II
FCC Bands	: 2,3,4 (BGR)
Projection	: Polyconic
Data type	: Geocoded
Scale	: 1:50,000

Table 4.1. Details of satellite data used.

Path	Row	Map ID	Date
O25	O54	55P/3	3.1.94
O25	O54	55P/7	3.1.94
O25	O54	55P/8	3.1.94
O25	O54	55P/11	3.1.94
O25	O54	55P/12	3.1.94

4.2.2. Characteristics of IRS IB, LISS-II Satellite

It is an Indian satellite launched by the National Remote Sensing Agency (NRSA). Following are the salient features of the platforms and the sensors.

Nature	: Sun Synchronous
Altitude (km)	: 904
Orbital period (minutes)	: 101
Inclination (degrees)	:98.7
Temporal resolution (day)	: 36.5
Equatorial crossing (A.M)	: 10:00
Sensor	: LISS-II
Spectral Resolution	: 0.45 - 0.52 mm
	: 0.52 - 0.59 mm
	: 0.62 - 0.68 mm
	: 0.77 - 0.86 mm
Radiometric resolution	: 128 levels

4.2.3. Survey of India Toposheets

The Survey of India (SOI) toposheets used for the preparation of baseline map of the study area are 55 P/3, 55 P/7, 55 P/8, 55 P/11, 55 P/12 (1:50,000 scale).

4.2.4. Ancillary Data

Compartment maps at the scale of 1:50,000 were taken from Maharashtra Forest Department for Tadoba National Park and Andhari Wildlife Sanctuary for use.

4.2.5. Visual Interpretation

4.2.5.1. Base map preparation and delineation of boundary

Base map was prepared using Survey of India (SOI) Toposheets and the process involved tracing of permanent features like rivers, streams, roads, habitations etc. SOI sheets no. 55P/3,7,8,11,12 were put together to produce a composite area. Boundaries were delineated using the compartment maps of the study area.

4.2.6. Mapping

A reconnaissance survey of the study area was carried out from April to June, 1994. This exercise was aimed at having a good idea about the vegetation types and to gain familiarity with the area. Compartment maps (1:50,000 scale) were used as guide maps to move through different parts of the study area. Compartment history was used to understand the broad vegetation composition and to have an idea about the abundance of plant species in different localities and vegetation types.

4.2.6.1. Ground work

After developing a general understanding of vegetation types and the physiography of area, an exhaustive ground truthing was carried out in the month of Oct-Nov 1994. During this process areas showing different tonal and textural variations were marked on the satellite image. Effort was made to mark as many different tones and textures as possible. These marked sites on FCC were then located on ground to establish a relation between different tones and site characteristics on ground. SOI toposheets on the same scale as that of

FCC's i.e 1:50,000 were used to locate the areas on ground and relevant information was collected. Effort was made to locate all the marked areas on the FCC. The information was then collated to prepare the interpretation key for delineation of different vegetation types.

4.2.6.2. Image Interpretation

Based on the interpretation key, areas showing different tones and texture were traced on the base map of the area on a tracing sheet. Special care was taken to trace the smallest polygon, which could be determined by naked eye to get precise information on the spatial nature of vegetation types in the area. Entire TATR area is covered in five **FCC** scenes of **IRS LISS-II** data. Homogeneity in vegetation allowed the delineation of vegetation types with fairly good accuracy. Texture variations on the image were used to determine the canopy closure.

4.2.6.3. Classification Scheme

According to Champion and Seth classification the entire area falls under Group 5 and subgroup 5A and has been classified as Southern Tropical Dry Deciduous Forest. The vegetation of the area varies depending upon the terrain, site condition, moisture and other edaphic factors. Fourteen categories of vegetation types were identified based on the tones and textures on the FCC hard copy. The categories identified on the satellite data alongwith the interpretation key is given in Table 4.2.

Table 4.2 : Interpretation key for identifying vegetation types in TATR

Veg. Type	Tone	Texture	Shape	Pattern	Association
Teak-1	Dark Brownish Green	Medium	Irregular	Scattered	Gentle slopes to flatter areas
Teak-2	Light Green	Coarse	Irregular	Scattered	Slightly higher and rocky slopes
Teak-Bamboo	Brownish Red	Coarse	Irregular	Scattered	Gentle medium slopes
Teak-Miscellaneous Bamboo	Reddish Brown	Coarse	Irregular	Scattered	Moist slopes
Miscellaneous Forest	Deep Red	Smooth	Irregular	Contiguous	Flatter areas with good soil cover
Miscellaneous Bamboo I	Red	Smooth to Coarse	Irregular	Contiguous	Gentle moist slopes flatter areas with good soil
Miscellaneous Bamboo II	Reddish Yellow	Smooth	Irregular	Contiguous	Gentle moist slopes and flatter areas with good soil
Riparian	Dark Red	Coarse	Irregular	Contiguous	Along drainage
Meadows	Yellowish Green	Coarse	Elongated	Contiguous	Evacuated sites
Grassland on Plateau	Green	Smooth	Elongated	Contiguous	Plateau tops and hill slopes
Agriculture	Yellow	Smooth	Geometrical	Contiguous	Habitations
Water	Black/Dark Blue	Smooth to Coarse	Irregular	Contiguous	-
Miscellaneous open	Pink	Coarse	Irregular	Scattered	Poor soil and distributed areas

4.2.6.4. Ground Revalidation

Once the entire process of mapping was over a ground revalidation was carried out in January, 1995. During the process all doubtful and confusing points were corrected on the imagery and the same details were transferred on to the base map. All polygons were labelled to depict different vegetation types. Final map was digitized in GIS domain using Geographic Resource Analysis Support System **(GRASS)** software.

4.3. METHODS (STRUCTURE & COMPOSITION)

Standard field methods (Dombois Muller & Ellenberg , 1974) were used to quantify the vegetation parameters. Data was collected from 225 vegetation plots of 20m X 20m. Size of the plot was finalised using the nested plot technique (Dombois-Muller- & Ellenberg 1974). Sampling was based on the vegetation map (1:50,000 scale), prepared earlier in this study using satellite image. The objective of quantifying vegetation was to prepare extensive inventories of plants and to get information on their abundance and densities.

4.3.1. VEGETATION PARAMETERS

4.3.1.1. Density

Individuals of all the trees with girth class more than 20 cm at breast height viz. 1.3m and shrubs were counted in the 20m X 20m vegetation plot. Considering woody plants as trees and shrubs was decided based on the criteria given by Muller Dombois & Ellenberg, 1974). Recruitment class (woody plants with the straight bole and GBH $\leq$ 20cm) were counted in 20m X

20m plots. Seedlings were classified into two group ($\leq$ 50cm in height and $\geq$ 50cm but < 100cm in height). Seedlings were also recorded in 20m X 20m plot. For all these groups except seedling and sapling, GBH and height was measured.

4.3.1.2. Crown cover

Crown cover was measured for all the tree species falling inside the plot. With the help of a measuring tape two diameters for each tree species were recorded from the plot. These two diameters were then later averaged to get the mean radius. Using the formula for the area of circle (πr^2), the crown cover for each individual was calculated.

4.3.1.3. Shrub cover

Since the shrubs density alone cannot give a better picture of the shrub cover, shrub volume was considered as an important variable. All shrubs falling in the plot were counted. Two diameters for the extent of canopy for each individual were measured. Height of each individual shrub species was also measured.

4.3.1.4. Bamboo cover

Bamboo cover was enumerated separately. This was done by counting the number of bamboo stems in four 2m X 2m subplots in the main 20m X 20m vegetation plot. Height was occularly estimated.

4.3.1.5. Ground cover

Ground cover was recorded for grass, herbs and litter in terms of percentage cover in four 1m X 1m subplots in the main plot (20m X 20m).

4.3.1.6. Rock and bare soil

Rockiness and ground cover devoid of vegetation was also occularly measured by dividing the whole plot in 2m X 2m size grids and the plot was marked for presence and absence of rocks and bare soil. Later these tally marks were converted into percentages.

4.4. RESULTS (MAPPING)

In TATR the mapping of vegetation has been done primarily keeping three factors in mind. Firstly, mapping of the vegetation types, secondly the density of the canopy i.e. the canopy closure and lastly the vegetation map would serve as the baseline for evaluating habitat, using IRS, LISS-II FCC data. The satellite data acquired was very good for visual interpretation and was 100 % cloud free (10^{th} November, 1994). During this season all tree bear leaves and only grasses start drying up. This helps in getting better and sharper reflectance for different vegetation types. With a ground resolution of 36.5m X 36.5m and a fine quality FCC it was possible to delineate 15 mappable units based on colour/tone, texture, location, shape and validating it with sufficient ground truth (Plate 4.1). Attempt has also been made to measure and map the canopy closure using texture as the main element.

Following is the description of the mapped units.

(1) TEAK I: (TI)

Teak is the most dominant tree species in the study area and is distributed through out the reserve. Teak can be seen in all associations in varying proportions. Pure patches of teak can be seen on the undulating plains and hill tops where soil is sandy (murrum). This category has more than 70% teak trees and *Lagerstromia parviflora*, *Aegle marmelos*, *Chloroxylon swietenia* are the major associates. Middle storey is mainly dominated by *Wrightia tinctoria* and *Holarrhena pubescens.*

On satellite data Teak I appeared in dark brownish green tone. Depending upon the canopy closure which was > 40% in this category the texture varied from smooth to medium but by and large it was medium. In certain places the tone did appear slightly reddish in contiguity with the dark brownish green tone, which was due to under storey of *Holarrhena pubescens, Wrightia tinctoria* etc.

(2) TEAK II: (TII)

Teak II was also quite similar to Teak I except for the crown density which in this case was < 40%. Teak II type can be seen on slightly higher slopes and rocky slopes. This category has around 50% of Teak and *Chloroxylon swietenia*, *Odina cordifolia* and *Lagerstromia parviflora* occur as co-dominants. Shrub layer is very poor in this category except for occasional clumps of bamboo.

Teak II on satellite image appears light green in colour. The texture was mainly coarse because of low canopy closure and poor understorey cover. Shape was irregular with a wavy pattern.

(3) TEAK - BAMBOO: (TB)

This category was not found in large proportions as these were the old teak plantations and on very few site this association occurred naturally inside the reserve. This type was seen on gentle to medium slopes and flat areas. Teak was the dominant species with *Lagerstromia parviflora*, *Pterocarpus marsupium* and *Chloroxylon swietenia* as the co-dominants. Understorey is covered with thick bamboo clumps and occasionally *Zizyphus enoplia* and *Helictris isora*.

On satellite image this type appeared in brownish red colour. Texture was coarse because of thick bamboo clumps in under storey. Shape of this vegetation type was irregular with scattered pattern.

(4) TEAK-MISCELLANEOUS WITH BAMBOO: (TMB)

This association was found on the moist slopes. In this category teak and its co-dominants occured in almost equal proportions. Apart from teak, *Chloroxylon swietenia Gardenia latifolia*, *Odina cordifolia*, *Terminalia tomentosa* can be seen as dominant species and *Bridelia retusa* and *Bassia latifolia* as codominants ones. The under storey in this type was occupied by dense bamboo and *Helictris isora*.

This type appeared reddish brown on the image with a coarse texture. The shape was irregular with wavy pattern. This type had a crown density of > 60%.

(5) MISCELLANEOUS FOREST: (Misc.)

This mixed association can be seen in valleys and low lying flatter areas with good soil cover. This category was dominated by *Terminalia tomentosa*, *Gardenia latifolia*, *Anogeissus latifolia*, and *Chloroxylon swietenia*. The co-dominants in this type were *Odina cordifolia*, *Mitragyna parviflora*, *Bridelia retusa* and *Bassia latifolia*. Understorey was occupied by *Helictris isora* and occasionally bamboo clumps. This category had a crown cover > 40%.

Miscellaneous forests appeared deep red on the image. The texture of this category was smooth. Shape was irregular with contiguous pattern. There were hardly any blank spaces in such areas.

(6) MISCELLANEOUS FOREST WITH BAMBOO - I : (MB-I)

This category of Miscellaneous forest with bamboo-I can be seen on the gentle slopes and flat areas in plains on good soil cover. The floristic composition of this type is similar to that of Miscellaneous forest except for species like *Buchnania lanzan* and *Emblica officinalis* which are found in good proportion. Bamboo can be seen evenly distributed throughout this vegetation type but in medium density. This category has a crown cover varying from 40 to 60%.

These forests appeared red on the image. Texture varied from smooth to coarse depending upon the canopy closure and interspersion of different tree species. The shape was irregular with a wavy pattern.

(7) MISCELLANEOUS FOREST WITH BAMBOO - II : (MB II)

MB-II category was also seen on gentle slopes, but most of it was seen in the flatter areas with good black soil and with more moist conditions. This type also had similar species composition as that of MB-I, except for the bamboo density. In this case it was higher than MB-I. This category has crown density < 40 % and very high bamboo density. In all such areas bamboo can be seen evenly distributed. Under storey is dominated by thick clumps of bamboo which does not allow other shrubs to grow.

This type shows a reddish yellow reflectance and the texture is smooth. The shape of this association is irregular with a contiguous pattern.

(8) RIPARIAN

Riparian forests occur along the deep and moderately deep streams and rivulets. This type was not very clearly delineated on the image as they were extremely narrow in extent. These forest grow on deep soil where the eroded clay and loam from upper reaches are deposited. *Terminalia arjuna*, *Syzyzium cuminii* and *Mangifera indica* are the major species seen in this type. At some of the sites bamboo also grows in association with the trees. Riparian forests appeared dark red on the satellite image. The texture was coarse. The shape of this type is irregular with contiguous pattern. Narrow bands of these forest can be found along the major drainage.

(9) MEADOWS

There are very few grassland area in the reserve. The meadows were formed at the sites where earlier human settlements existed and then later were shifted out of the National Park area of the reserve. These areas developed into grasslands and are in their successional stage. These are found in the area which has very good soil. Dominant grasses are *Apluda spp*, *Themeda quadricalvis*, *Aristida spp*, *Vetiveria zizinoides*. Certain tree species like *Zizyphus zuzuba* and *Albizzia procera* can also be seen in low numbers.

Meadows appear as yellowish green on the image. Texture is coarse. Shape is irregular with contiguous pattern.

(10) GRASSLAND ON PLATEAU: (GP)

These grasslands mainly occur on the plateau and hill tops if they are flat. This type mainly is associated with rocky outcrops with poor and gravely soil. Grasses in this type attain a height of 1m. Main grasses are *Heteropogon contortis* and *Andropogon spp*.

Grassland on plateau appeared green on the satellite image. Texture is smooth. Shape is elongated with contiguous pattern. Such areas are very few in the study area.

(11) SCRUB : (Scr)

Scrub forest is found only at the peripheral areas of the reserve where biotic pressures are extremely high. Scrub forest is dominated by *Zyziphus zujuba*, *Zyziphus enoplia* and *Gymnosporia montana*.

Scrub forest appear as brownish pink on the image. Texture is coarse. Shape is irregular with scattered pattern.

(12) MISCELLANEOUS OPEN: (MO)

Miscellaneous open forest was found close to some of the habitations where lopping and grazing pressure was high. Main species in this category were *Soyamida febrifuga*, *Diospyros melanoxylon* and *Chloroxylon swietenia*. Crown cover of this forest was < 30 %.

Miscellaneous open forests appear pink on the satellite image. Texture is coarse. Shape is irregular with scattered pattern.

(13) AGRICULTURE AREAS

Agriculture areas could be easily delineated because of their location surrounding villages and their shape. Area with crop appeared bright to dark pink and fallow land appeared dark brown to black. Texture is smooth. Shape is geometrical with contiguous pattern. This also helped in delineating the encroachment areas by villagers taken in for seasonal cultivation.

(14) HUMAN SETTLEMENTS

Settlements showed a white reflectance and were demarcated with great ease. There are six village in TATR and with the help of SOI 1:50,000 toposheets they were easily delineated.

(15) WATER BODY: (WB)

In TATR there are natural as well as artificial water bodies. Areas with water appear light to dark blue to blackish blue on satellite data depending on the depth of the water body. Texture is smooth. Shape is irregular with scattered pattern.

4.4.1. Area Calculation

Table 4.3 describes the summary of area details of these vegetation types. GRASS software algorithim was used to calculate the areas falling in different vegetation categories. The areas were later converted to percentages to find out the relative proportion of areas occupied by each vegetation type.

Teak in varying composition occupies a large area. Teak-miscellaneous bamboo has the largest area (133 km^2). Pure stands of Teak cover 18.72 km^2 (3.04%). Teak-2 occupies 75.94 km^2 (12.45%). Miscellaneous forest has an area 32.04 km^2 (5.39%). Miscellaneous forest with bamboo I & II has the maximum area which falls in the flat and good soil cover areas. They have an area of 156 km^2 (25.27%) and 129 km^2 (21.01%) respectively. Meadow and GP constitute 0.84 Km^2 & 2.7712 km^2 respectively. Scrub has an area of 7.126 km^2 and Miscellaneous open 9.6624 Km^2. Agriculture area cover about 14.5 km^2 (2.45%). Riparian forest are very narrow and thin in extent because of the shallow streams. They have an area of 1.5 km^2 (0.26%).

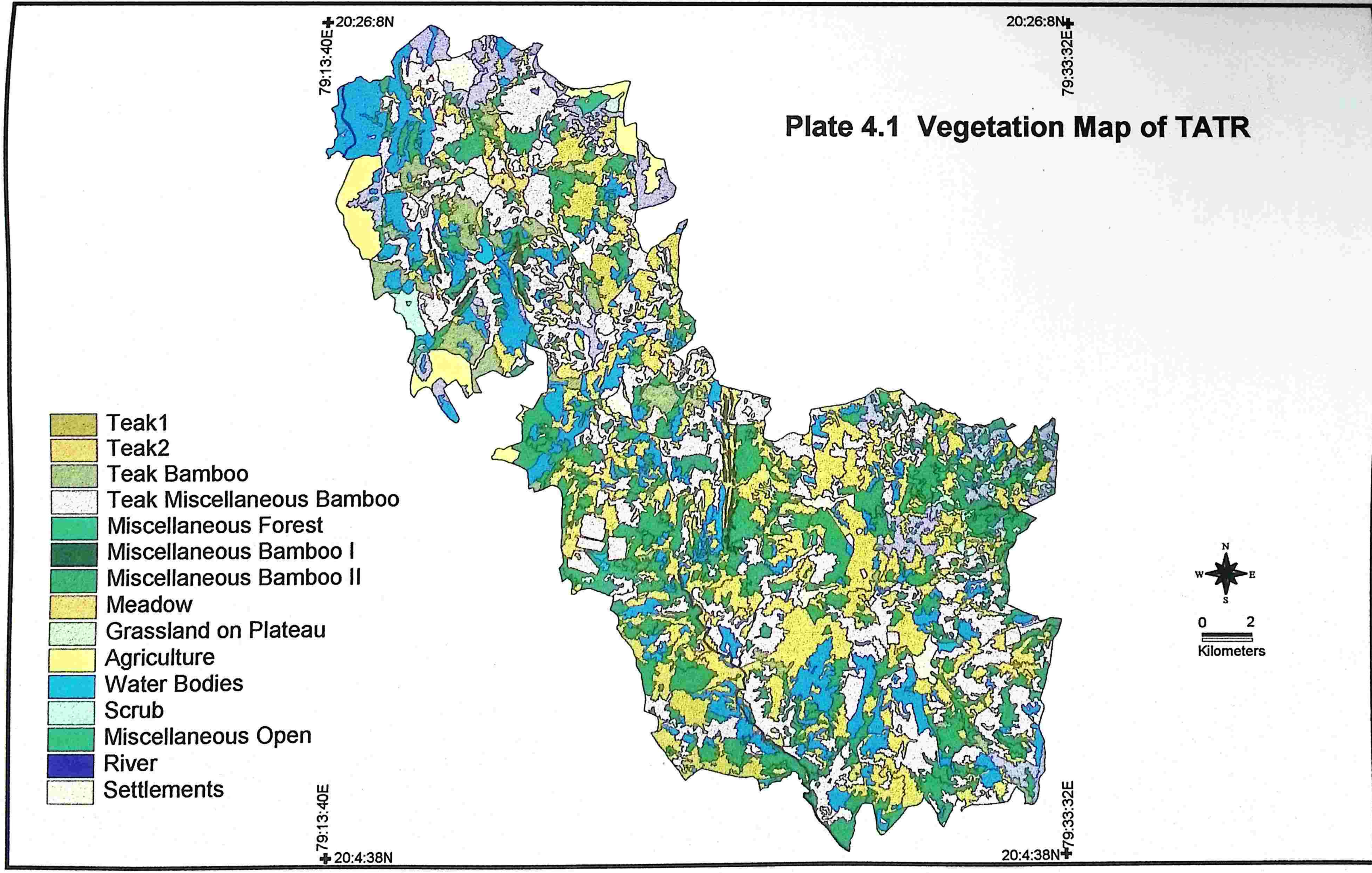


Plate 4.1 Vegetation Map of TATR

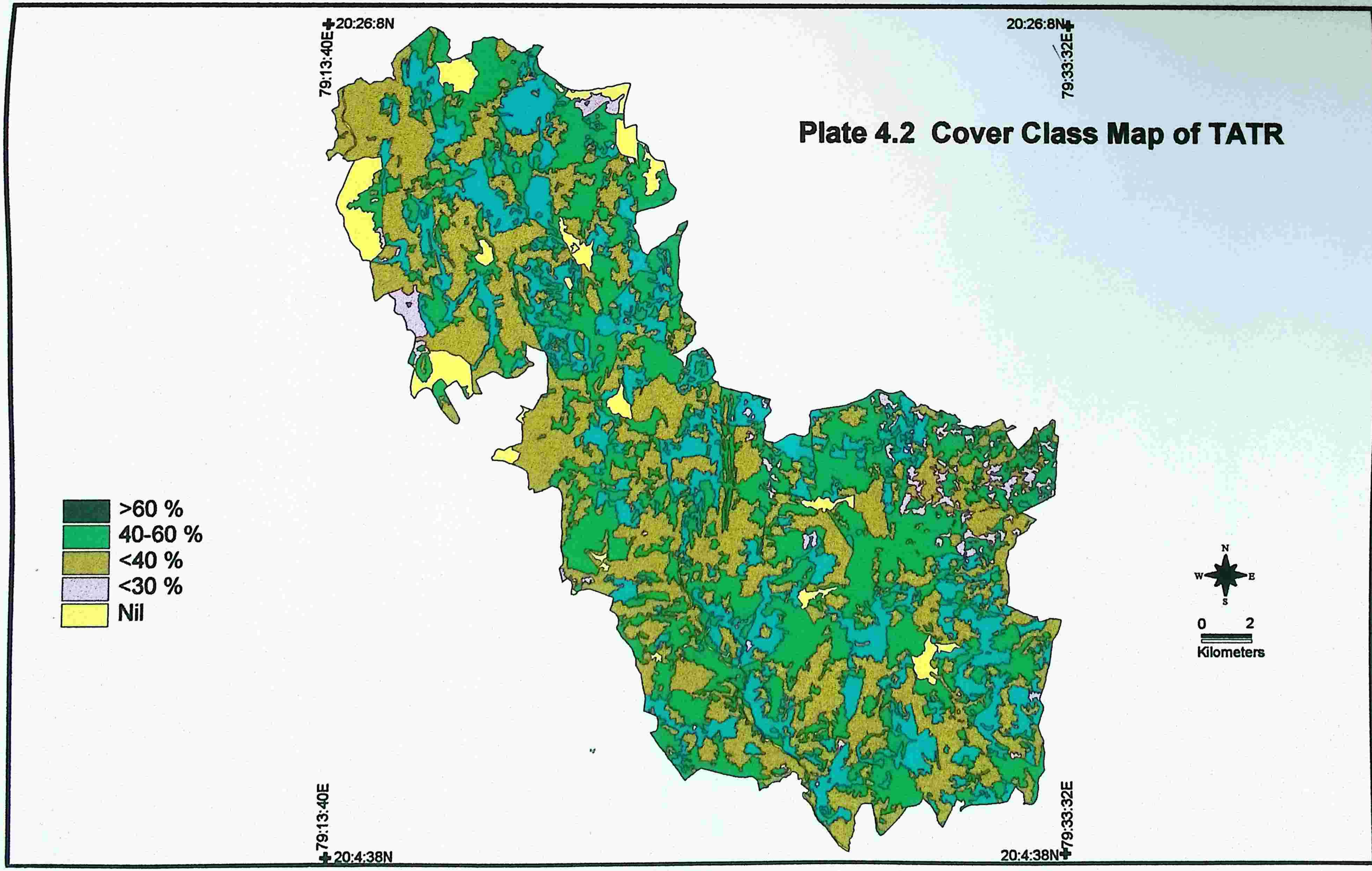
Table (4.3). Area of different vegetation types in TATR.

S.N.	VEGETATION TYPE	Area (km^2)	%
1.	TEAK-1	18.72	3.04
2.	TEAK-2	76.8	12.45
3.	TEAK BAMBOO	21.8	3.54
4.	TEAK MISCELLANEOUS BAMBOO	133.7	21.65
5.	MISCELLANEOUS	33.3	5.39
6.	MISCELLANEOUS BAMBOO I	156.02	25.27
7.	MISCELLANEOUS BAMBOO II	129.7	21.01
8.	RIPARIAN	1.6	0.26
9.	MEADOW	O.84	0.14
10.	GRASSLAND ON PLATEAU	2.8	0.45
11.	SCRUB	7.9	1.17
12.	MISCELLANEOUS OPEN	9.8	1.59
13.	AGRICULTURE AREAS	15.1	2.45
14.	HUMAN SETTLEMENT	8.16	1.32
15.	WATER BODIES	1.7	0.28

4.4.2. Cover Mapping of Forest

Though it was slightly difficult to map the forest on the basis of canopy cover owing to the resolution of **IRS LISS II** data (36.5m X 36.5m), still during the course of field work, correlation between cover class of the forest and image characteristics was established. Only in some cases did the thick and broad leaved understorey in open forest appeared as dense forest (pseudo density). Canopy cover appearing in smooth texture, with no soil exposed were classified as > 60 %. Similarly, areas with medium to coarse texture were marked as 60-40 % and areas showing very coarse texture were delineated as > 40 %. Only in the case of Miscellaneous open forest the crown cover was <

Plate 4.2 Cover Class Map of TATR



30 % (Table 4.4). Plate 4.2 shows the areas under different cover class in the TATR.

Table 4.4. Cover classes in different vegetation types.

S.N.	COVER CLASS	VEGETATION TYPES
1.	> 60 %	TMB
2.	60-40 %	TEAK-1, MISC.FOREST, MB-I, RIPARIAN,
3.	< 40 %	TEAK-II, TB, MB-II,
4.	< 30 %	MISC.OPEN, Scrub

4.5. ANALYSIS (STRUCTURE & COMPOSITION)

Vegetation classification was done using **TWINSPAN** (Hill, 1979) analysis and **IVI** values were calculated. The IVI calculation was based on relative density, relative dominance of the basal area and relative frequency of species.

Species diversity in different vegetation associations was measured using the most widely used Shannon-Wiener Index (Pielou 1975, Magurran 1988), i.e.

$$H' = S \ PiLogPi$$

Where

H' = Shannon Wiener diversity index

Pi = Proportion of i^{th} species in a community.

Species richness was calculated using the Menhinick index (Magurran 1988).

R = S / Ö N

R = Species richness

S= number of species in a community

N = number of individuals of all species in a community

Species evenness (i.e, species with equal abundance) was calculated using index J (Magurran, 1988)

J=H'/logs

Where:

J = Evenness index

S= Total number of species in a community

Distribution pattern of species was calculated using variance to mean ratio (Pielou, 1977). The mean and variance of species per plot was calculated from the number of individuals of a species in all the vegetation plots. If variance to mean ratio was less than 1, the distribution was assumed to be random, if equal to one, it was uniform, and if the ratio is greater than one the distribution it was assumed to be clumped.

4.6. RESULTS

4.6.1. Vegetation classification:

Twinspan analysis resulted in delineation of major vegetation associations in Tadoba. A list of plant recorded in all the vegetation plots is given in Appendix (i). Quantitative results are presented in form of mean ± SE (Standard error of mean at 95% confidence interval) followed by n i.e. number of samples.

4.6.1.1. *Tectona grandis-Chloroxylon swietenia-Diospyros melanoxylon* (TCD) : Mean tree density in this association was 457± 76 trees per hectare (n=11) and seedling and sapling density was observed to be 2177 ± 623 and 350 ± 97 individuals per hectare (n=11). Mean diversity, richness and evenness were 1.83, 2.54 and 0.57 respectively. Density of plants in recruitment class was 218 ± 47 individuals per hectare. Shrub density was 115 ± 69 clumps per hectare (n=5).

4.6.1.2. *Chloroxylon sweitenia-Diospyros melanoxylon-Tectona grandis-lagerstromia parviflora* (CDTL) : Mean tree density was 396 ± 26 trees per hectare (n=36). Mean diversity, richness and evenness were 1.58, 2.25 and 0.69 respectively. Seedling and sapling density was observed to be 1710 ± 246 and 527 ± 98 respectively (n=36). Density of plants in recruitment class was 212 ± 39 and shrub density was 87 ± 24 clumps per hectare (n=19).

4.6.1.3. *Tectona grandis-Lagerstromia parviflora-Chloroxylon swietenia-Diospyros melanoxylon* (TCLD) : Mean tree density 385 ± 34 trees per hectare (n=37). Mean diversity, richness and evenness were 1.51, 2.16 and 0.70 respectively. Seedling and sapling density was calculated to be 1132 ± 182 and 494 ± 84 individuals per hectare respectively (n=37) and recruitment class density was 227 ± 30. Shrub density in this association was 74 ± 19 clumps per hectare (n=25).

4.6.1.4. *Tectona grandis-Chloroxylon swietenia-Lagerstromia parviflora-Zyzyphus xyolopyra* (TCLZ): Mean tree density was 386 ± 44 trees per hectare (n=23). Mean diversity, richness and evenness were 1.83, 2.52 and 0.57 respectively. Seedling and sapling density was 1563 ± 347 and 591 ±

132 respectively (n=23). Recruitment class density was 216 ± 66 and shrub density was 66 ± 16 clumps per hectare (n=14).

4.6.1.5. *Terminalia belerica-Emblica officinalis-Anogeissus latifolia* (TEA): Tree density in this association was 317 ± 59 trees per hectare (n=3). Mean diversity, richness and evenness were 1.99, 2.71 and 0.50 respectively. Seedling density was observed to be 1300 ± 1054 and Sapling density was 892 ± 669 per hectare (n=3). Recruitment class density was 50 ± 25 individuals per hectare. Shrub density was 75 ± 50 clumps per hectare (n=2).

4.6.1.6. *Tectona grandis-Lagerstromia parviflora-Gardenia latifolia-Annogeisssus latifolia* (TLGA) : Mean tree density was 439 ± 42 individuals per hectare (n=11). Mean diversity, richness and evenness were 2.07, 2.77 and 0.50 respectively. Seedling and sapling density was observed to be 2044 ± 552 and 1116 ± 371 individuals per hectare (n=11). Recruitment class density was 261 ± 69 plants per hectare. Shrub density was 117 ± 47 clumps per hectare (n=3).

4.6.1.7. *Tectona grandis-Lagerstromia parviflora-Annogeissus latifolia-Bassia latifolia* (TLAB) : Mean tree density was 314 ± 33 trees per hectare (n=7). Mean diversity, richness and evenness were 1.88, 2.59 and 0.55 respectively. Seedling and sapling density was 593 ± 280 and 625 ± 260 individuals per hectare. Recruitment class density was 82 ± 40 trees per hectare. Shrub density was 231 ± 124 clumps per hectare (n=4).

4.6.1.8. *Chloroxylon sweitenia-Tectona grandis-Cassia fistula-Emblica officinalis* (CTEO) : Tree density was 432 ± 36 trees per hectare (n=16). Mean diveristy, richness and evenness were 2.13, 2.94 and 0.49 respectively. Seedling and sapling density was 891 ± 185 and 430 ± 102 individuals per hectare (n=16). Recruitment class density was 293 ± 54 plants per hectare. Shrub density was 96 ± 40 clumps per hectare (n=7).

4.6.1.9. *Cleistanthus collinus-Madhuca latifolia-Terminalia tomentosa-Diospyros melanoxylon* (CBTDL) : Mean tree density was 335 ± 22 trees per hectare (n=37). Mean diversity, richness and evenness were 1.82, 2.51 and 0.56 respectively. Seedling and sapling density was 896 ± 139 and 493 ± 92 individuals per hectare. Recruitment class density was observed to be 144 ± 29 individulas per hectare (n=37). Shrub density was 52 ± 8 clumps per hectare (n=32).

4.6.1.10. *Diospyros melanoxylon-Madhuca latifolia-Terminalia tomentosa* (DBT) : Tree density in this association was 340 ± 34 trees per hectare (n=24). Mean diversity, richness and evenness were 1.77, 2.47 and 0.59 respectively. Seedling and sapling density was 1763 ± 301 and 581 ± 106 individuals per hectare (n=24). Recruitment class density was 150 ± 25 plants per hectare and shrub density was 107 ± 39 clumps per hectare (n=20).

4.6.1.11. *Terminalia tomentosa - Madhuca latifolia- Cleistanthus collinus* (TBC) : Mean tree density was 320 ± 31 trees per hectare (n=20). Mean diversity, richness and evenness were 1.42, 2.10 and 0.66 respectively. Seedling and sapling density was 1913 ± 352 and 760 ± 216 individuals per hectare (n=20). Recruitment class density was 133 ± 30 plants per hectare and shrub density was 41 ± 10 clumps per hectare (n=8).

4.6.2. TREE DENSITY

4.6.2.1. Tree, Seedling/Sapling & Recruitment class Density

Both maximum and minimum tree density were observed in plots in TCLD association (Table 4.6). Maximum average tree density was in TCD association while minimum was observed in TLAB association (Fig. 4.1). The over all variation in mean tree density among vegetation association was significant (K-W $X^2 = 29.20$, $P < 0.05$, n=225).

Maximum seedling density was observed in a plot in TCD association (7600/ha) followed by TCLZ (7525/ha), while a minimum of (0.00/ha) was observed in one plot each in eight association (Table 4.6). Mean seedling density was maximum (2177/ha) in TCD association and minimum (593/ha) in TLAB association (Fig. 4.2). The overall difference among vegetation associations was significant (K-W $X^2 = 19.95$, $P < 0.05$, n=225).

Maximum sapling density (4050/ha) was observed in a plot in TLGA association and minimum (0.00/ha) in one plot in ten associations (Table 4.7). maximum average sapling density was observed in TLGA association while minimum (350/ha) was observed in TCD association (Fig. 4.2). The overall variation was however not significant (K-W $X^2 = 5.31$, $P > 0.05$, n=225).

Maximum recruitment class density (1525/ha) was observed in a plot in TCIZ association while minimum of (25/ha) was observed in at least one plot in each association (Table 4.7). Mean maximum density (261/ha) was observed in TCLZ association and minimum (50/ha) in TEA (Fig. 4.2). The overall difference in mean density among vegetation association was significant (K-W X^2 = 19.21, $P < 0.05$, n=225). Mostly commonly occuring species contributed more to recruitment class (Table 4.12).

4.6.2.2. Shrub Density and Volume

Maximum shrub density (750/ha) was in a plot in DBT association and minimum of (25/ha) in one plot each in ten associations (Table 4.10). Average shrub density was highest (231/ha) in TLAB association and minimum (41/ha) in TBC. The overall difference in mean shrub density among vegetation associations was not significant (K-W X^2 = 13.37, $P > 0.05$, n = 138)

Maximum shrub volume (4050 m^3/ha) was in a plot in TCLD association while a minimum of (0.00/ha) was in at least one plot each, in nine associations (Table 4.10). Mean shrub volume was maximum in CTEO (1275 m^3/ha) while minimum of (50 m^3/ha) in CDTL. The overall variation was however not significant (K-W X^2 = 11.62, $P > 0.05$, n = 138).

4.6.2.3. Tree Distribution

Tree distribution of most of the species turned out to be uniform. 30% of total species showed highly clumped distribution whereas 18% showed their tendency towards clumped distribution and 52% species showed an uniform distribution. The extent of dispersion can be estimated from (Table4.5). The most clumped species were *Zizyphus xylopyra*, *Cleistanthus collinus*, *Chloroxylon Swieteni*, *Terminalia tomentosa*, *Acacia catechu*, *Tectona grandis*, *Diospyros melanoxylon* and *Ficus scandens*.

4.6.2.4. Diversity indices

Maximum tree species diversity (2.56) was in a plot in DBT association and minimum (0.00) in a plot in TBC association (Table 4.8). Average tree diversity was maximum in CTEO association whereas minimum was in TBC association (Fig. 4.3) The overall variation in tree species diversity was significant (K-W $X^2 = 56.87$, $P < 0.05$, $n = 225$).

Maximum tree species richness (3.61) was observed in a plot in DBT association while a minimum of (1.00) was in a plot in TBC association (Table4.9). Average tree species richness was maximum in CTEO association while minimum in TBC association (Fig. 4.3). The overall difference in tree species richness among vegetation association was significant (K-W $X^2 = 56.87$, $P < 0.05$, $n = 225$).

Maximum species evenness (1.44) was observed in a plot in CDTL and TCLD association while a minimum (1.00) in TBC association (Table 4.8). Average species eveness was maximum in TCLD association and minimum in CTEO association (Fig. 4.3). The overall variation was significant (K-W $X^2 = 54.83$, $P < 0.05$, $n = 225$).

4.6.2.5. GBH and Crown Cover

Maximum gbh was recorded in a plot in CDTL association and minimum in TCLZ association (Table 4.11). Average maximum gbh was observed in TEA association while minimum was in TCLZ association (Fig. 4.4). The overall variation was found to be significant (K-W $X^2 = 31.67$, $P < 0.05$, $n = 225$).

Mean maximum crown cover was observed in a plot in TLGA association while minimum was observed in a plot in TCLD association (Table 4.11). Average maximum crown cover was in TLGA associaton while minimum was in TLCZ association (Fig. 4.5). The overall variation in crown cover amoung vegetation associations was significant (K-W X^2 = 28.23, $P < 0.05$, n = 225).

Table 4.5. Distribution pattern of tree species in Tadoba Andhari Tiger Reserve.

SPECIES	MEAN	VARIANCE	DISPERSION PATTERN
Buchnania lanzan	1.56	0.62	0.39
Terminalia tomentosa	2.89	7.2	2.49
Cassia fistula	1.19	0.28	0.23
Bauhinia racemosa	1.00	0.00	0.00
Bauhinia malabarica	5.00	2.07	0.41
Terminalia arjuna	1.5	0.25	0.17
Hardwickia binata	3.00	0.00	0.00
Emblica officinalis	1.32	0.44	0.33
Terminalia belerica	1.54	1.11	0.72
Aegel marmelos	1.5	1.63	1.08
Zyzyphus zuzuba	2.50	6.75	2.70
Chloroxylon swietenia	4.36	11.47	2.63
Semecarpus anacardium	1.00	0.00	0.00
Pterocarpus marsupium	1.33	0.67	0.50
Albizzia doratissima	1.30	0.21	0.16
Acacia caesia	1.00	0.00	0.00

Anogeissus latifolia	1.69	1.05	0.62
Gardenia lucida	1.00	0.00	0.00
Gardenia latifolia	1.74	1.46	0.84
Adina cordifolia	1.33	0.22	0.17
Balanites roxburghii	3.50	6.25	1.79
Acacia leucophloea	3.40	4.24	1.25
Tamarindus indica	1.40	0.64	0.46
Schyzizium cuminii	1.25	0.19	0.15
Feronia elephantum	1.50	0.25	0.17
Flacoutia ramontchi	1.33	0.22	0.17
Mytragyna parviflora	2.05	4.52	2.21
Dalbergia latifolia	1.28	0.89	0.70
Miliusa velutina	1.47	0.99	0.67
Acacia catechu	2.07	5.13	2.48
Bombax malabaricum	1.43	1.29	0.90
Albizzia procera	1.17	0.14	0.12
Sterculia urens	1.00	0.00	0.00
Carea arborea	1.44	0.47	0.32
Schleichera oleonoides	1.00	0.00	0.00
Bridelia retusa	1.45	1.75	1.21
Ixora parviflora	1.50	0.75	0.50
Bassia latifolia	2.24	2.54	1.13
Schrebera swieteniodes	1.00	0.00	0.00
Odina cordifolia	1.65	0.97	0.59
Euphorbia nivilia	1.00	0.00	0.00

Ficus scandens	1.50	1.75	1.17
Butea monosperma	2.60	5.04	1.94
Erythrina indica	1.00	0.00	0.00
Nyctanthes Arbor-tristis	1.00	0.00	0.00
Gardenia turgida	2.00	0.00	0.00
Soyamida febrifuga	2.00	0.71	0.36
Tectona grandis	5.00	17.61	3.52
Boswelia serrata	1.40	0.24	0.17
Dalbergia sissoo	1.15	0.18	0.16
Dalbergia paniculata	1.71	1.92	1.12
Lagerstromia parviflora	2.73	12.79	4.68
Diospyros melanoxylon	2.72	6.18	2.27
Ficus glomerata	1.00	0.00	0.00
Ficus benghalensis	1.00	0.00	0.00
Azadirachta indica	1.00	0.00	0.00
Stereospermum suaveolens	1.14	0.12	0.11
Strychnos nuxvomica	1.67	0.89	0.53

Table 4.6: Tree and Seedling density (number/ha) in different vegetation association in TATR (n=225).

VEGETATION ASSOCIATION	TREE DENSITY/ha			SEEDLING DENSITY/ha		
	MEAN	MIN	MAX	MEAN	MIN	MAX
TCD	456	175	1125	2177	150	7600
CDTL	396	150	850	1710	0.00	5825
TCLD	385	100	1375	1132	0.00	4875
TCLZ	386	300	1275	1563	0.00	7525
TEA	317	225	425	1300	0.00	3400
TLGA	439	275	775	2004	425	5375
TLAB	314	200	400	593	0.00	2035
CTEO	432	200	825	891	0.00	2425
CBTDL	335	150	625	896	20	3375
DBT	340	125	775	1763	0.00	4575
TBC	320	25	600	1913	0.00	5125
TOTAL	386±12	25	1375	1428±9	0.00	7600

Table 4.7. Sapling and Recruitment class density (number/ha) in different vegetation associations in TATR (n=225).

VEGETATION ASSOCIATION	SAPLING DENSITY/ha			RECRUITMENT CLASS DENSITY/ha		
	MEAN	MIN	MAX	MEAN	MIN	MAX
TCD	350	0.00	1050	218	25	450
CDTL	527	0.00	2275	211	25	1000
TCLD	494	0.00	1900	227	25	775
TCLZ	591	0.00	2275	216	25	1525
TEA	892	0.00	2200	50	25	100
TLGA	1116	50	4050	261	25	600
TLAB	625	0.00	1875	82	25	300
CTEO	430	0.00	1400	239	25	700
CBTDL	493	0.00	2775	144	25	650
DBT	581	0.00	1875	150	25	375
TBC	760	0.00	3375	133	25	500
TOTAL	570±43	0.00	4050	191±14	25	1525

Table 4.8. Tree species diversity and evenness in vegetation association in TATR (n=225)

VEGETATION ASSOCIATION	DIVERSITY			EVENNESS		
	MEAN	MIN	MAX	MEAN	MIN	MAX
TCD	1.83	1.10	2.40	0.57	0.42	0.91
CDTL	1.58	0.69	2.30	0.69	0.43	1.44
TCLD	1.51	0.69	2.08	0.70	0.48	1.44
TCLZ	1.83	1.10	2.48	0.57	0.40	0.91
TEA	1.99	1.95	2.08	0.50	0.48	0.51
TLGA	2.02	1.61	2.48	0.50	0.40	0.62
TLAB	1.88	1.39	2.30	0.55	0.43	0.72
CTEO	2.13	1.10	2.48	0.49	0.40	0.91
CBTDL	1.82	1.10	2.40	0.56	0.42	0.91
DBT	1.77	1.10	2.56	0.59	0.39	0.91
TBC	1.42	0.00	1.95	0.66	0.00	0.91
TOTAL	1.73	0.69	2.56	0.61	0.00	1.44

Table 4.9. Tree species richness in vegetation associations in TATR (n=225).

VEGETATION ASSOCIATION	RICHNESS		
	MEAN	MIN	MAX
TCD	2.54	1.73	3.32
CDTL	2.25	1.41	3.16
TCLD	2.16	1.41	2.83
TCLZ	2.52	1.73	3.46
TEA	2.71	2.65	2.83
TLGA	2.77	2.24	3.46
TLAB	2.59	2.00	3.16
CTEO	2.94	1.73	3.46
CBTDL	2.51	1.73	3.32
DBT	2.47	1.73	3.61
TBC	2.10	1.00	2.65
TOTAL	2.42 ± 0.03	1.00	3.61

Table 4.10. Shrub density (number/hectare) and volume (cu.m/hectare) in different vegetation associations in TATR (n=138).

VEGETATION ASSOCIATION	SHRUB DENSITY/ha			SHRUB VOLUME (m^3/ha)		
	MEAN	MIN	MAX	MEAN	MIN	MAX
TCD	115	25	375	512	0.00	1339
CDTL	87	25	325	50	0.00	143
TCLD	74	25	350	541	0.00	4050
TCLZ	66	25	225	278	0.00	1395
TEA	75	25	125	947	18.74	1875
TLGA	117	25	175	1105	0.00	225.57
TLAB	231	50	350	538	56.84	2545.31
CTEO	96	25	525	1275	0.00	3254.11
CBTDL	52	25	175	159	0.00	3060
DBT	106	25	750	175	0.00	1378
TBC	41	25	225	95	0.00	791.68
TOTAL	80±10	25	750	334±61	0.00	4050

Table 4.11. Average GBH (in mts) and Crown cover (in sq.mts) in different vegetation associations in TATR (n=225).

VEGETATATION ASSOCIATION	GIRTH AT BREAST HEIGHT			CROWN COVER		
	MEAN	MIN	MAX	MEAN	MIN	MAX
TCD	0.63	0.44	0.99	18.42	11.55	34.24
CDTL	0.72	0.47	1.64	19.68	7.55	63.33
TCLD	0.72	0.38	1.28	17.96	5.14	48.76
TCLZ	0.57	0.29	0.97	11.87	5.87	26.48
TEA	0.94	0.91	0.97	22.46	21.57	23.3
TLGA	0.82	0.67	1.19	35.53	9.52	138.4
TLAB	0.86	0.69	1.05	18.37	12.2	39.05
CTEO	0.68	0.49	0.84	21.94	8.72	36.83
CBTDL	0.77	0.38	1.31	20.11	7.71	41
DBT	0.77	0.44	1.17	22.32	10.2	52.03
TBC	0.78	0.55	1.49	22.17	7.2	61.23
TOTAL	0.77±0.7	0.29	1.64	21.24±0.86	5.14	138.4

Table 4.12. Contribution of tree species in recruitment class (n=225).

TREE SPECIES	No. of Individuals	Percentage %
Diospyros melanoxylon	224	12.9
Lagerstromia parviflora	169	9.8
Tectona grandis	570	33.2
Holarrhena antidysentrica	99	5.7
Cleintanthus collinis	75	4.3
Zyzyphus zuzuba	63	3.6
Chloroxylon swietenia	43	2.5
Terminalia tomentosa	55	3.2
Cassia fistula	33	1.9
Emblica officinalis	31	1.8
Aegel marmelos	20	1.1
Flacourtia ramontchi	23	1.34
Bombax malabaricum	38	2.2
Madhuca latifolia	23	1.34
Others	250	14.5
TOTAL	1716	100%

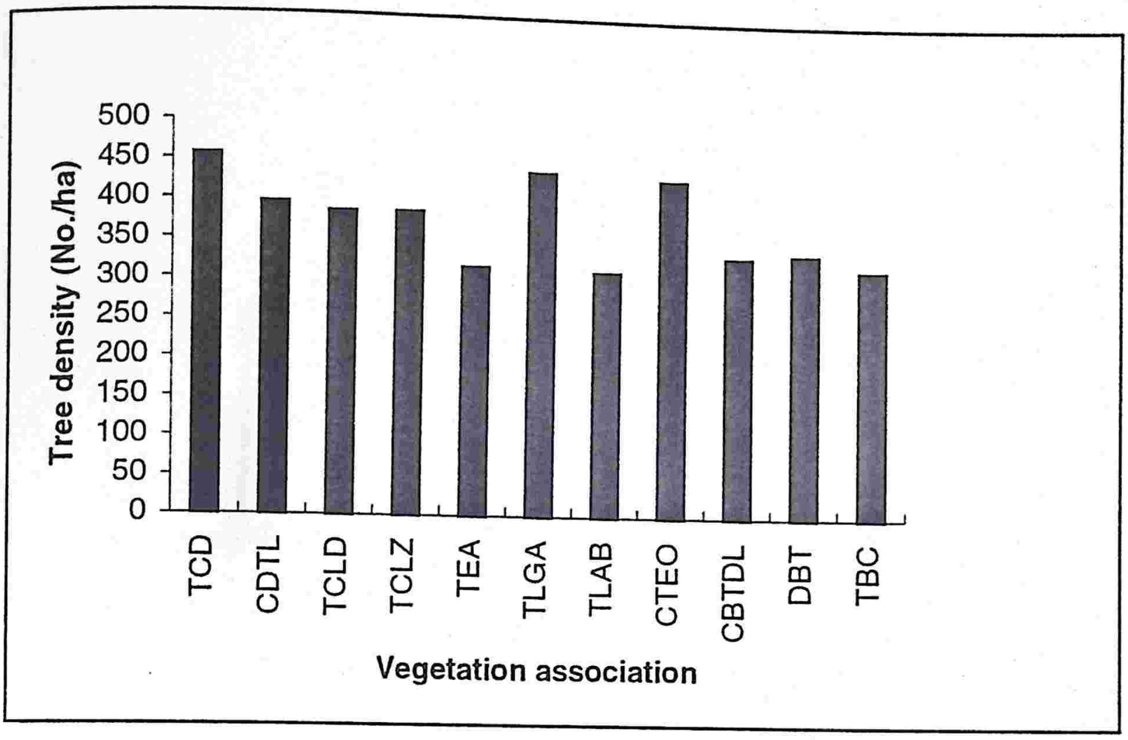


Fig.4.1. Average tree density (number/hectare) in vegetation association in TATR

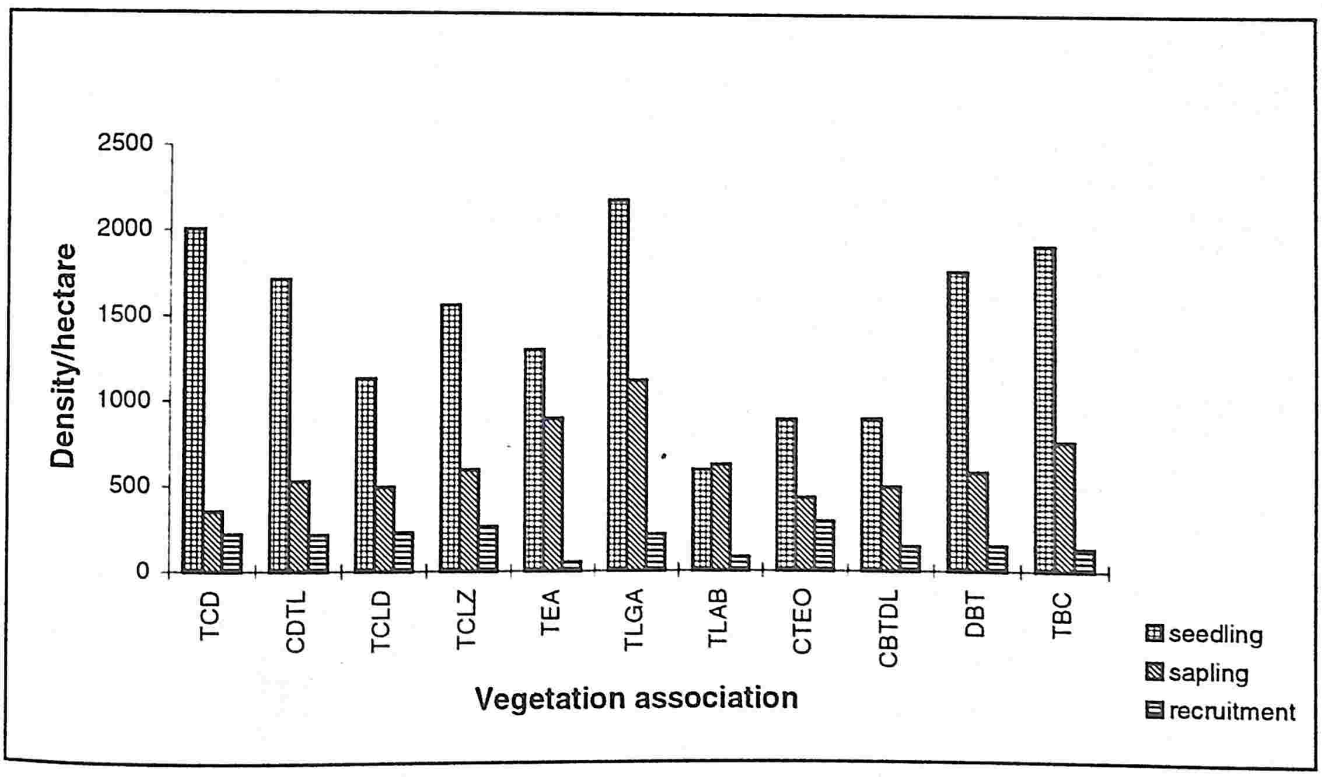


Fig 4.2. Average seedling/sapling & recruitment class density (number/hectare) in vegetation association in TATR

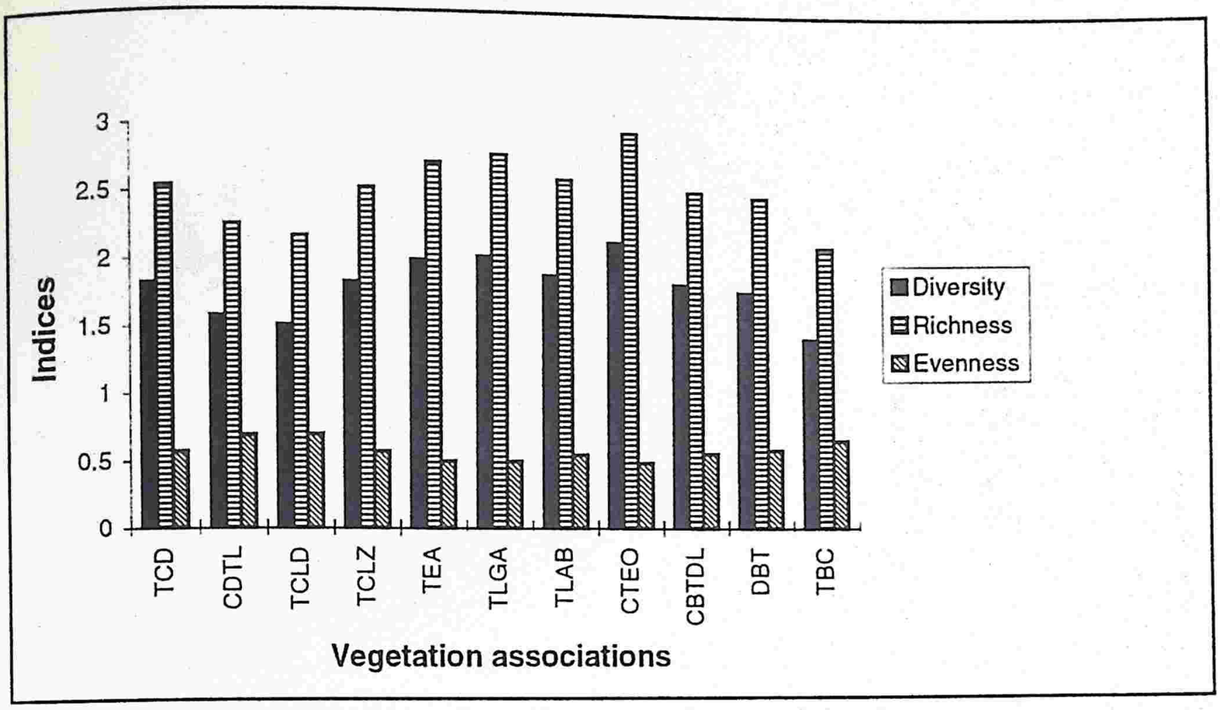


Fig 4.3. Average diversity indices for tree species in vegetation association in TATR

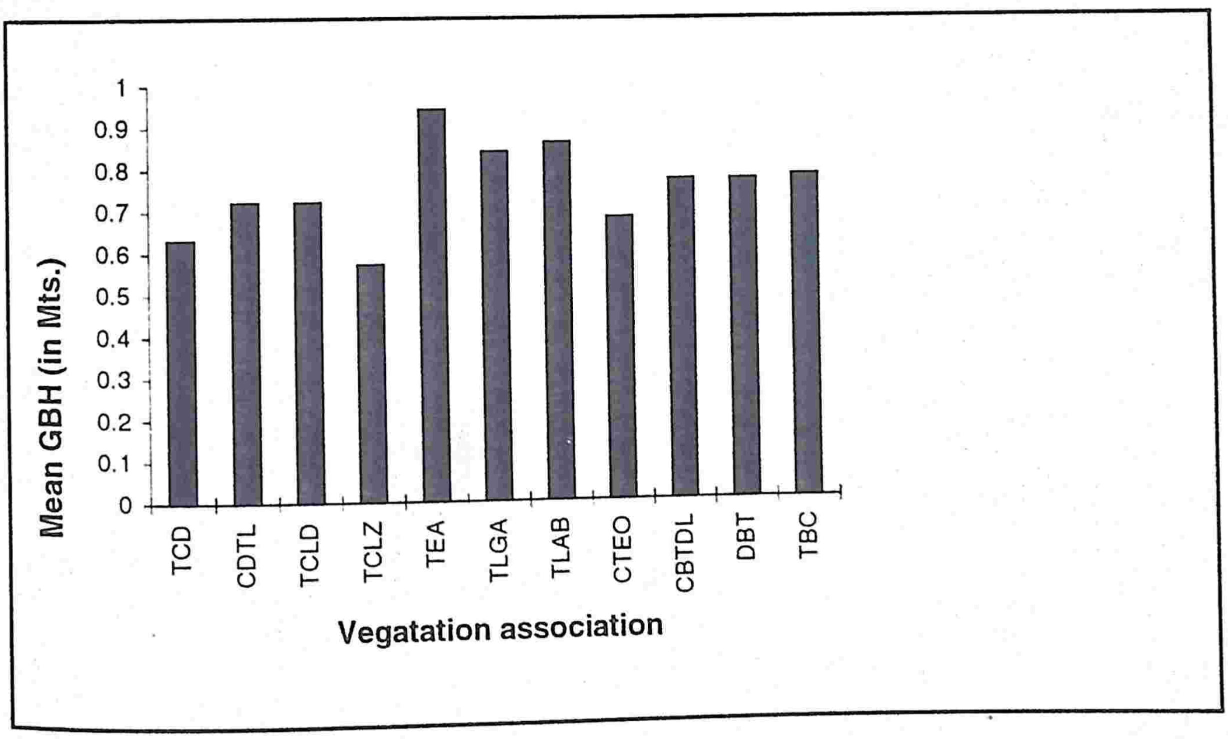


Fig. 4.4. Average GBH in different vegetation association in TATR

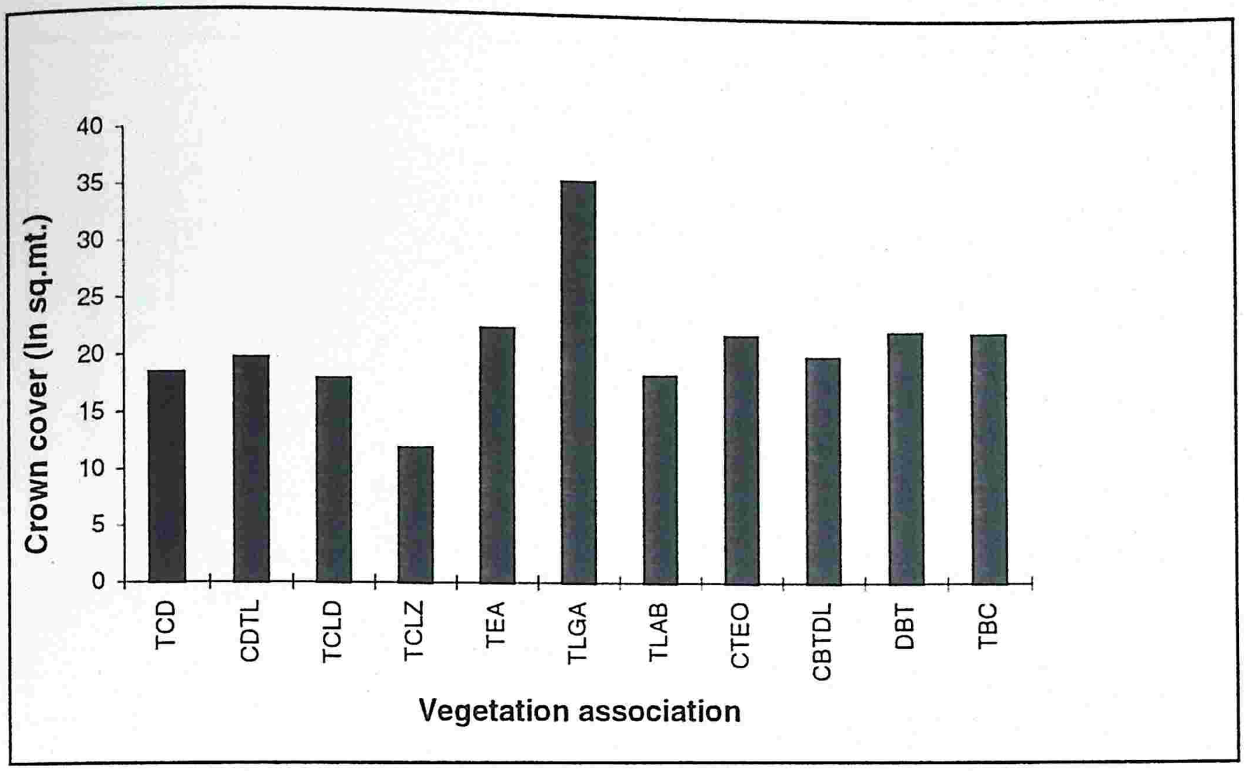


Fig 4.5. Average crown cover (in sq.mts) in vegetation associations in TATR

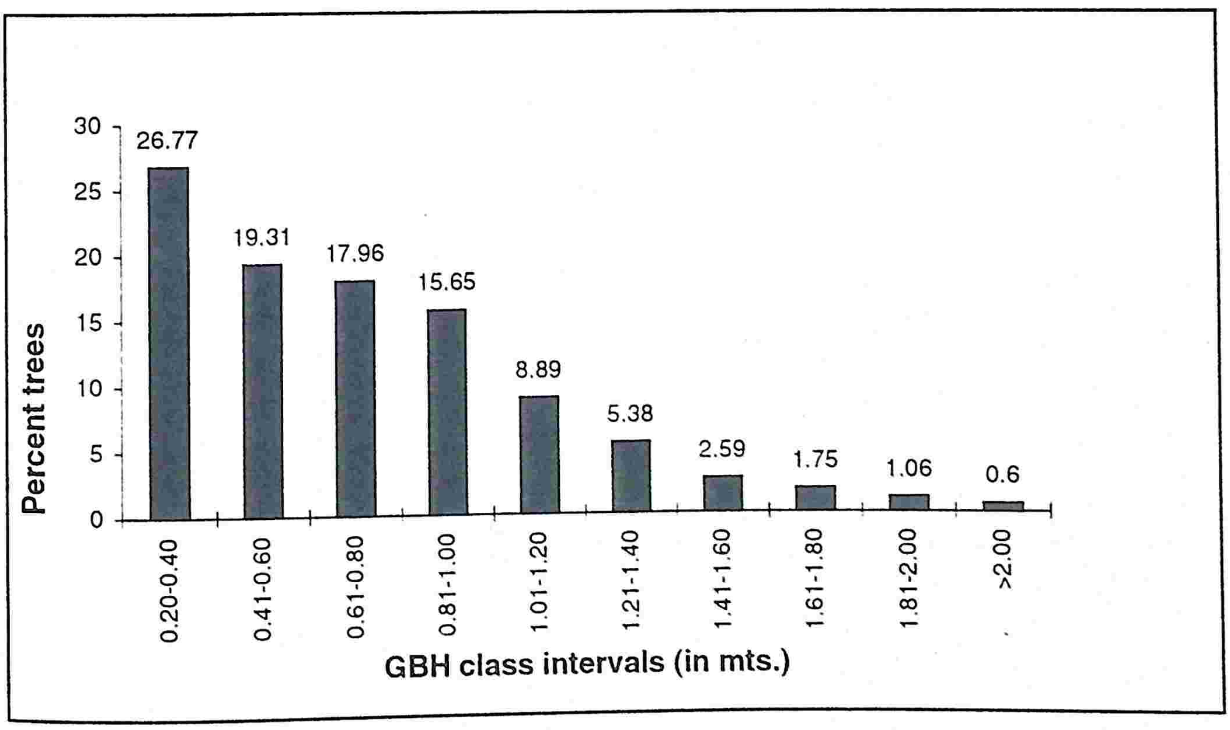


Fig. 4.6. Pooled GBH distribution in TATR

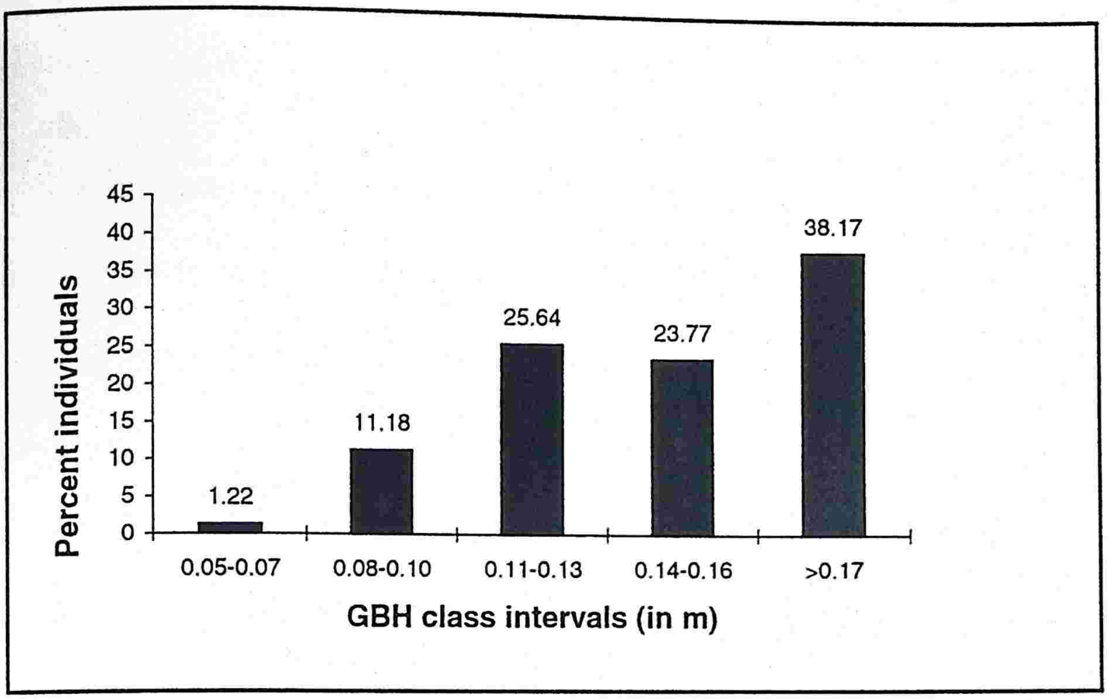


Fig. 4.7. GBH distribution in recruitment class in TATR

4.7 DISCUSSION

4.7.1. Mapping

The Teak dominated belt has been referred as the second largest of the Indian biogeographic provinces covering a potential area of 53 million hectares, encompassing much parts of central and southern Indian peninsula (Gadgil & Homji, 1982). The first vegetation classification was attempted by Champion (1936) followed by Champion & Seth (1968). This classification was not based on mapping , on some of the selected forest stands of the country. Gaussen *et al*, (1959) had mapped the vegetation of the entire Indian peninsula. This was the first classification which was done with careful and detailed planning (Gadgil & Homji, 1990). Tadoba falls under deccan phytogeographic zone (Chaterjee, 1939), with an average annual rainfall varying from 700 - 1500 mm and average length of dry season ranging from 5 - 8 months. These areas are considered poor in term of endemism (Bharucha & Homji, 1965) because of high degree of homogeneity in habitat.

Vegetation mapping of the area was attempted for the first time as it is considered to be an important layer in most of the analysis. Vegetation mapping is helpful for understanding the spatial patterns and relation of plant communities. It is better to subdivide the general vegetation cover in to more homogenous stands for ecological investigation. Vegetation map derived from satellite data were used in describing floristic composition of each homogenous stands delineated from satellite image. Vegetation mapping was done at the scale of 1:50,000. Vegetation Map at this scale is appropriate to document the vegetation of the Reserve. The dominance, structure and composition of species formed the mapping criteria along with the site factors.

Vegetation classification

TWINSPAN (Hill 1979) despite some limitations is the best computer programme available for classification of species and samples simultaneously. The programme presents the results in a comprehensive two way table. The limitation of the programme are due to its format and options for analysis which are described in Hill (1979), Greg-Smith (1983), Causton (1988) and Kent & Coker (1992).

The vegetation was classified and named based on association concept. This involves communities of definite floristic composition, uniform physiognomy and when occurring in similar habitat conditions, based on definition of the International Botanical Congress in Brussels in 1910 (Muller-

Dombois & Ellenberg, 1974). This criteria was not fulfilled in this study as is apparent from the descriptions of vegetation because most of the associations occurred in various types of habitat. Since Tadoba is a dry deciduous ecosystem, many habitat conditions were common for different vegetation associations. Despite all that, the association concept along with satellite mapping gives the best description of vegetation for TATR at this stage.

4.7.2. Density

Tree density was highest in TCD association as it is evident from the results (Table 4.6). This was possibly because of low bamboo density in TCD association which is also supported by high seedling density. TLAB association had the lowest tree density as the bamboo density was high. TLAB association had lowest seedling density also. This was due to high bamboo density as seedling survival rate becomes low under the thick canopy of bamboo. TLGA association had highest sapling and recruitment class density. Tree density in this association was high but bamboo density medium which supported better growth of sapling and recruitment class individuals.

TLAB association had highest mean shrub density as tree density was low in this association. This was also due to high number of *Cassia tora* and *Balanites roxburghii* growing in this association. Shrub volume was higher in CTEO as this association mostly comprised of *Chloroxylon swietenia* , *Cassia fistula* and *Zyziphus zuzuba* in shrub form which had wider spread and hence high volume.

Species composition and its distribution in TATR is very homogenous in nature and hence the community chracterization was quite difficult. Nearly all species occurred in all associations,but in varying proportions. Teak invariably dominated most associations and in some it occured as co-dominant species.

4.7.3. Tree Distribution

Natural distribution of plants is clumped and not random as was believed earlier. However, the pattern is TATR was slightly different. Only 30% species showed clumped distribution and 18% a tendency towards clumping. Rest were randomly distributed. In a study conducted by Hubbell, 1979 it was found that adult trees were more clumped. Hubble also recorded more clumping in the rarer species unlike in this case where rarer species were randomly or uniformly distributed. Similair results have been obtained in study conducted in Gir Lion Sanctuary (Sharma, 1995).

Chapter 5

Prey Abundance, Distribution and Habitat Utilization

5.1. INTRODUCTION

Expressions of population density, abundance and biomass of ungulates have been widely used to relate estimates of carrying capacity for different habitat types (Petrides, 1956; Bourliere, 1963; Lamprey, 1964; Sharkey, 1970; Schaller, 1972; Coe *et al.*, 1976; Eisenberg and Seidensticker, 1976; Bell, 1982; East, 1984; Brown, 1984; Karanth, 1988; Mathur, 1991) and interspecific relationships in a community (Sinclair *et al.*, 1990). Ungulate abundance and biomass have also been used to examine differences in carrying capacities of different habitats (Eisenberg, 1980; Eisenberg & Seidensticker, 1976) and for developing management and conservation strategies for wildlife species and habitats under threat (Berwick, 1974; Dinerstein, 1980; Varman & Sukumar, 1995).

The ungulate population, which forms the major proportion of diet for large carnivores, is the most crucial requirement for the survival of a predator population. An understanding of the structure and organization of ungulate population is inevitable for its long term conservation as it gives information not only on the internal dynamics of various components of the population of a given species, but also indicates how various components of a population interact with each other and their environment, along the seasonal gradient.

The population structure of a species is generally expressed as the proportions/ratios of various age and sex classes, and the change that takes place in these ratios under the influence of various ecological and intra population factors (Schaller, 1967).

A wide range of field methods are now available for the estimation of animal density. The choice of method depends on the nature of population, distribution in area under investigation and the method of sampling the population. Both direct and indirect methods of estimating mammal densities have been used in tropical forest (Barnes & Jensen 1987; Koster & Hart 1988; Varman 1988; Sale *et al.* 1990; Karanth & Sunquist 1992; Srikosamatra 1993; Sankar, 1994; Sathyakumar, 1994; Varman *et al.* 1995, Bhatnagar, 1997, Manjrekar, 1997). Estimates based on indirect methods usually involve counting animal droppings, whereas direct methods use visual sightings. Transect sampling technique was used for the study. Transect sampling has been widely used in wildlife research for estimating the size of the populations (Anderson & Pospahala, 1970). The first known estimator for predicting population density from line transect was proposed by R.T.King in an unpublished work reported by Leopold, (1933). Webb (1942); Hayne (1949); Yapp (1956); Dasmann & Mossman (1962); Hirst (1969) made modifications to the strip count method proposed by Leopold, 1933 to describe ungulate census techniques which are cost effective, reasonably accurate and user friendly with less man power required. Eberhardt (1968; 1978) reviewed the line transects and came up with estimation of bias, arising from several distance estimators. Varman & Sukumar (1995) compared the results obtained from line transects using different models and field experiments. Density estimation from the use of line transects is practical, efficient and inexpensive for many populations (Anderson *et al.* 1979; Burnham *et al.* 1980; Buckland *et al.* 1993).

Central to the study of animal ecology and management is the use an animal makes of its environment in terms of habitat it occupies (Johnson 1980). Wildlife managers therefore require efficient and reliable methods for assessing the habitat requirement of free ranging animals. The density and distribution of faeces can provide valuable information regarding habitat use (Putman 1984). Fecal transects have been widely used to assess the habitat use by wild animals (Sharma, 1995 and Macleod *et al* 1996). It helps in managing the distribution and abundance of concerned animal species by manipulating some of the habitat factors (Sharma, 1995). Studies conducted in India (Joslin 1973, Berwick 1974, Khan *et al.* 1990, Chakrabarty 1991, Bhunjanga Rao 1991, Johnsingh & Sankar 1991, Mathur 1991, Chellam 1993) provide information about habitat utilization by some of the Indian ungulates. Other studies conducted else where and in India have reported the variation in habitat utilization by animals within (De & Spillett 1966, Ben-Shahar 1990) and between seasons (Pratt *et al.* 1986; Bhujanga Rao 1991).

The concept of habitat is of prime importance in ecology as habitat forms the basic link between the organisms and their external environment (Mathur 1991). Habitat as defined by Giles, 1978 is the location that supports a population which includes space, food, cover and other animals and is characterized by vegetation, land form and hydrology (Odum, 1971). Every organism is dependent on its habitat for food, shelter, cover , water and other resources. The variation in resources and other physical attributes of habitat often result in differences in animal abundance (Mathur 1991). The quality of habitat is reflected in the spatial arrangement of habitats and their ability to provide all life requisites to an animal (Lancia *et al.*, 1982). Although the concept of wildlife habitat relationships is fairly new, but still it is neither a new philosophy nor a new approach to resource management (Salwasser *et al.* 1980).

The present chapter deals with the analysis of the density, biomass and habitat utilization by ungulates in TATR.

5.2. Methods

5.2.1. Density and Abundance

5.2.1.1. Vehicle count

Road transects were run to collect data on wild ungulate density. The TATR has fairly good network of roads, bisecting almost all the habitat types. The good road network enabled the efficient coverage of the study area. Plate 5.0 shows the placement of transects used for road counts. Systematic counts were carried out in both the field seasons (summer and winter) from a motorcycle with the author on the pillion, travelling at speeds between 10 and 20 km per hour. Attempt was made to observe as many animal as possible. Rider mainly concentrated on area right in front of him so as not to miss animals falling straight on the transect, whereas Observer on pillion covered rest of the area. Counting was done between 0600 and 0830 hrs in the morning and from 1600 and 1830 hrs in the evening. Motor cycle transects counts were conducted in the summers of 1995, 1996 and 1997 and the winters of 1994, 1995, 1996, 1997. These counts were not attempted in monsoons as the roads became unfit for travel and dense vegetation made sightings difficult. A total of 75.5 km of road length was monitored 14 times in the year 1994-95, 34 times in the year 1995-96 and 48 times in the year 1996-97. The details of transects, their lengths and repeatability are given in Table 5.1.

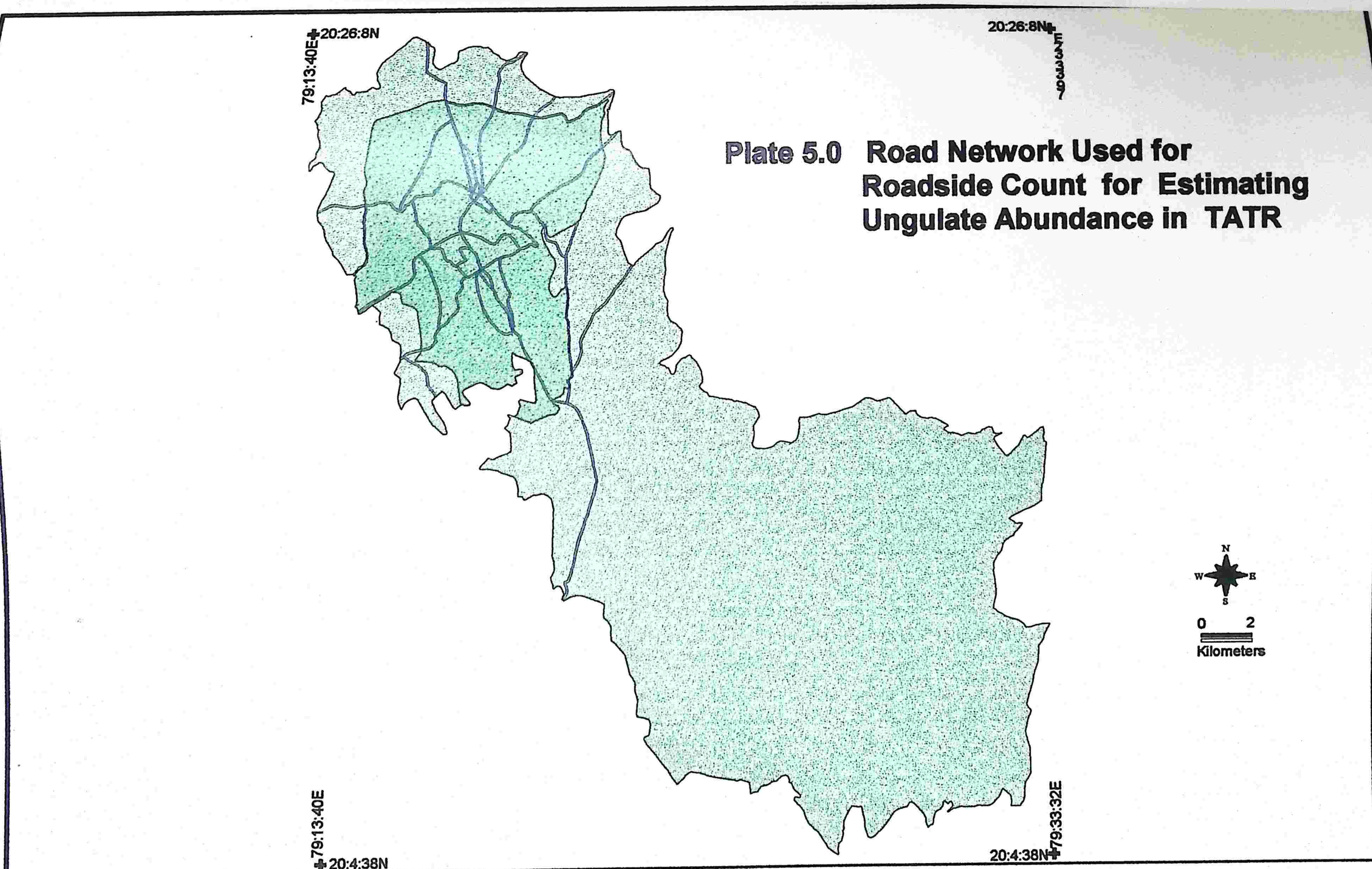


Plate 5.0 Road Network Used for Roadside Count for Estimating Ungulate Abundance in TATR
20:26:8N
79:13:40E
20:4:38N
79:33:32E
N
W
E
S
0
2
Kilometers

From all sightings , the perpendicular distance from the animal to the center of the road was initially measured by pacing and later converting it into measurable units. For each sighting, the following data was recorded: 1. Species name 2. Number of individuals 3. Age/Sex 4. Perpendicular distance from the center of the animal group to the observer 5. Habitat type 6. Terrain type.

It is important that transect line be placed randomly with respect to the animal distribution; it is this random placement that justifies extrapolating results to an area larger than just the immediate vicinity of the transect line (Burnham *et al.* 1980). Since the roads were used as transect lines there was a certain bias, as they do not pass evenly through all habitats. To overcome this problem, the density estimates were calculated for the entire reserve rather than calculating for individual habitat. Percent encounter rates of ungulates in each habitat type were used as index of abundance in each habitat type.

Burnham *et. al.* (1980) mentions four basic assumptions which are critical for achieving reliable estimation of population abundance from line transect sampling:

1. Points directly on the line will never be missed. This means the animals on the road will never be missed.

2. Points are fixed at the initial sighting position and they do not move before being detected and none are counted twice. Since ungulates are mobile animals hence this condition is slightly violated while conducting vehicle counts. At the same time we were able to fix the position of initial sighting with some reference point to estimate the perpendicular distance. Since

motorcycle was used for the counts and we always moved in one direction the chances of counting animals twice were negligible.

3. Distances and angles are measured accurately. In this study only perpendicular distances were used. The perpendicular distances were occularly estimated and were periodically checked by prestandardized paces.

4. Sightings are independent events.

5.2.2. Biomass estimates

Calculating accurate biomass poses problem because there is no easy way to determine 'unit mass' i.e. the mean mass of all the individuals in a given population. It is dependent on series of variables like age and sex structure, nutritional status and habitat. Biomass as a result of so many controlling factors may vary considerably within species. In the present study the biomass was calculated by multiplying the mean density of each species by its unit mass as given by Schaller (1967) and Berwick & Jordan (1971). Schaller (1972) had proposed to take 75% of the average body weight of an adult female of a species to represent biomass of an individual if one is interested to calculate biomass at population level. This would avoid under estimation of biomass for certain classes like adult males but at the same time avoid overestimation of biomass for young ones in the population. Present study has focussed on all ungulate species. Apart from ungulates, Common Langur (*Presbytes entellus*) has also been included in biomass estimates as it forms a major prey species for predators like Leopard.

5.2.3. Determination of Sex - ratio and group size of ungulates

Ungulates were classified into various age and sex categories during vehicle counts. The data was later analyzed to see the trends in sex ratios and mean group sizes across different seasons. Only those animals which were clearly seen were sexed and aged. The animals which were not seen clearly were not classified and were omitted from counts. Therefore there was no unclassified category in this study.

5.2.4. Habitat utilization

5.2.4.1 Habitat types

Habitat types were classified based on the **IRS LISS-II** image interpretation. A total of 15 habitat categories were identified and later ground truthed. The same categories were used for habitat utilization.

5.2.4.2. Field methods

Habitat utilization by ungulates was studied by direct and indirect methods. Direct methods included vehicle based transects on six routes adequately covering the different habitat types all over the study area. Indirect method included pellet group count.

5.2.4.3. Pellet Count

Pellets of Chital, Sambar, gaur, Nilgai, Barking deer, Chowsingha and Wild Pig were counted in 100m X 2m belt transects and then removed. This area was thoroughly searched with the help of two assistants to increase the search efficiency. There were 239 such transects spread over different habitat types. This exercise was carried out in winter (November- February) and repeated during summer (March-June).

5.2.4.4. Direct observations

Direct observations included observations on animals in the winter of 1994, 1995, 1996 and summer of 1995, 1996, 1997. The animals were observed in the mornings (0630 - 0830hrs) and evening (1700 - 1900hrs). Data collection was done by two observers on motor cycle, traversing different routes. For each observation, data on ungulate species, group size, vegetation type, terrain were recorded.

5.2.5. Ungulate distribution

Distribution maps were prepared for all species based on the information collated from vehicle counts and habitat use. The information so collated was grouped into different levels of abundance categories as high, medium, low. The results were linked with the vegetation map created in GIS domain prepared from remotely sensed data to generate distribution maps. Plate 5.1 to Plate 5.7 show distribution of different ungulate species in TATR.

5.3. RESULTS

5.3.1. Density and population estimates for prey species

Table 5.1 present the lengths of different transects used in the study and their repeteability in different years *viz.*1994 - 1995, 1995 - 1996, 1996 - 1997 respectively. Data on the pooled density of various prey species in TATR is shown in Table 5.2. Distance program was used to calculate densities of prey species and the model which gave the lowest Akaike information criterion value were used. Chital density was highest in the reserve (17.23/km^2). Sambar and Wild pig densities were 5.1/km^2 and 4.46/km^2 respectively. Gaur density was 2.75/km^2. Nilgai, Chowsingha and Barking deer densities were the lowest. Owing to low sample sizes the population estimates for these three species were not calculated.

Prey densities caculated across three years revealed an increasing trend for all species except for Chital and langur (Figure 5.2 and Table 5.3, 5.4 & 5.5). Densities for chital showed an increasing trend in year 1995 and then decreased in year 1997. Densities for langur revealed a decreasing trend in year 1995 and increased in year 1997.

There was not much of a seasonal variation in prey density across summer and winter. Sambar, gaur and langur densities were higher in summers than winters whereas chital, wild pig and barking deer densities were higher in winter than summers (Figure 5.3 and Table 5.7 & 5.8).

Prey densities were also calculated from morning and evening counts separately. Densities obtained from evening counts were found to be higher than densities obtained from morning counts for all species (Figure 5.4 and table 5.8 & 5.9).

Table 5.1. Length and Replicates of Road transects used for Density Estimation

S.No	Name of the transect	Length (in km)	No. of replicates (1994 - 95)	No. of replicates (1995 - 96)	No. of replicates (1996 - 97)	Total distance (in km)
1	Tadoba - Moharli	18	14	34	48	1728
2	Tadoba- Nawegaon	11	14	34	48	1056
3	Tadoba-Jamni-Khatoda	17	14	34	48	1632
4	Jamunbodi- Kolara	9	14	34	48	864
5	Tadoba- Jamunbodi-Chital Road	11.5	14	34	48	1104
6	Ambathira-Katejhari	9	14	34	48	864
TOTAL LENGTH SAMPLED						**7248**

Table 5.2. Density estimates of prey species in TATR

SPECIES	DENSITY (No/Km^2)	CV %	95% CI	MODEL USED	AKAIKE VALUE
Chital	17.23	10.59	15.072 - 20.766	Half normal/Cosine	- 8138.5
Sambar	5.1	9.16	3.58 - 7.89	Half normal/Cosine	- 5017.3
Wildpig	4.36	8.16	3.6 - 6.84	Uniform/Cosine	- 2763.9
Gaur	2.75	8.84	1.95 - 4.16	Negative exponential/Cosine	- 1868.2
Barking deer	1.41	39.25	0.81 - 2.36	Uniform/Cosine	- 2466.2
Langur	19.07	13.80	14.574 - 24.973	Half Normal/Cosine	- 4162.5
Chowsingha	0.33	26.37	0.25 - 0.60	Uniform/Cosine	- 782.07
Nilgai	1.04	22.94	0.648 - 1.07	Uniform/Cosine	- 727.47

***Table* 5.3 Prey density in the year 1994 - 1995 in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	15.45	12.03	15.002 - 24.00	Negative Exponential/Cosine	- 1236
Sambar	3.17	15.41	2.34 - 4.28	Uniform/Cosine	- 709.95
Wild Pig	2.97	12.0	2.35 - 3.75	Uniform/Cosine	- 802.86
Gaur	1.54	19.41	1.04 - 2.26	Uniform/Cosine	- 383.45
Barking Deer	0.32	15.02	0.24 - 0.43	Uniform/Cosine	- 334.76
Langur	19.65	17.99	16.45 - 24.67	Uniform/Cosine	- 537.08
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

Table 5.4 **Prey density in the year 1995 - 1996 in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY(No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	18.97	12.03	15.002 - 24.00	Uniform/Cosine	- 1236.0
Sambar	4.72	6.41	3.62 - 5.11	Uniform/Cosine	- 2313.4
Wild Pig	5.17	29.47	2.92 - 9.17	Negative Exponential/Cosine	- 432.35
Gaur	2.2	23.83	1.35 - 3.53	Uniform/Cosine	- 212.45
Barking Deer	1.35	33.71	0.68 - 2.63	Negative Exponential/Cosine	- 203.7
Langur	16.54	10.82	12.751 - 19.462	Uniform/Cosine	- 1289.3
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

Table 5.5 **Prey density in the year 1996 - 1997 in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	17.73	5.76	15.839 - 19.848	Uniform/Cosine	- 4006.6
Sambar	7.41	5.80	6.41 - 8.15	Uniform/Cosine	- 2954.9
Wild Pig	6.27	8.10	5.35 - 7.35	Uniform/Cosine	- 1570.8
Gaur	4.39	9.54	3.64 - 5.29	Uniform/Cosine	- 1384.1
Barking Deer	1.49	27.59	0.87 - 2.54	Uniform/Cosine	- 1624.3
Langur	21.61	21.61	14.06 - 33.20	Uniform/Cosine	- 2401.9
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

Table 5.6 **Prey density in Summer 1994 - 1997 based on road count data in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	18.33	15.9	13.45 - 24.99	Half normal/Cosine	- 4860.8
Sambar	4.9	5.58	4.01 - 5.31	Uniform/Cosine	- 3193.1
Wild Pig	5.01	16.78	3.61 - 6.94	Uniform/Cosine	- 1890.0
Gaur	3.55	19.83	2.74 - 3.96	Negative Exponential/Cosine	- 1365.7
Barking Deer	1.06	18.75	0.74 - 1.53	Half Normal/Cosine	- 1524.7
Langur	21.34	16.83	15.38 - 29.61	Half Normal/Cosine	- 2912.0
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

***Table 5.7.* Prey density in winter (1994 - 1995) based on road count data in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	18.54	6.7	16.26 - 21.14	Uniform/Cosine	- 3337.2
Sambar	3.38	7.24	2.93 - 3.89	Uniform/Cosine	- 1879.3
Wild Pig	5.2	27.27	3.08 - 8.8	Uniform/Cosine	- 867.03
Gaur	2.69	16.27	1.95 - 3.71	Uniform/Cosine	- 540.77
Barking Deer	1.19	21.48	0.79 - 1.81	Uniform/Cosine	- 937.63
Langur	15.62	15.51	11.548 - 21.138	Uniform/Cosine	- 1255.7
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

Table 5.8. **Prey density from Morning road Count data (1994 - 1997) in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAIKE VALUE
Chital	16.06	24.05	10.092 - 25.56	Half Normal/Cosine	- 3010.6
Sambar	4.07	7.46	3.791 - 5.393	Uniform/Cosine	- 1612.6
Wild Pig	3.80	11.1	3.05 - 4.72	Uniform/Cosine	- 939.91
Gaur	2.39	13.26	1.84 - 3.09	Uniform/Cosine	- 653.07
Barking Deer	1.11	21.03	0.738 - 1.67	Uniform/Cosine	- 1042.1
Langur	14.49	22.92	9.299 - 22.579	Half Normal/Cosine	- 1382.6
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

Table 5.9. **Prey density from Evening road count data (1994 - 1997) in Tadoba Andhari Tiger Reserve**

SPECIES	DENSITY (No/km^2)	% CV	95% CI	MODEL USED	AKAKE VALUE
Chital	20.57	12.59	16.093 - 26.307	Negative Exponential/Cosine	- 4014.6
Sambar	6.17	17.18	4.99 - 8.83	Half Normal/Cosine	- 3383.7
Wild Pig	5.68	19.02	3.929 - 8.228	Uniform/Cosine	- 1844.9
Gaur	2.71	10.20	2.22 - 3.314	Uniform/Cosine	- 1204.3
Barking Deer	1.02	17.38	0.727 - 1.431	Uniform/Cosine	- 1422.3
Langur	22.567	16.10	16.494 - 30.875	Half Normal/Cosine	- 2778.2
Chowsingha	–	–	–	–	–
Nilgai	–	–	–	–	–

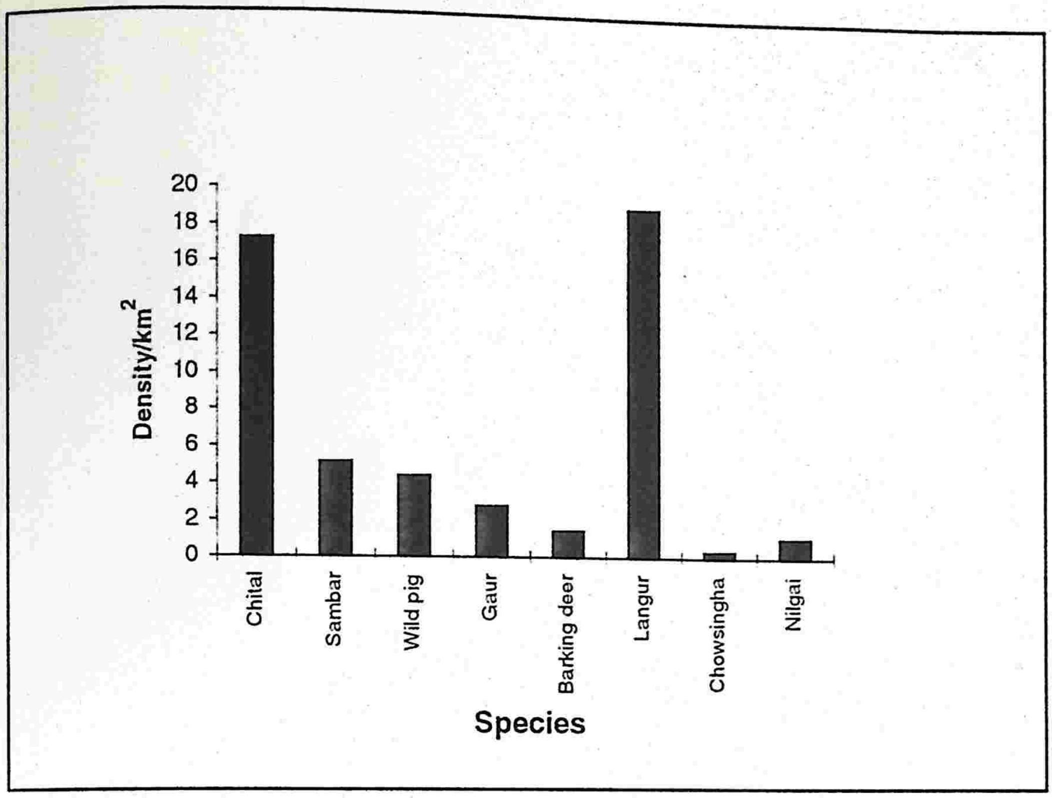


Figure 5.1. Pooled densities of prey species in TATR

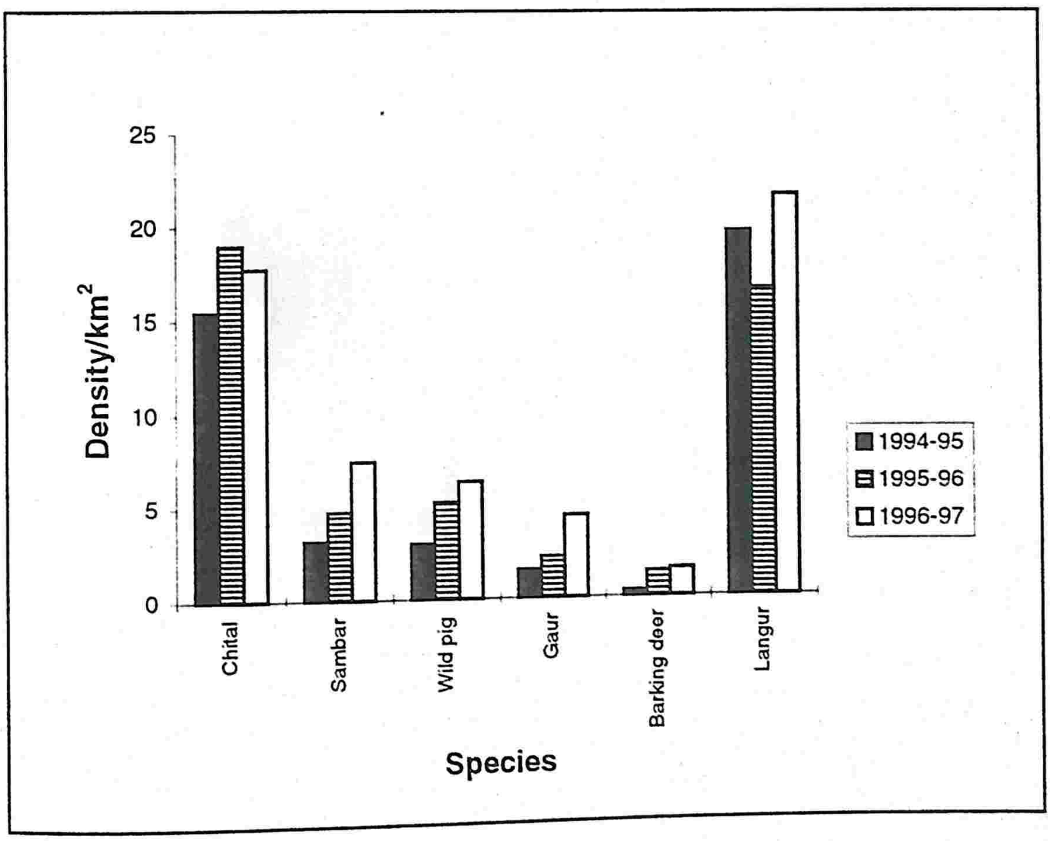


Figure 5.2. Prey densities in three years

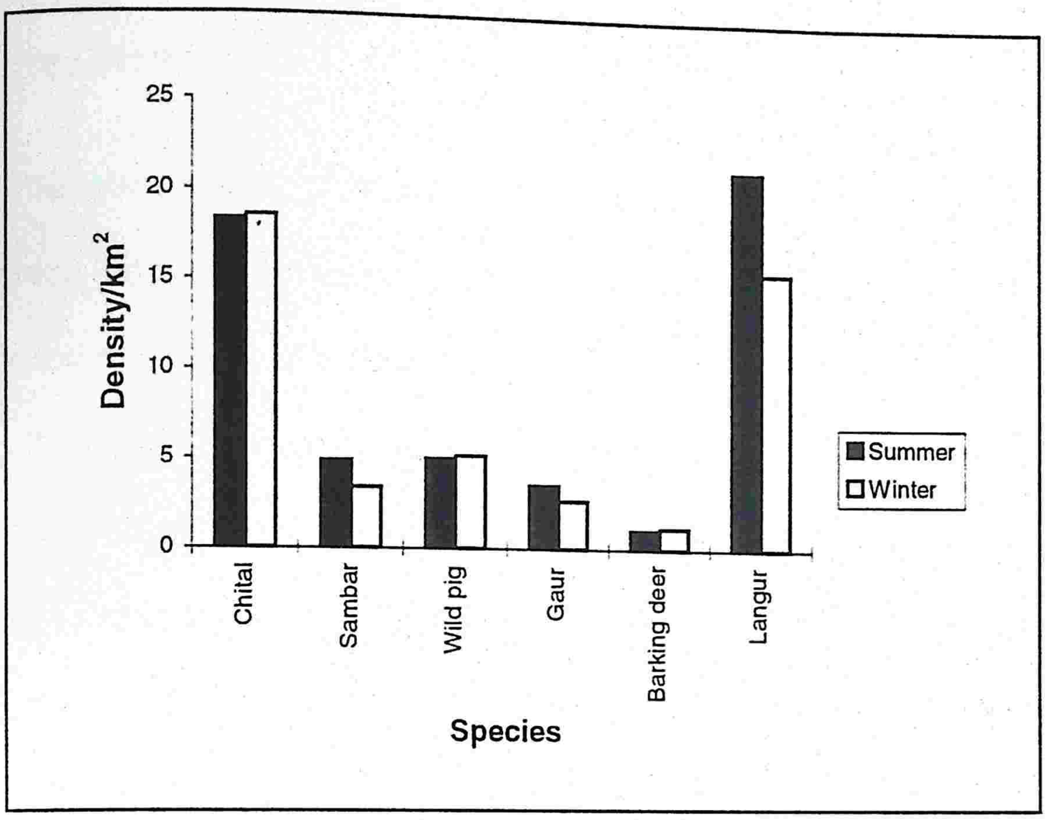


Figure 5.3. Seasonal variation in prey density in TATR

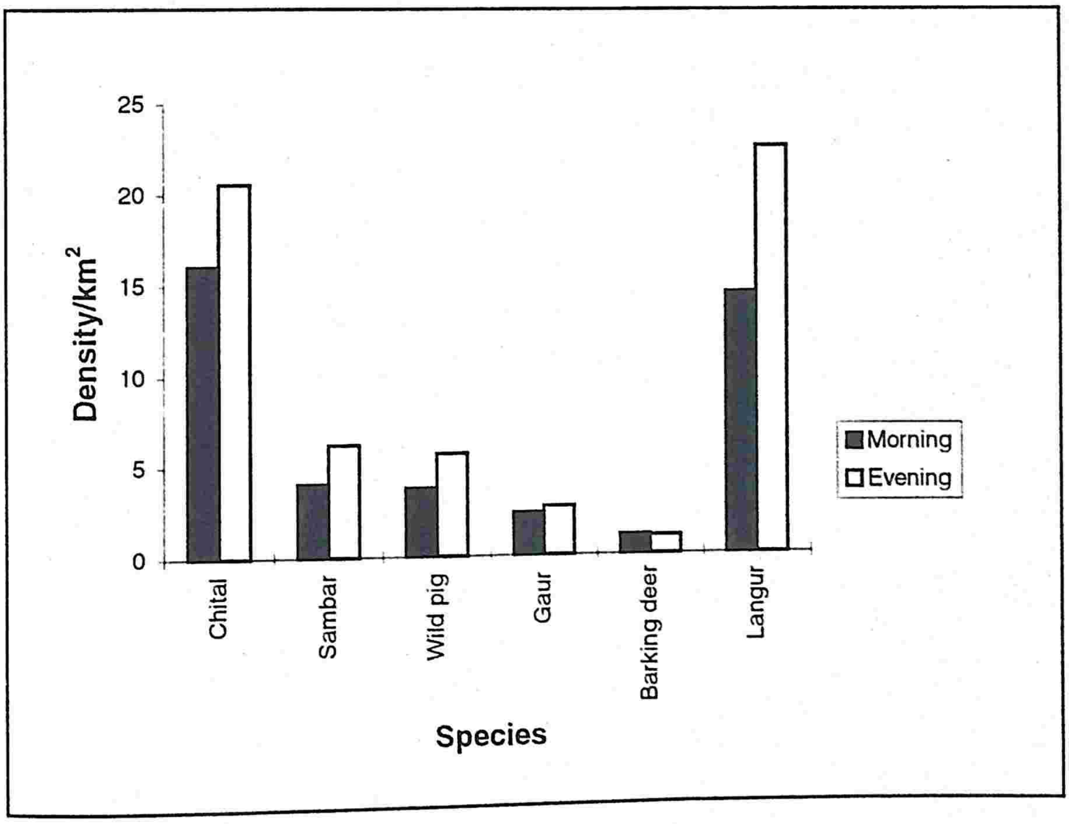


Figure 5.4. Densities from morning and evening transects in TATR.

5.3.2. Prey Biomass

The total ungulate biomass in TATR was calculated to be 3858.4 Kg Km^2. Gaur which occur numerically at low density contributed 39.98% to the total ungulate biomass. Table 5.10 shows the biomass estimates of prey species in TATR. Chital and Sambar contributed 23.15% and 18.91% of the total biomass respectively. Nilgai which occurs in low density contributed on 4.88% to the total biomass. Wildpig and langur contributed 6.98% and 5.39% to the total biomass. Barking deer and Chowsingha contributed negligibly to the overall biomass. The three ungulate species, Gaur, Chital and Sambar together contributed significantly to the total ungulate biomass. Their contribution was 86% in the area (Table 5.12). These figures reveal the relative importance of these species in forming the major prey base for carnivores in the area. Results of this study are comparable with other studies conducted in India (Table 5.11).

Table 5.10. Herbivore Density, Population and Biomass in TATR

Species	Density (N/km^2	Population	Population Composition %						Mean Unit Wt (kg)	Biomass (kg/Km^2)	% of Total Wild Biomass
			M1	M2	F1	F2	Y	Juv			
Chital	17.23	10,637	17.75	6.44	46.82	14.27	8.46	6.23	51.83	893.03	23.15
Sambar	5.1	3148	20.99	7.06	42.6	11.91	13.2	4.11	143.11	729.86	18.91
Wild pig	4.36	2691	30.7	3.41	35.43	0.96	7.17	22.3	61.80	269.44	6.98
Gaur	2.75	1697	18.2	8.31	45.23	10.75	9.12	8.36	561	1542.75	39.98
Barking deer	1.41	870	52.01	0.80	40.5	0.64	2.1	4.6	18.12	20.65	0.53
Chowsingha	0.33	203	29.05	–	52.02	1.35	2.7	14.86	18.0	5.94	0.15
Nilgai	1.04	642	24.5	6.75	60.5	6.0	1.25	1.0	181.20	188.45	4.88
Langur	20.42	12606	25.03	9.31	40.76	7.57	8.51	8.78	10.20	208.28	5.39
Total Wild Biomass (Kg/km^2)										3858.4	

Table 5.11. Biomass (Kg / Km^2) of prey population in other studies

Species	Tadoba,	Tadoba,	Kanha,	Sariska,	Bandhavgarh,
	This study, 1997	Mathur, 1991	Mathur, 1991	Mathur, 1991	Pabla, 1998
Chital	893.03	1071	1227	470	1083
Sambar	729.86	1050	529	702	575
Wild pig	269.44	116	130	186	220
Gaur	1542.75	1447	432	-	26
Barking deer	20.65	15	15	-	2.85
Chowsingha	5.94	8	4	6	25.8
Nilgai	188.45	1168	124	2022	384
Langur	208.28	-	-	-	320

Table 5.12. Composition of terrestrial ungulate community in some wildlife reserves of India, South Asia and Africa

Site	Total No. of Species	No. contributing ≥ 70%	percent contribution	Reference
Tadoba, India	7	3	86.66%	This study
Tadoba, India	7	3	76.0%	Mathur, 1991
Kanha, India	9	3	85.5%	Mathur, 1991
Sariska, India	6	3	94.0%	Mathur, 1991
Nagarhole, India	7	2	81.0%	Karanth, 1988
KBR, Nepal	6	2	88.0%	Dinerstein, 1980
Gal Oya, Sri Lanka	6	2	82.0%	Mackay and Eisenberg, 1974
Udjung kulon, Java	6	2	74.3%	Hoogerwerf, 1970
Umfolozi, S.Afr	18	5	75.4%	Mentis, 1970
Nairobi, Kenya	16	4	77.2%	Foster & Coe, 1968
Tarangire West, Tanzania	14	5	83.6%	Lamprey, 1964
Tarangire, East	14	3	78.9%	Lamprey, 1964
Bandhavgarh, India	11	3	76.41%	Pabla, 1998

5.3.3. Sex ratio and Population Structure

Animal sighting records for the year 1994-95, 1995-96, and 1996-97 were pooled and analyzed for determining the population structure of the prey population. A total of 1330 sightings of chital groups were classified in various age and sex category. Similarly, for other prey species also total sighted groups were classified which includes 779 groups of Sambar, 443 groups of Wildpig, 310 groups of Gaur, 371 groups of barking deer, 89 groups of Nilgai, 52 groups of Chowsingha and 618 groups of langur.

It is quite evident from the results that the sex ratios are skewed towards females in all the cases except for the Barking deer (Table 5.13). Females constitute nearly 40-50% of the total prey population in all the species (Table 5.13).

Table 5.13. Population Structure by % of Age and Sex Classes

Species	M1	M2	F1	F2	Y	Juv	N
Chital	17.75	6.44	46.82	14.27	8.46	6.23	10,715
Sambar	20.99	7.06	42.6	11.91	13.2	4.11	1896
Wild pig	30.7	3.41	35.43	0.96	7.17	22.3	2794
Gaur	18.2	8.31	45.23	10.75	9.12	8.36	1961
Barking deer	52.01	0.80	40.5	0.64	2.1	4.6	619
Chowsingha	29.05	–	52.02	1.35	2.7	14.86	148
Nilgai	24.5	6.75	60.5	6.0	1.25	1.0	400
Langur	25.03	9.31	40.76	7.57	8.51	8.78	6363

M1=Adult male, M2=Sub-adult male, F1=Adult female, F2=Sub=adult female

Y= Yearling, Juv = Juvenile, N= Total No. of animals classified.

Table 5.14. Population Structure of Prey population

Species	M:100F1	M2:100M1	F2:100F1	Y:100F1	Juv:100F1	M2:100F2	Total
Chital	39.6	36.33	30.49	31.39	13.31	45.16	10,715
Sambar	51.45	33.6	27.97	31.18	9.6	59.29	1896
Wild pig	93.75	11.11	2.71	20.24	62.96	354.54	2794
Gaur	47.35	45.65	23.78	20.18	18.48	77.25	1961
Barking deer	126.27	1.99	1.59	5.17	11.55	125	619
Chowsingha	54.43	_	2.5	5.19	28.57	_	148
Nilgai	46.99	27.55	9.91	16.35	5.9	112.5	400
Langur	71.06	37.22	18.5	20.89	21.54	123.02	6363

M1=Adult male, M2=Sub adult male, F1=Adult female, F2=Sub adult female, Y=Yearling, Juv=Juvenile

Table 5.15. **Comparison between Age and Sex Structure of Prey population in other Studies.**

	Sex Ratio (M:100F)						Age Ratio (Young:100F)					
Spp.	This study	Schaller 1967	Seidensticker 1976	Berwick & Jordan 1971	Karanth & Sunquist 1992	Pabla 1998	This study	Schaller 1967	Seidensticker 1976	Berwick & Jordan 1971	Sankar 1994	Pabla 1998
Chital	39.6	70.50	115	35	72	37.45	31.39	67	28	31	22	28.67
Sambar	51.45	29.70	102	33	42	43.68	31.18	33.7	50	55	27-45	33.03
W.pig		–	–	–	–	88.98	20.24	–	–	–	–	96.56
Gaur	47.35	80.00	–	–	18	33.7	20.18	42	–	–	–	37.32
B.deer	126.3	–	74	–	76	120	5.17	–	11	–	–	7.49
FHA	54.43	–	–	100	–	135	5.19	–	–	–	–	0.00
Nilgai	46.99	59.00	–	69	–	36.92	16.35	68	–	4	48	31.9
Langur	71.06	–	–	–	–	–	20.89	–	–	–	–	–

5.3.4. Group Size and Composition

The grouping pattern and grouping tendencies of the prey population in TATR were studied through the analysis of variations in Mean Group Size across various seasons and cover types. Mean Group Size (MGS) was essentially chosen to be able to compare the results with other studies. Seasonal patterns in group size were examined through MGS. Results of mean group size calculated from this study are comparable with other studies (Table 5.17). Results from Non parametric Kruskal - Wallis test showed that seasonal changes in MGS are not significant ($p>0.05$) for any species. The seasonal variation in MGS among prey species is shown in Figure 5.5 and Table 5.16 and overall MGS observed throughout the study period is shown in Figure 5.6. MGS was analysed for different cover types and analysis revealed that Group size tends to be slightly high in open grasslands and habitats with relatively less cover (Table 5.18) , in almost all species except Barking deer and Sambar which are relatively solitary by nature. Differences in MGS in different cover types were found to be significant for Chital, Wild pig, Gaur, Barking deer, Chowsingha and Nilgai ($p<0.05$) and it was not significant in the case of Sambar ($p>0.05$). The mean group size of Sambar remained more or less constant in all cover types.

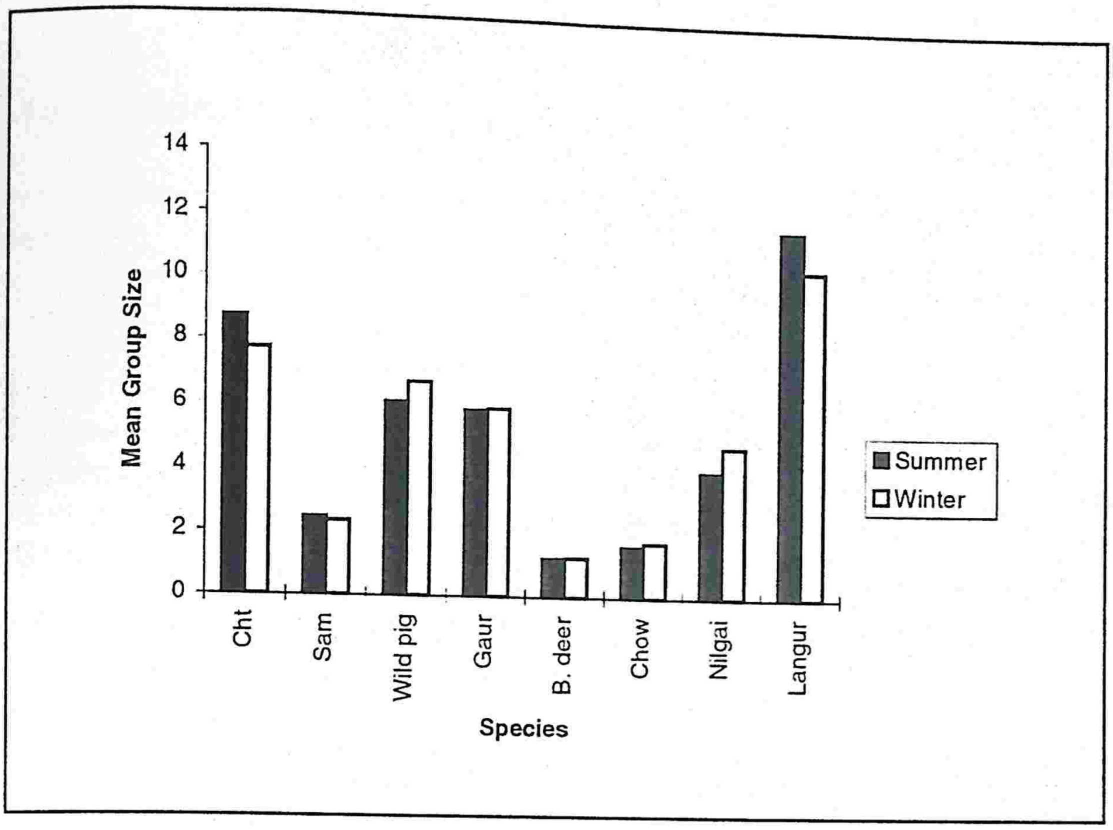


Figure 5.5. Seasonal variation in Mean Group size

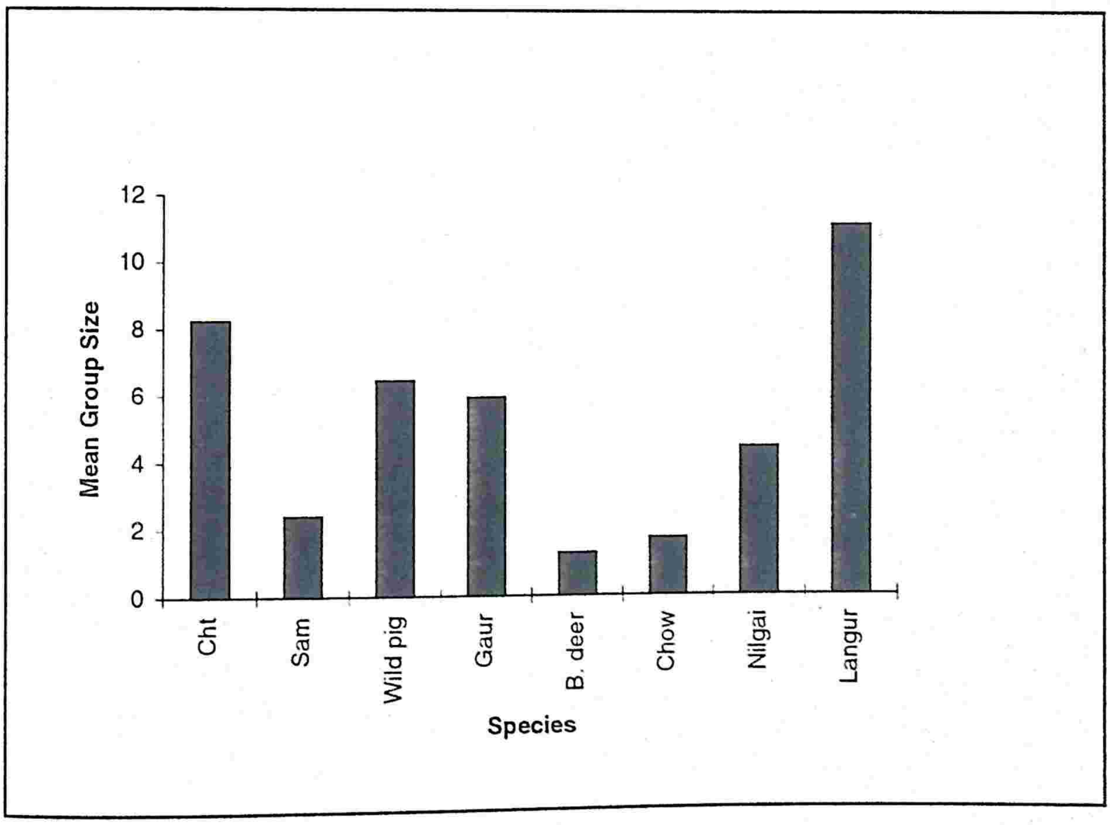


Figure 5.6. Mean Group size of Prey population

Table 5.16. Seasonal changes in Mean Group Size of prey population in TATR

Species	Summer	Winter	Overall
Chital	8.71±0.37 (n = 773)	7.72±0.4 (n = 557)	8.21±0.38 (n = 1330)
Range (Min - Max)	(1 - 75)	(1 - 90)	(1 - 90)
Sambar	2.45±0.08 (n = 496)	2.33±0.10 (n = 303)	2.39±0.09 (n = 799)
Range (Min - Max)	(1 - 16)	(1 - 18)	(1 - 18)
Wild pig	6.11±0.32 (n = 302)	6.74±0.44 (n = 141)	6.42±0.38 (n = 443)
Range (Min - Max)	(1 - 26)	(1 - 25)	(1 - 26)
Gaur	5.9±0.39 (n = 226)	5.94±0.72 (n = 84)	5.92±0.55 (n = 310)
Range (Min - Max)	(1 - 20)	(1 - 28)	(1 - 28)
Barking deer	1.25±0.04 (n = 228)	1.27±0.04 (n = 143)	1.26±0.04 (n = 371)
Range (Min - Max)	(1 - 5)	(1 - 3)	(1 - 5)
Chowsingha	1.64±0.16 (n = 35)	1.75±0.15 (n = 56)	1.69±0.15 (n = 96)
Range (Min - Max)	(1 -2)	(1 - 2)	(1 - 2)
Nilgai	4.04±0.84 (n = 40)	4.82±0.98 (n = 49)	4.43±0.91 (n = 89)
Range (Min - Max)	(1 - 5)	(1-12)	(1 -12)
Langur	11.75±0.34 (n = 428)	10.49±0.46 (n = 190)	11.12±0.4 (n = 618)
Range (Min - Max)	(1 - 48)	(1 -30)	(1 - 48)

Table 5.17. Ungulate Mean Group Size in other sutdies

Species	This study 1998	Schaller 1967	Dinerstein 1980	Sankar 1994	Khan *et al* 1995	Pabla 1998
Chital	8.21	5 - 10	10.7	7.8	5.6	11.23
Sambar	2.39	2.3 - 3.8	-	4.00	1.7	4.00
Wild pig	6.42	-	3.1	-	-	10.35
Gaur	5.92	8 - 11	-	-	-	7.86
Barking deer	1.26	-	1.1	-	-	1.51
Chowsingha	1.69	-	-	-	1.1	1.54
Nilgai	4.43	-	2.9	4.00	1.9	4.91

Table 5.18. Mean Group Size in Different Cover Types.

Cover Type	Species						
	Chital	Sambar	Wildpig	Gaur	Barking deer	Chowsingha	Nilgai
Teak1	12.04	2.33	7.91	7.67	_	_	_
Teak2	8.3	2.03	6.97	9.00	_	_	_
TB	10.71	3.63	6.5	7.14	1.08	_	5.14
TMB	5.79	2.37	7.27	3.45	1.10	2.33	5.75
Misc.	6.74	2.8	3.74	7.79	1.00	1.47	5.11
MBI	6.17	2.34	8.05	4.95	1.31	1.5	4.5
MBII	4.07	1.83	5.67	5.41	1.21	1.75	1.00
Rip	7.63	2.83	6.58	4.50	1.00	_	_
Meadow	12.95	1.88	11.21	9.30	_	_	5.0
GP	8	2.77	8	5.47	_	2.4	_
Scr	_	_	4.21	_	_	2.67	7.1

5.3.5. Habitat Utilization

The statistical difference in the overall habitat utilization was tested using non-parametric Kruskal-Wallis X^2 test at p<0.05 (Sokal & Rolph 1981). The seasonal variation in habitat utilization was tested using Mann-Whitney test at p<0.05 level. Habitat utilization described in this chapter is for seven species of ungulates found in the study area. Data from direct observations and pellet count was pooled according to habitat types derived from the classification developed from IRS LISS II data (detailed summary in chapter 4). The results are presented in the form of density i.e. average number of pellet groups/hectare for every habitat.

The data from direct observation of animals counted during vehicle based transects was modified and is presented as percent observations of animal group sighted per habitat. The data collected through direct observation was subjected to treatment for individual species under consideration as the roads passed unevenly through different habitats. The length of roads passing through different habitats were corrected for proportions by dividing the length of road passing through a given habitat by total length of that road. Later the total number of animals seen in each habitat were divided by the corrected proportions to obtain proportional estimates of the numbers observed in each habitat type using the following formulae

Proportion of numbers observed = $N/(l_{1\text{-}12}/L_{1\text{-}6})$

where N = Total number of animals observed in any habitat.

l = Length of transect passing through habitat.

L = Total length of transect.

5.3.5.1. Habitat utilization by chital

Direct observations: The average chital group sighted (Fig. 5.7) was maximum in meadows (42.35%) followed by Teak II and Teak I showing 28.29% and 11.12 % use respectively. There were no sighting in Miscellaneous Open and Scrub

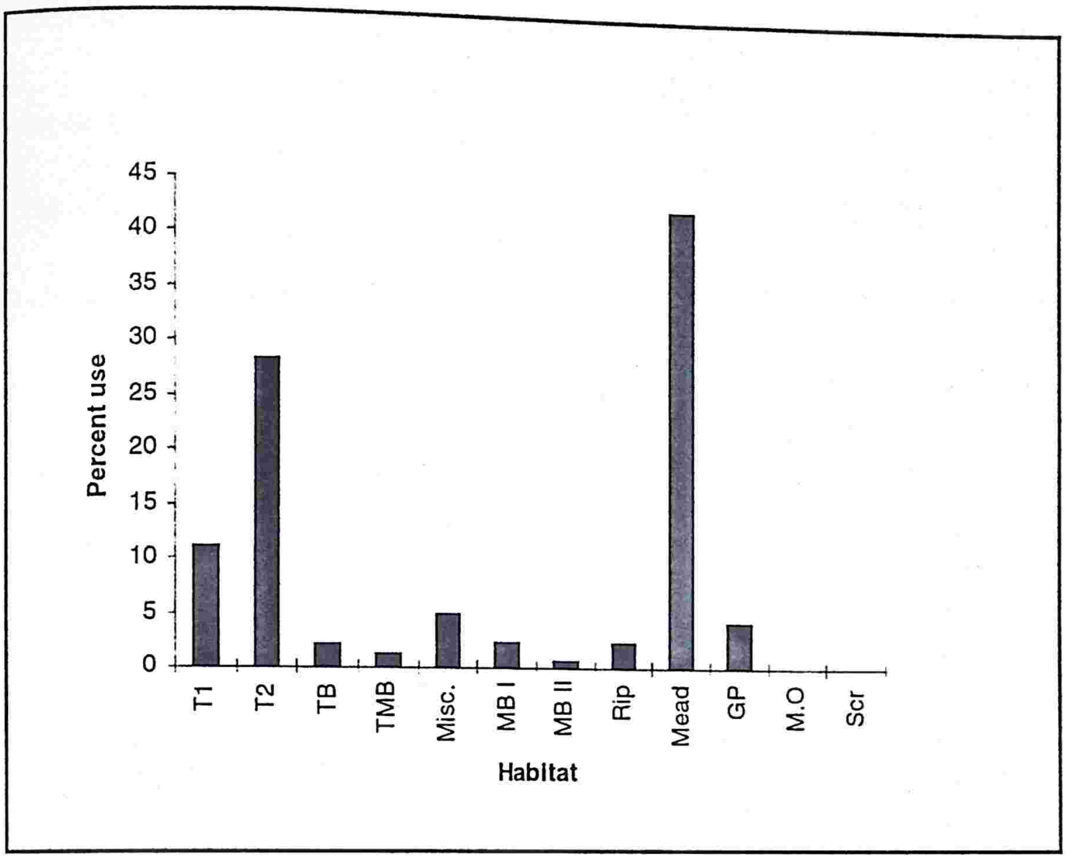


Figure 5.7. Percent chital groups sighted in different habitat types.

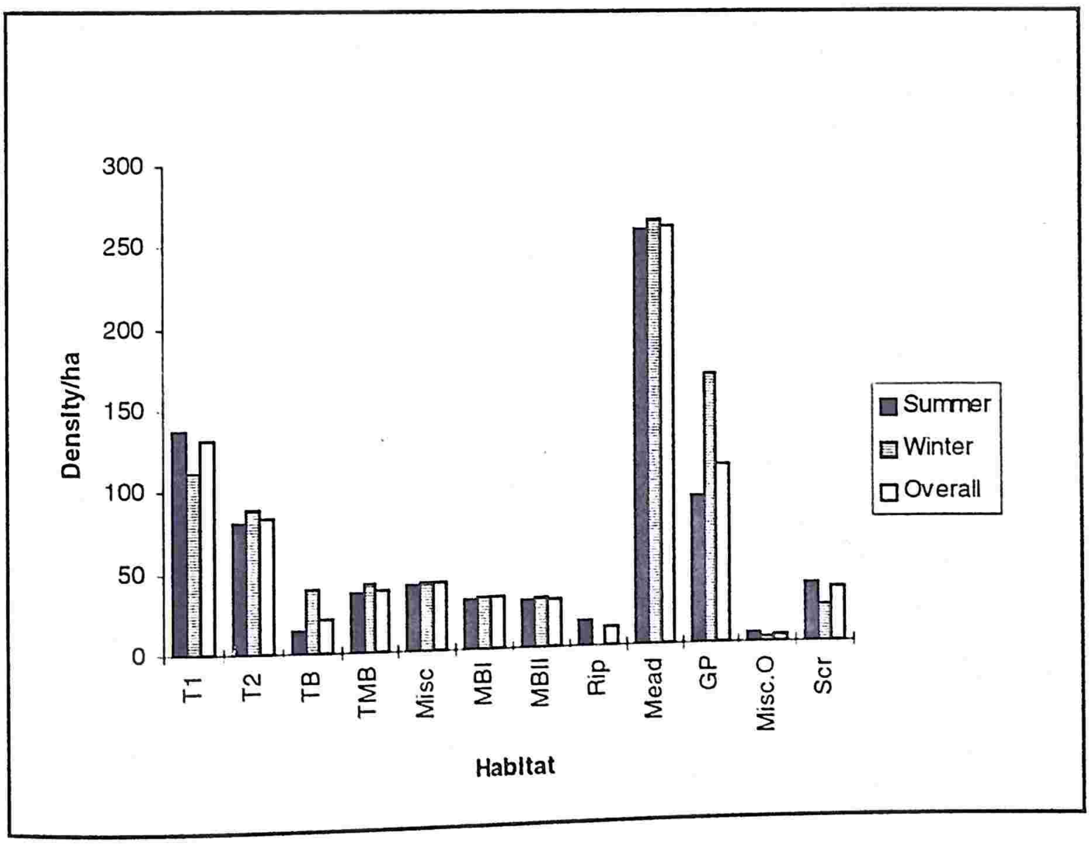


Figure 5.8. Average chital pellet group density in different habitats.

5.3.5.2. Habitat utilization by sambar

Direct observation: Maximum average number of sambar groups were sighted in Teak II (24.83%) followed by Teak Miscellaneous Bamboo (17.9%) and Miscellaneous Bamboo I (14.7%) and minimum in Teak I (1.08%), Meadows (5.33%) and Grassland on Plateau (5.06%). No groups were sighted in Miscellaneous Open and Scrub forest (Fig 5.9). The overall difference in groups sighted in different habitats was not significant (K-W, $X^2 = 17.85$, $p>0.05$, n=463). Seasonal variation in groups across habitat was also not significant ($p>0.05$).

Pellet count: The average pellet group density was maximum in Teak I and Grassland on Plateau and minimum in Riparian and Scrub forest (Fig. 5.10).The overall variation in pellet group density across habitats was significant (K-W $X^2 = 110.77$, $p<0.05$, n = 1163). The overall seasonal variation in habitat use was significantly different (K-W $X^2 = 110.77$, $p<0.05$, n=1163). Overall variation in pellet group density in summer and winter was significantly different (K-W $X^2 = 86.92$, $p< 0.05$, n=852) and ((K-W $X^2 = 31.6$, $p< 0.05$, n=311). No significant seasonal variation was observed within habitats.

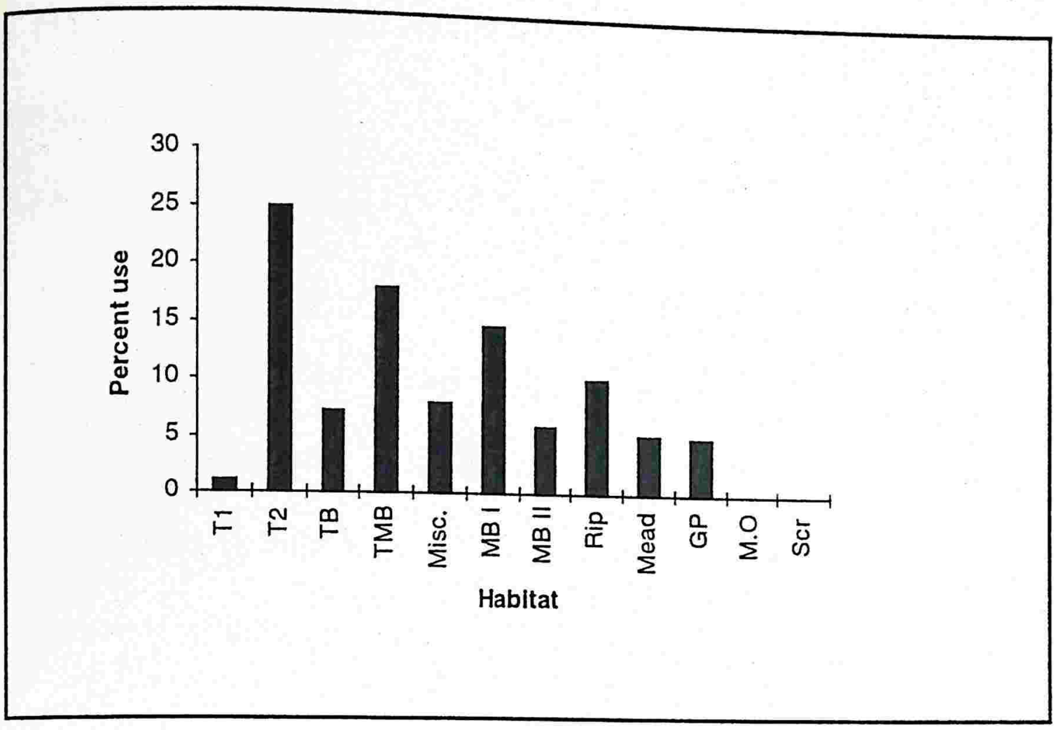


Figure 5.9. Percent sambar groups sighted in different habitats.

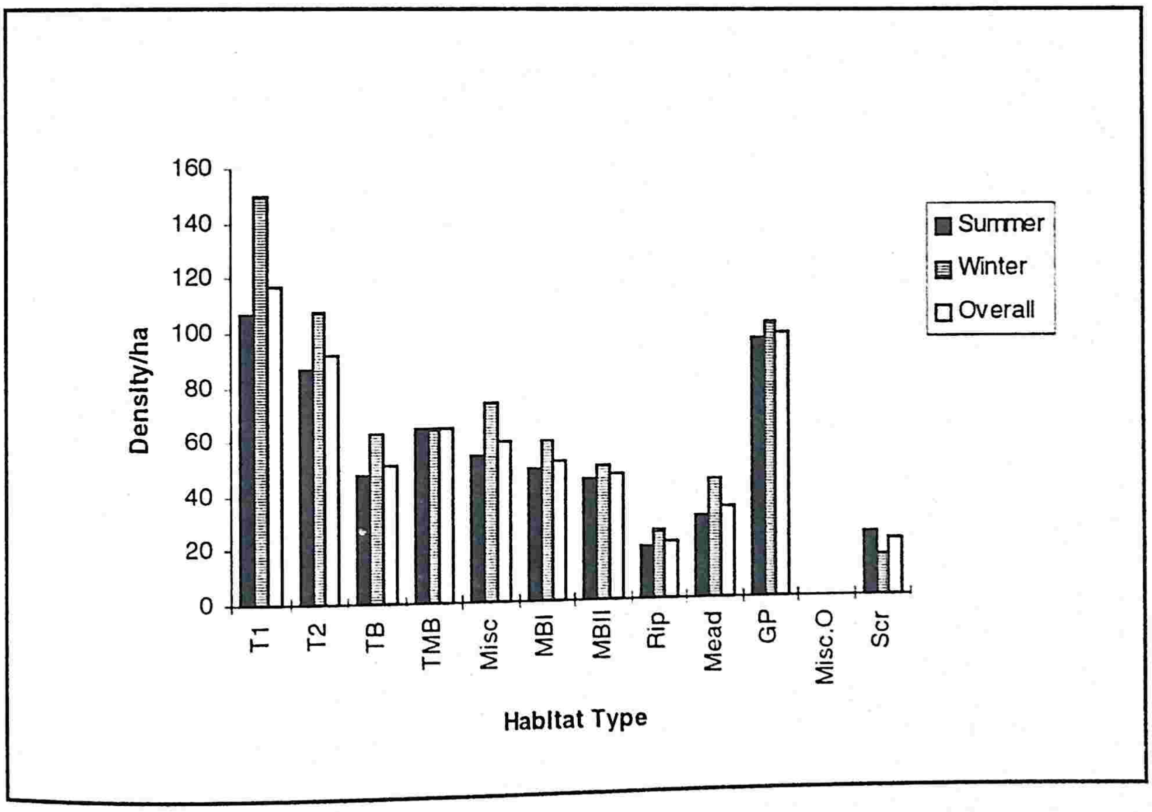


Figure 5.10. Average sambar pellet group density in different habitats.

5.3.5.3. Habitat utilization by Wildpig

Direct observation: Mean maximum wildpig groups was sighted in Meadow (49.08%) followed by Teak II (19.49 %), Teak Miscellaneous Bamboo (5.38%), Teak I (5.32%) and Miscellaneous Bamboo I (5.22%). Mean minimum groups were sighted in Miscellaneous open forest (0.27%), Teak bamboo (1.27%) and Grassland on Plateau (0.28%) (Fig 5.11). Overall variation in groups sighted in vaious habitat was significantly different (K-W X^2 = 25.66, $p < 0.05$ n=252). Overall seasonal variation was not significant.

Pellet count: Mean maximum wild pig pellet group density was observed in Teak I (93.75 ± 20.26 groups/ha) followed by Meadow (67.71 ± 21) and Teak II (43.13 ± 7.92) (Fig. 5.13) and (Table 5.12). The mean minimum pellet group density was observed in Riparian, Teak Bamboo and Grassland on plateau forest types. Difference in overall variation in habitat utilization was significant (K-W X^2 = 122.86, $p < 0.05$, n = 415). There was overall no significant difference in habitat utilization pattern between summer and winter. The overall difference in habitat utilization in winter and summer across habitats was significant (K-W X^2 = 86.09, $p < 0.05$, n = 90) and (K-W X^2 = 44.64, $p < 0.05$, n = 325) respectively. In winters Riparian forest and Grassland on plateau were not utilized at all by wildpig.

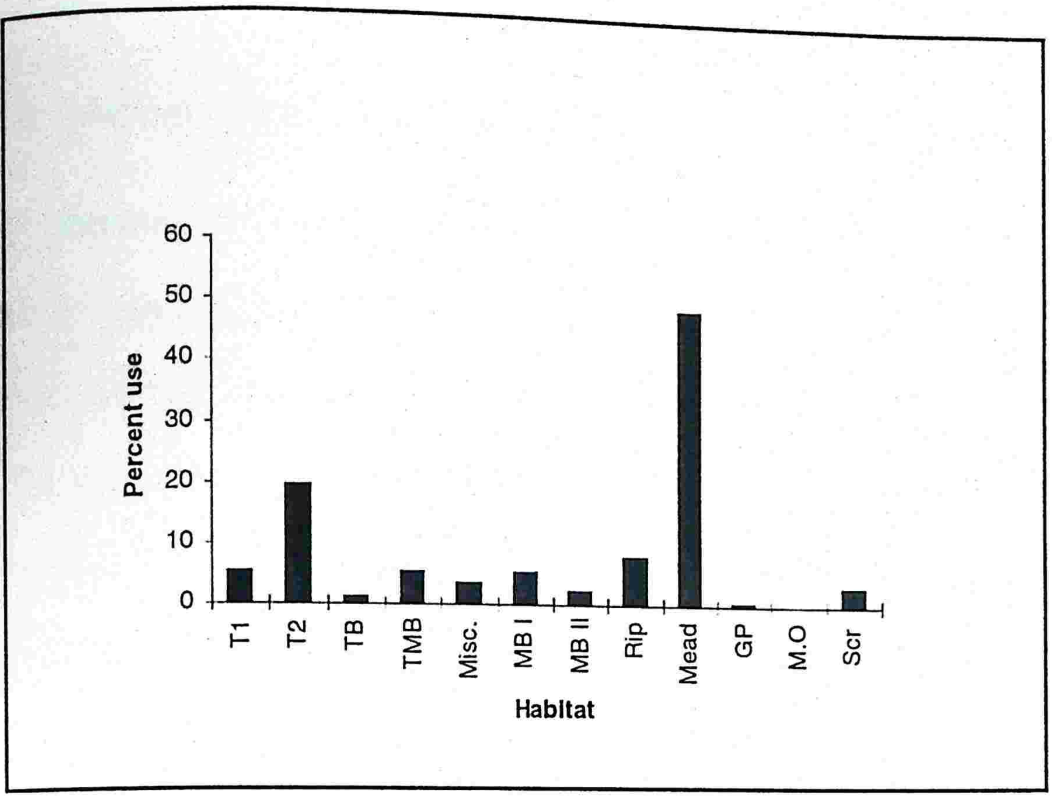


Figure 5.11. Percent wildpig groups sighted in different habitats

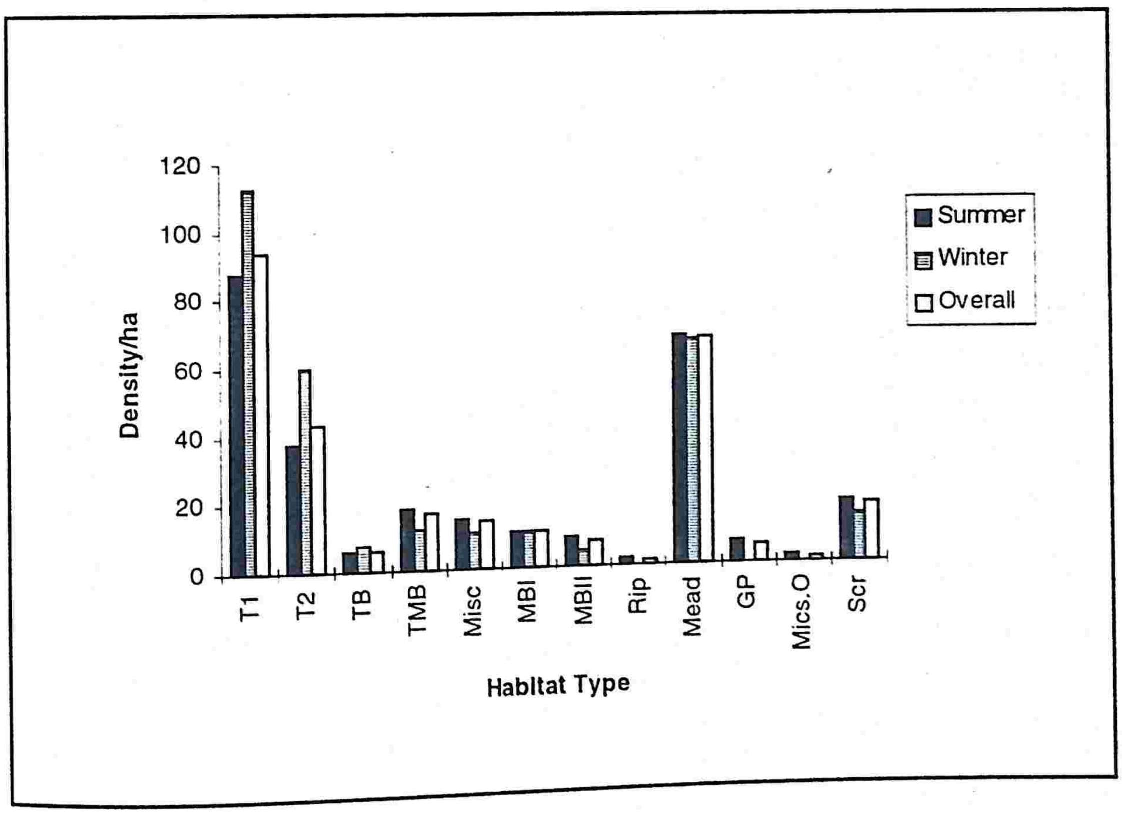


Figure 5.12. Average wild pig pellet group density in different habitats.

5.3.5.4. Habitat utilization by Gaur

Direct observation: Mean maximum gaur groups were sighted in Miscellaneous Bamboo I forest type (39.6%) followed by Grassland on plateau (9.42%), Teak Bamboo (9.3%), Miscellaneous Forest (8.84%) and Miscellaneous Bamboo I (8.52%).The minimum was in Teak Miscellaneous bamboo, Teak 2 and Riparian (Fig. 5.13). There were no sightings of groups in Miscellaneous open and Scrub forests. The overall variation in groups sighted in different habitat types was not significant (K-W X^2 = 11.13, p>0.05, n=218). Differences in seasonal variation across habitat was not significant.

Pellet counts: Mean maximum dung pile density was observed in Grassland on plateau (29.12 ± 7.5 dungpiles / ha) followed by Riparian forest (27.78 dungpile / ha). Mean minimum dung pile density was observed in Scrub (2.43 ± 1.5 dungpile/ha). Generally gaur showed high degree of use in Grassland on plateau, Meadow, Riparian, Miscellaneous, Teak Miscellaneous Bamboo and Teak I (Fig. 5.14). The overall variation in dung density was significantly different (K-W X^2 = 32.76, p < 0.05, n = 476). Seasonal difference across various habitats was not significant. The overall variation in summer was significantly different (K-W X^2 = 33.01, p < 0.05, n = 365) across the habitat types. Overall differences in habitat utilization was not significantly different in winter across different habitat types (K-W X^2 = 14.88, p > 0.05, n = 111). There were no dung piles observed in winter in Teak I forest. Gaur generally showed a consistent pattern of habitat use in winter across different habitat types.

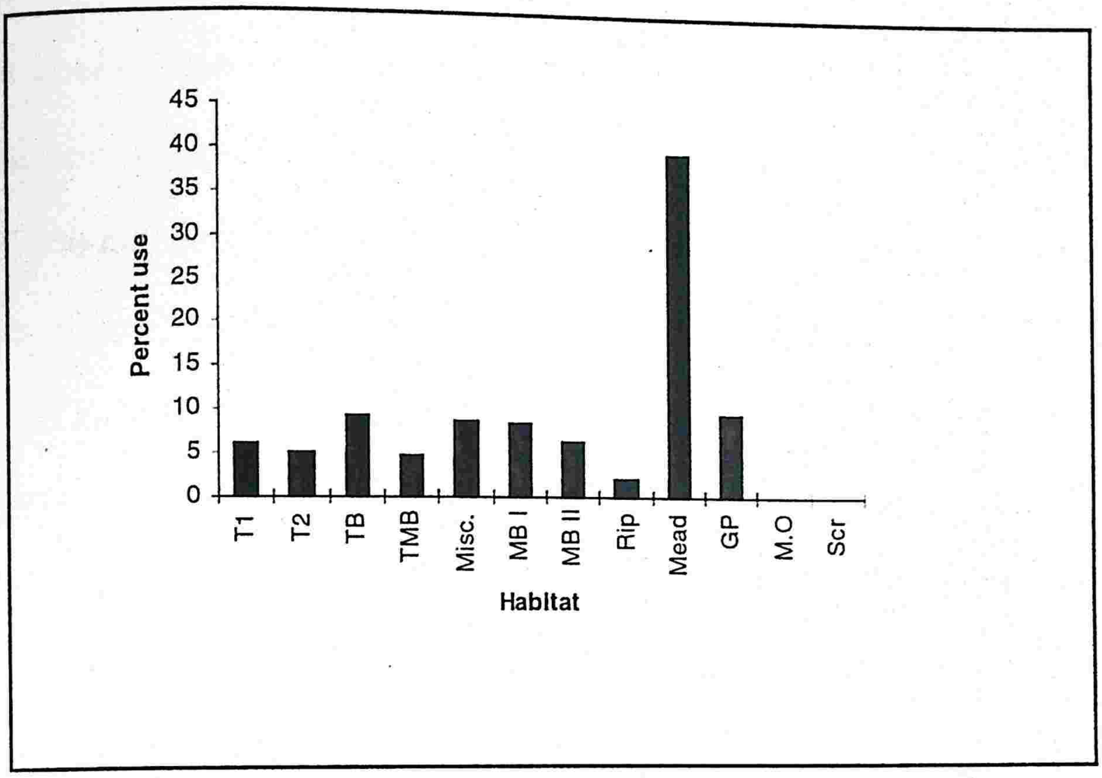


Figure 5.13. Percent gaur group sighted in different habitat types.

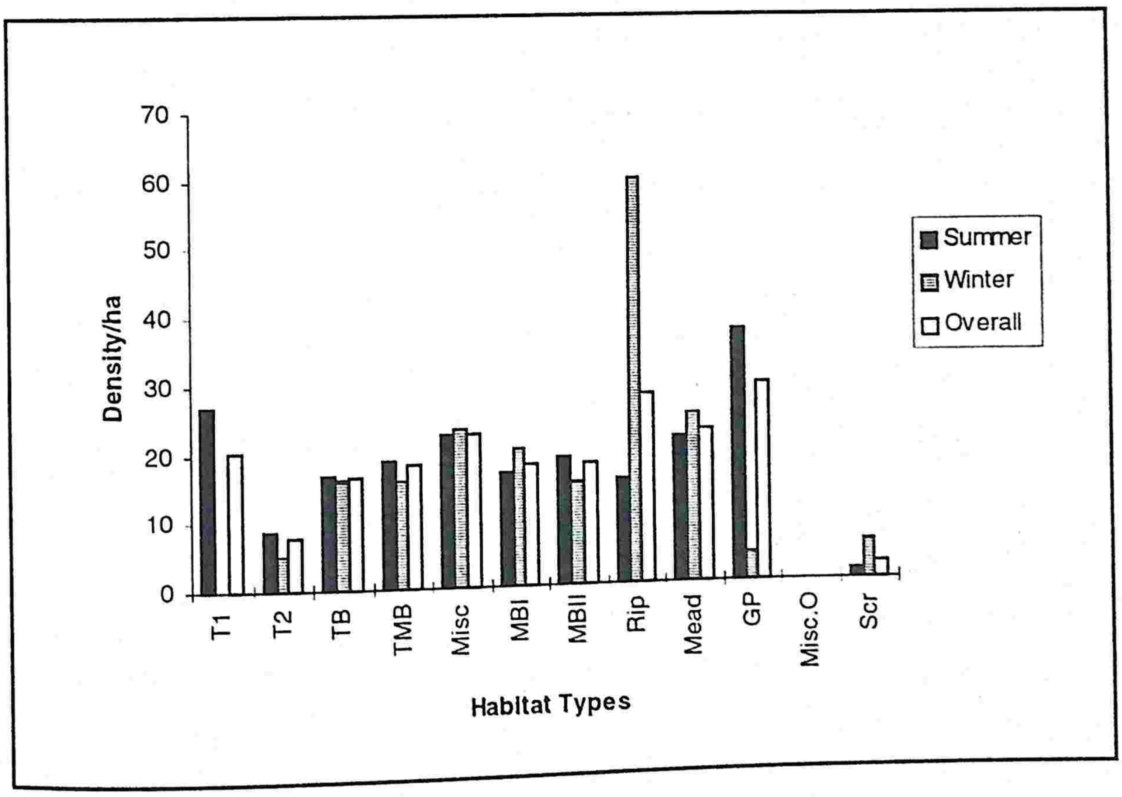


Figure 5.14. Average gaur dung pile density in different habitat types.

5.3.4.5. Habitat utilization by Barking deer

Direct observation: Barking deer showed a higher number of sightings in Miscellaneous Bamboo I forest (46.85%) followed by Teak Bamboo (26.9%) and Miscellaneous Bamboo II (10.34%). Mean minimum number of Barking deer groups were sighted in Miscellaneous forest (2.4 %). There were no Barking deer sightings in Meadow, Grassland on plateau, Miscellaneous open, Scrub, Teak I and Teak Ii (Fig. 5.15). Overall variation in groups sighted in different habitats was significantly different (K-W X^2 = 27.26, P<0.05, n = 238). Generally, Barking deer being a solitary animal was restricted to habitats with good forest cover as is evident from the results.

Pellet counts: The average pellet group density was highest in Miscellaneous Bamboo I I (8.51 ± 1.0 pellet groups / ha) followed by Miscellaneous Bamboo I (7.22 ± 0.75 pellet groups / ha) and Teak bamboo (7.14 ± 1.97 pellet groups / ha) (Fig. 5.16). The average pellet group density was lowest in Scrub (0.69 ± 0.5 pellet groups / ha) (Table 5.14). No pellet groups were observed in Grassland on plateau showing the avoidance of rocky area. The overall variation in pellet group density in different habitats differed significantly (K-W X^2 = 52.9 p < 0.05 n = 300). Seasonal variation in the pellet group density across habitats was not significant. In summer the pellet group density was high in Teak Bamboo (8.93 ± 2.5 pellet group / ha) followed by Miscellaneous bamboo II and Miscellaneous Bamboo II (Fig. 5.16). The overall difference in pellet group density in summer differed significantly (K-W X^2 = 41.87 p < 0.05, n = 214). The overall difference in pellet group density in winter was not significant.

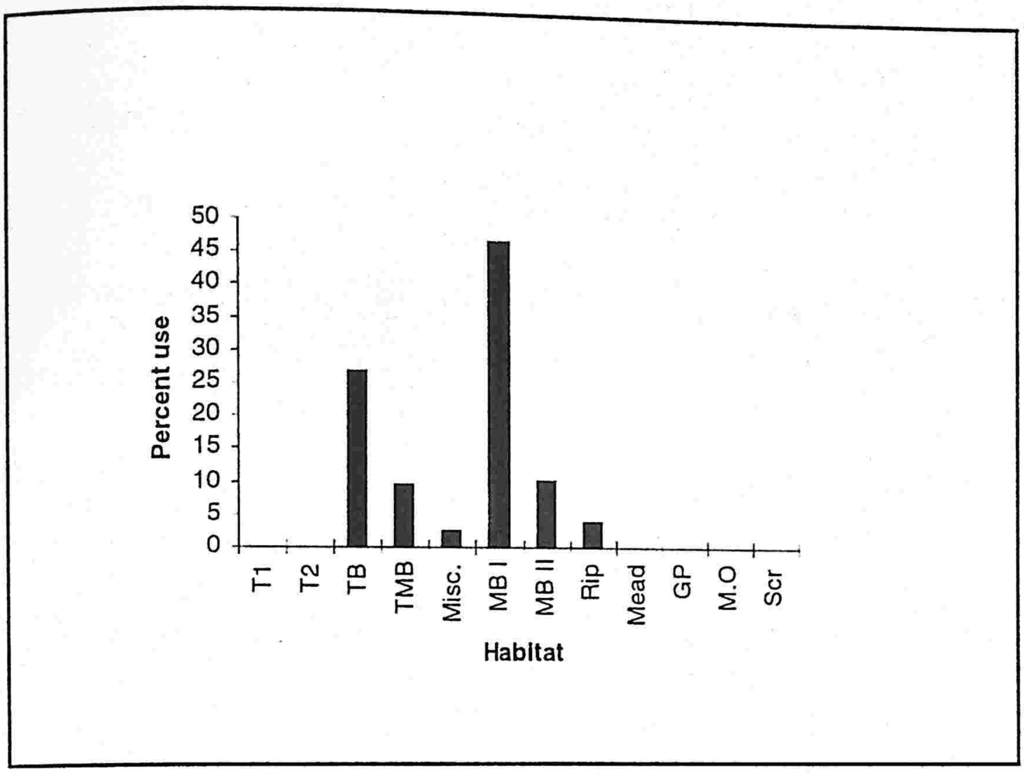


Figure 5.15. Percent Barking deer group sighted in different habitats.

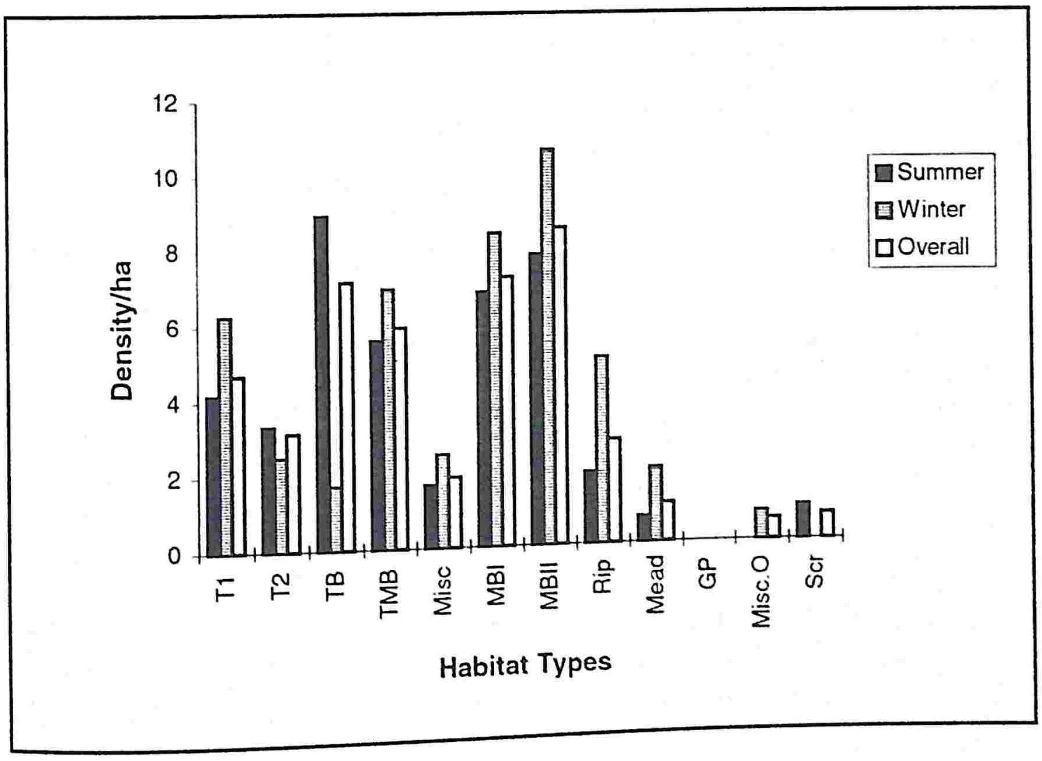


Figure 5.16. Average Barking deer pellet group density in different habitats.

5.3.5.6. Habitat utilization by Four Horned Antelope

Direct observation: The highest mean number of chowsingha groups were sighted in Miscellaneous forest (49.7 %) followed by Scrub (20 %) and Miscellaneous Forest (10.1%). The minimum chowsingha group were sighted in Miscellaneous Bamboo II (2%). No groups were sighted in Riparian forest, Teak I, and Meadow (Fig. 5.17). The overall variation in animals groups sighted in different habitats was significantly different (K-W $X^2 = 25.18$, $P<0.05$, $n = 44$). Chowsingha generally preferred open habitats as is evident from the results. It showed an avoidance for dense vegetation and grassland amidst thick vegetation.

Pellet counts: The average pellet group density was highest in Scrub (22.57 ± 5.5 pellet group / ha). The mean minimum pellet group density was observed in Teak Bamboo forest (1.34 ± 1 pellet group / ha) (Fig. 5.18). The overall variation in mean pellet group density observed in different habitats differed significantly (K-W $X^2 = 82.72$ $p < 0.05$ $n = 136$). There was no significant differences in variation in pellet group density across seasons. The mean pellet group density group density differed significantly in summer and winter (K-W $X^2 = 52.81$, $p < 0.05$ $n = 110$) and (K-W $X^2 = 45.21$ $p < 0.05$ $n = 26$) respectively. In winter chowsingha showed a skewed use of Scrub forest. Very little evidence was found in other vegetation types in winter whereas in summer other habitats were also used (Table 5.18).

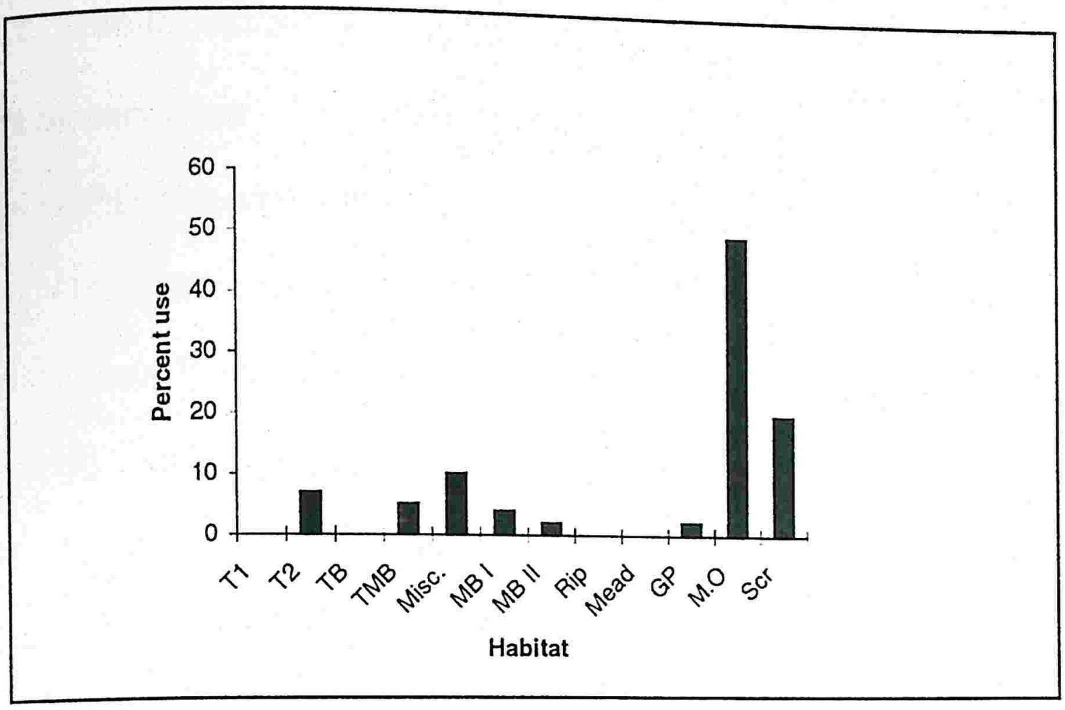


Figure 5.17. Percent chowsingha groups sighted in different habitats.

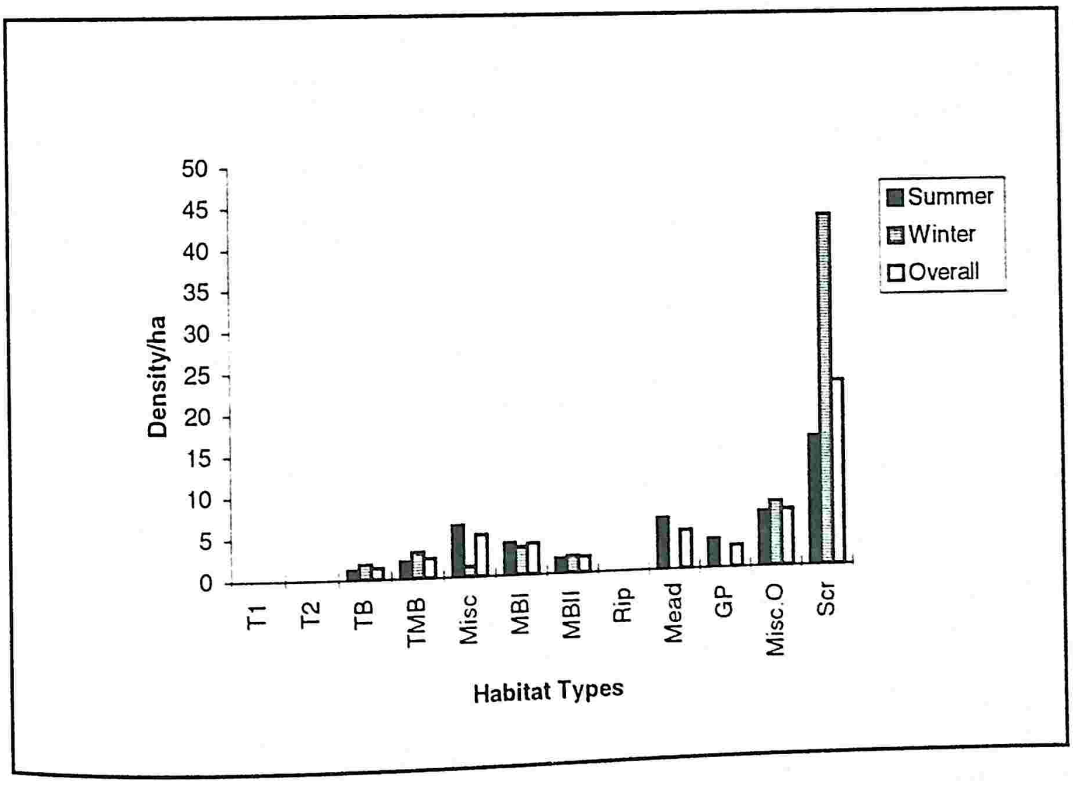


Figure 5.18. Average chowsingha pellet density in different habitat types.

5.3.5.7. Habitat utilization by Nilgai

Direct observation: The maximum number of mean groups were sighted in Scrub (25%) followed by Miscellaneous Open (22.82%) and Miscellaneous Forest (15.54%). The minimum mean number of groups were sighted in Miscellaneous Bamboo II (0.84%) and Teak Miscellaneous Bamboo (3.88%) (Fig. 5.19). No groups were sighted in Teak I, Teak II, Riparian forest and Grassland on plateau . The overall variation in Nilgai groups observed in different habitats were not significant (K-W $X^2 = 18.21$, $P>0.05$, $n = 55$).

Nilgai mainly occupied the open and degraded areas. Very few groups were sighted in Miscellaneous Bamboo I, Miscellaneous Bamboo II, Teak bamboo and Teak Miscellaneous bamboo which are dense. Nilgai showed avoidance for dense habitats (Fig 5.19).

Pellet counts: The average Nilgai pellet group density was high in Scrub forest (23.26 ± 4.5 pellet group/ha). Pellet group density was minimum in Miscellaneous Bamboo II (0.1 ± 0.02 pellet group/ha) (Table 5.17). No pellet groups were observed in Teak I, Teak Miscellaneous Bamboo, Riparian forest and Grassland on plateau (Fig 5.20). Overall variation in pellet group density in different habitats differed significantly (K-W $X^2 = 251.46$, $p < 0.05$ $n = 73$). Seasonal variation in pellet group density within habitats was not significant. The overall variation in pellet group density in summer was significantly different (K-W $X^2 = 161.97$, $p < 0.05$, $n = 55$). The overall variation in pellet group density in winter was also significant (K-W $X^2 = 99.5$, $p < 0.05$, $n = 18$).

Nilgai pellet group density figures suggests more use of open areas with less vegetation cover.

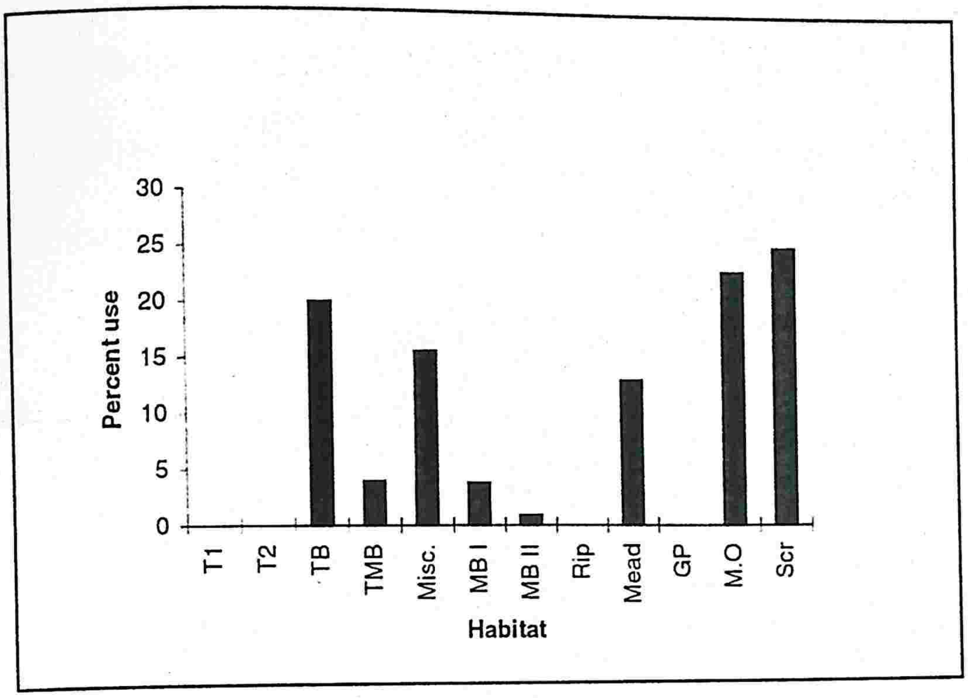


Figure 5.19. Percent Nilgai groups sighted in different habitat types.

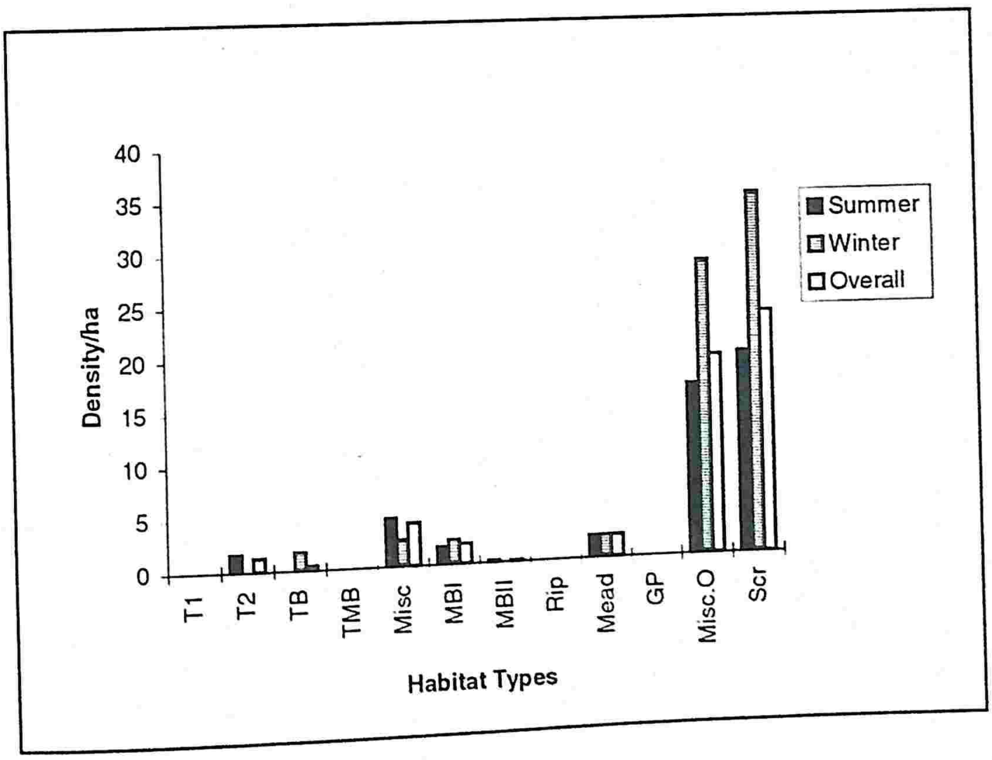


Figure 5.20. Average Nilgai pellet group density in different habitat types.

5.3.6. Terrain use by ungulates

By and large all the ungulate species preferred flat terrain. Medium slopes were used by mainly by Sambar and Gaur. Except for sambar all other ungulates showed avoidance for steep slopes (Fig 5.21).

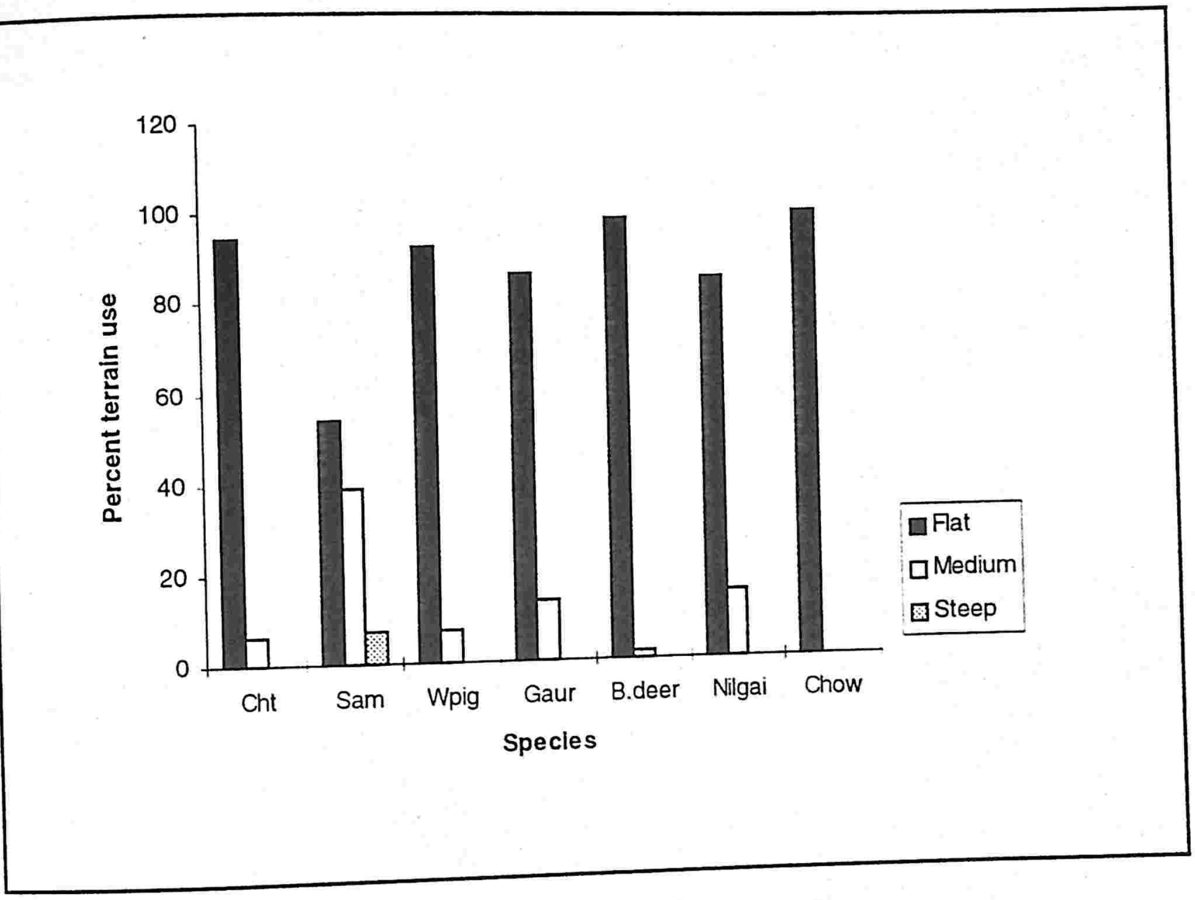


Figure 5.21. Terrain use by ungulates in TATR

Table 5.19. Pellet group density of chital in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	137.5 ± 23.75 (n=12)	112.5 ± 33 (n=4)	131.25 ± 19.25 (n=16)
Teak 2	81.25 ± 9.5 (n=56)	88.75 ± 19.5 (n=14)	83.13 ± 8.5 (n=70)
Teak Bamboo	14.29 ± 4.25 (n=12)	39.29 ± 14 (n=9)	20.54 ± 4.95 (n=21)
Teak Misc. Bamboo	36.57 ± 3.75 (n=108)	42.36 ± 8.25 (n=40)	38.02 ± 3.25 (n=148)
Misc.	41.39 ± 4.75 (n=67)	43.13 ± 9.5 (n=22)	41.82 ± 0.75 (n=89)
Misc. Bamboo I	31.51 ± 2.25 (n=215)	33.23 ± 3.75 (n=80)	31.94 ± 0.5 (n=295)
Misc. Bamboo II	30.14 ± 2.5 (n=165)	31.04 ± 5.25 (n=52)	30.36 ± 0.05 (n=217)
Riparian	15.38 ± 7.25 (n=4)	00 ± 00 (n=0)	11.11 ± 11 (n=4)
Meadow	258 ± 78.75 (n=26)	264.58 ± 90.75 (n=10)	259.9 ± 62.75 (n=36)
Grassland on Plateau	92.36 ± 20.5 (n=25)	168.75 ± 49.5 (n=11)	111.46 ± 20 (n=36)
Miscellaneous open	5.78 ± 2.08 (n=16)	3.45 ± 1.68 (n=9)	4.23 ± 1.95 (n=25)
Scrub	37.5 ± 6.75 (n=26)	22.22 ± 8.25 (n=13)	33.68 ± 5.5 (n=39)

Table 5.20. Pellet group density of Sambar in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	106.25± 17.75 (n=12)	150.0 ± 22.75 (n=4)	117.19 ± 14.93 (n=16)
Teak 2	86.25 ± 11.25 (n=58)	107.5 ± 24.5 (n=14)	91.56 ± 10.25 (n=62)
Teak Bamboo	47.02 ± 7.75 (n=24)	62.50 ± 15.75 (n=11)	50.89 ± 7.06 (n=35)
Teak Misc. Bamboo	64.58 ± 5 (n=146)	64.58 ± 7.75 (n=53)	64.58 ± 4.22 (n=199)
Misc.	54.83 ± 6.5 (n=69)	73.75 ± 13.25 (n=29)	59.59 ± 6 (n=98)
Misc. Bamboo I	48.80 ± 3 (n=272)	59.63 ± 6.25 (n=97)	51.52 ± 2.75 (n=364)
Misc. Bamboo II	45.21 ± 3.75 (n=203)	49.58 ± 6 (n=73)	46.29 ± 3.25 (n=276)
Riparian	19.23 ± 7 (n=6)	25 ± 8 (n=4)	20.83 ± 5.5 (n=10)
Meadow	30.56 ± 6.75 (n=18)	43.75 ± 11.5 (n=9)	33.85 ± 5.75 (n=27)
Grassland on Plateau	96.53 ± 12.75 (n=33)	102.08 ± 21.5 (n=11)	97.92 ± 10.75 (n=44)
Miscellaneous open	–	–	–
Scrub	23.61 ± 5.5 (n=21)	15.28 ± 5.75 (n=6)	21.53 ± 4.5 (n=27)

Table 5.21. Pellet group density of Wild pig in different habitat types.

HABITAT	SUMMER	WINTER	OVERALL
Teak1	87.5 ± 18.25 (n=11)	112.5 ± 65.75 (n=4)	93.75 ± 20.26 (n=14)
Teak 2	37.5 ± 8 (n=30)	60 ± 20.5 (n=12)	43.13 ± 7.92 (n=42)
Teak Bamboo	5.95 ± 2.5 (n=6)	7.14 ± 4 (n=3)	6.25 ± 2.05 (n=9)
Teak Misc. Bamboo	18.52 ± 2.75 (n=58)	11.81 ± 4.25 (n=12)	16.84 ± 2.37 (n=72)
Misc.	15.13 ± 2.75 (n=29)	10.63 ± 3.75 (n=9)	13.99 ± 2.25 (n=38)
Misc. Bamboo I	10.47 ± 1.25 (n=97)	10.56 ± 2.25 (n=31)	10.49 ± 1 (n=128)
Misc. Bamboo II	8.63 ± 1.25 (n=66)	5 ± 1.5 (n=14)	7.73 ± 1 (n=80)
Riparian	1.92 ± 2 (n=1)	00 ± 00 (n=0)	1.39 ± 1.5 (n=1)
Meadow	68.06 ± 30 (n=12)	66.67 ± 37 (n=3)	67.71 ± 21 (n=15)
Grassland on Plateau	6.94 ± 3 (n=6)	00 ± 00	5.21 ± 2.25 (n=6)
Miscellaneous open	2.3 ± 0.95 (n=16)	–	1.56 ± 0.99 (n=25)
Scrub	18.52 ± 6.5 (n=9)	13.89 ± 7.5 (n=3)	17.36 ± 5.25 (n=12)

Table 5.22. Pellet group density of Gaur in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	27.08 ± 12.5 (n=6)	00 ± 00	20.31 ± 9.75 (n=6)
Teak 2	8.75 ± 3.5 (n=9)	5.0 ± 4 (n=2)	7.81 ± 2.87 (n=11)
Teak Bamboo	16.67 ± 4.5 (n=14)	16.07 ± 5.75 (n=16)	16.52 ± 3.62 (n=30)
Teak Misc. Bamboo	18.98 ± 2.75 (n=63)	15.97 ± 4 (n=19)	18.23 ± 2.3 (n=82)
Misc.	22.48 ± 4.5 (n=35)	23.13 ± 7.25 (n=10)	22.64 ± 3.75 (n=45)
Misc. Bamboo I	16.82 ± 1.75 (n=108)	20.34 ± 3.5 (n=43)	17.71 ± 1.5 (n=151)
Misc. Bamboo II	18.9 ± 2.5 (n=98)	15.21 ± 3.75 (n=22)	17.99 ± 2 (n=120)
Riparian	15.38 ± 7.75 (n=4)	60.0 ± 37.5 (n=3)	27.78 ± 12 (n=7)
Meadow	21.53 ± 6.75 (n=14)	25.0 ± 22.75 (n=2)	22.40 ± 7.5 (n=16)
Grassland on Plateau	37.5 ± 9.75 (n=13)	4.17 ± 2.75 (n=2)	29.12 ± 7.5 (n=15)
Miscellaneous open	–	–	–
Scrub	1.39 ± 1.5 (n=12)	5.56 ± 3.75 (n=8)	2.43 ± 1.5 (n=20)

Table 5.23. Pellet group density of Barking deer in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	4.17 ± 4.17 (n=1)	6.25 ± 6.25 (n=1)	4.69 ± 3.4 (n=2)
Teak 2	3.33 ± 1.5 (n=5)	2.5 ± 1.75 (n=2)	3.13 ± 1.2 (n=7)
Teak Bamboo	8.93 ± 2.5 (n=12)	1.7 ± 1.75 (n=1)	7.14 ± 1.97 (n=13)
Teak Misc. Bamboo	5.56 ± 1 (n=37)	6.94 ± 1.5 (n=17)	5.9 ± 0.77 (n=54)
Misc.	1.68 ± 0.75 (n=5)	2.5 ± 1.5 (n=3)	1.89 ± 0.75 (n=8)
Misc. Bamboo I	6.82 ± 0.75 (n=82)	8.39 ± 1.75 (n=31)	7.22 ± 0.75 (n=113)
Misc. Bamboo II	7.81 ± 1 (n=68)	10.63 ± 2.5 (n=29)	8.51 ± 1.0 (n=97)
Riparian	1.92 ± 2 (n=1)	5.0 ± 5 (n=1)	2.78 ± 2.0 (n=2)
Meadow	0.69 ± 0.75 (n=1)	2.0 ± 2 (n=1)	1.04 ± 0.75 (n=2)
Grassland on Plateau	00 ± 00	00 ± 00	00 ± 00
Miscellaneous open	–	–	–
Scrub	0.93 ± 0.75 (n=4)	00 ± 00	0.69 ± 0.5 (n=6)

Table 5.24. Pellet group density of Chowsingha in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	00 ± 00	00 ± 00	00 ± 00
Teak 2	00 ± 00	00 ± 00	00 ± 00
Teak Bamboo	1.25 ± 1.25 (n=1)	1.79 ± 1.75 (n=1)	1.35 ± 1.0 (n=2)
Teak Misc. Bamboo	2.08 ± 0.5 (n=12)	3.13 ± 2.0 (n=3)	2.34 ± 0.67 (n=15)
Misc.	6.30 ± 1.75 (n=18)	1.25 ± 0.75 (n=2)	5.03 ± 1.25 (n=20)
Misc. Bamboo I	3.91 ± 0.75 (n=44)	3.42 ± 1.25 (n=9)	3.78 ± 0.75 (n=53)
Misc. Bamboo II	1.78 ± 0.5 (n=17)	2.03 ± 1.25 (n=4)	1.86 ± 0.5 (n=21)
Riparian	00 ± 00	00 ± 00	00 ± 00
Meadow	6.25 ± 4 (n=3)	00 ± 00	4.69 ± 3.0 (n=3)
Grassland on Plateau	3.47 ± 3.5 (n=1)	00 ± 00	2.6 ± 2.5 (n=1)
Miscellaneous open	6.74 ± 1.08 (n=16)	7.86 ± 1.43 (n=9)	6.94 ± 1.13 (n=25)
Scrub	15.74 ± 4.75 (n=30)	43.06 ±16.75 (n=17)	22.57 ± 5.5 (n=47)

Table 5.25. Pellet group density of Nilgai in different habitat types

HABITAT	SUMMER	WINTER	OVERALL
Teak1	00 ± 00	00 ± 00	00 ± 00
Teak 2	1.67 ± 1.0 (n=3)	00 ± 00 (n=0)	1.25 ± 1.25 (n=3)
Teak Bamboo	00 ± 00	1.79 ± 1.75 (n=1)	0.45 ± 0.45 (n=1)
Teak Misc. Bamboo	00 ± 00	00 ± 00	00 ± 00
Misc.	4.62 ± 1.25 (n=15)	2.5 ± 1.25 (n=4)	4.09 ± 1.0 (n=19)
Misc. Bamboo I	1.72 ± 0.5 (n=16)	2.33 ± 1.75 (n=4)	1.87 ± 0.5 (n=20)
Misc. Bamboo II	0.14 ± 01 (n=2)	00 ± 00	0.10 ± 0.02 (n=2)
Riparian	00 ± 00	00 ± 00	00 ± 00
Meadow	2.08 ± 1.5 (n=2)	2.08 ± 0.5 (n=1)	2.08 ± 1.25 (n=3)
Grassland on Plateau	00 ± 00	00 ± 00	00 ± 00
Miscellaneous open	16.44 ± 3.46 (n=16)	28.34 ± 7.44 (n=9)	19.13 ± 5.96 (n=25)
Scrub	19.44 ± 5.0 (n=35)	34.72 ± 10.0 (n=15)	23.26 ± 4.5 (n=50)

5.3.6. Ungulate distribution

Based on the results obtained from Vehicle based transects and pellet density, the distribution and abundance of seven ungulate species was mapped in GIS domain. The habitat map generated from IRS LISS II data was used to derive these maps. Direct observations and pellet density were taken as key variables in deriving these maps. The data from direct sightings and pellet abundance was grouped into different level of abundance categories as very high, high, medium, low and absent. These abundance values were spatially integrated with the habitat map to produce the distribution and abundance maps for seven species of ungulates (Plate 5.1 to Plate 5.7).

5.4. DISCUSSION

5.4.1. Density

Sambar, Wild pig, Gaur and Barking deer densities showed a steady increase when looked across 1994-95, 1995-96 and 1996-97. Chital and Langur showed a decreasing trend, but ultimately showed an increase. The results of this study are comparable with those obtained by Mathur, 1991. There was not much of seasonal variation in the prey densities. The increase in prey population is a function of habitat quality. Growth rate of ungulates is governed by climatic conditions and increase in forage availability (Peek, 1980). The reason for increasing trend in density could possibly be attributed to the mass flowering of Bamboo in the entire southern Maharashtra in early eighties. Since there was no working practicised in the reserve area, as a result bamboo attained a very diffused structure and hence provided more forage to all animals.

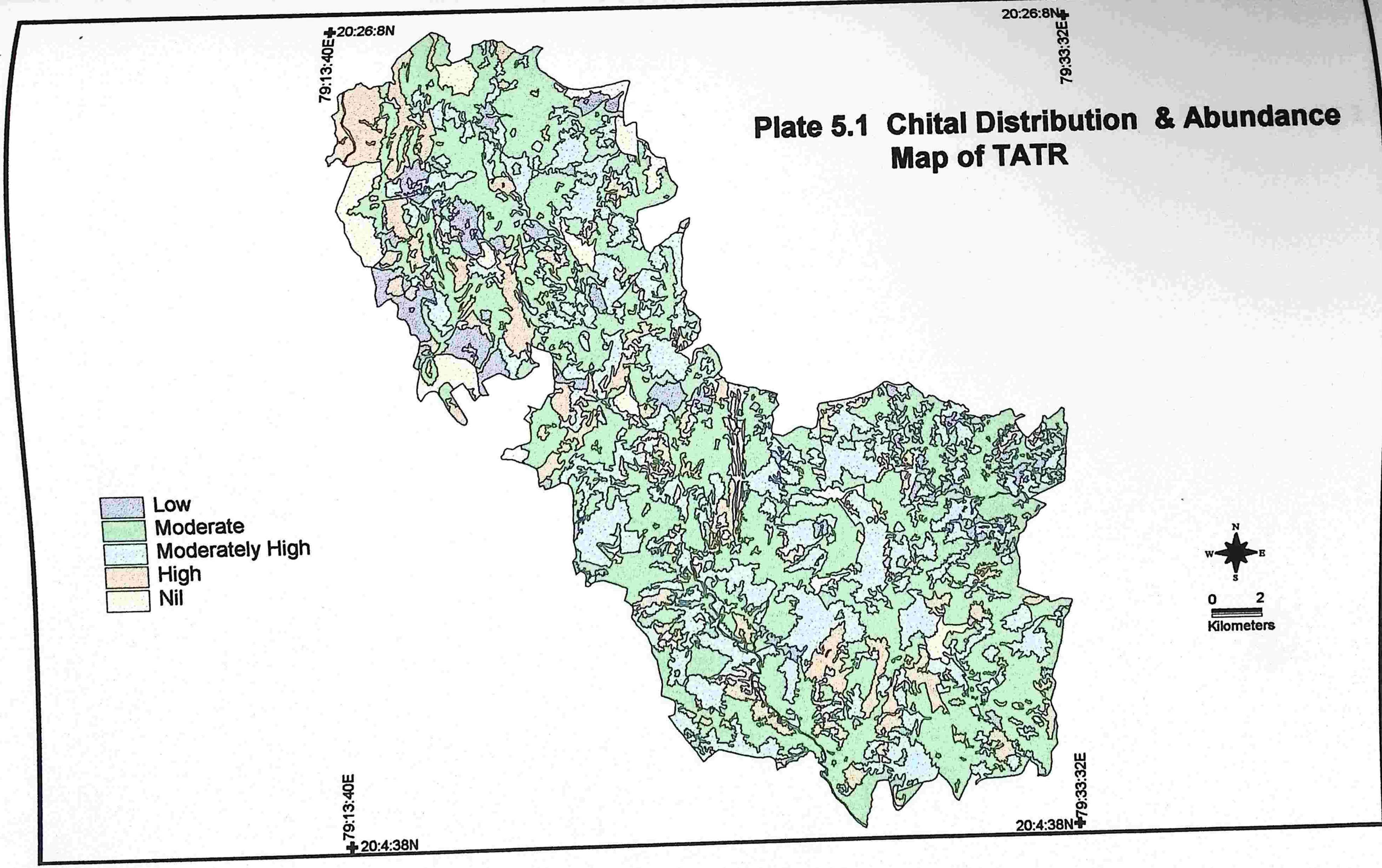


Plate 5.1 Chital Distribution & Abundance Map of TATR

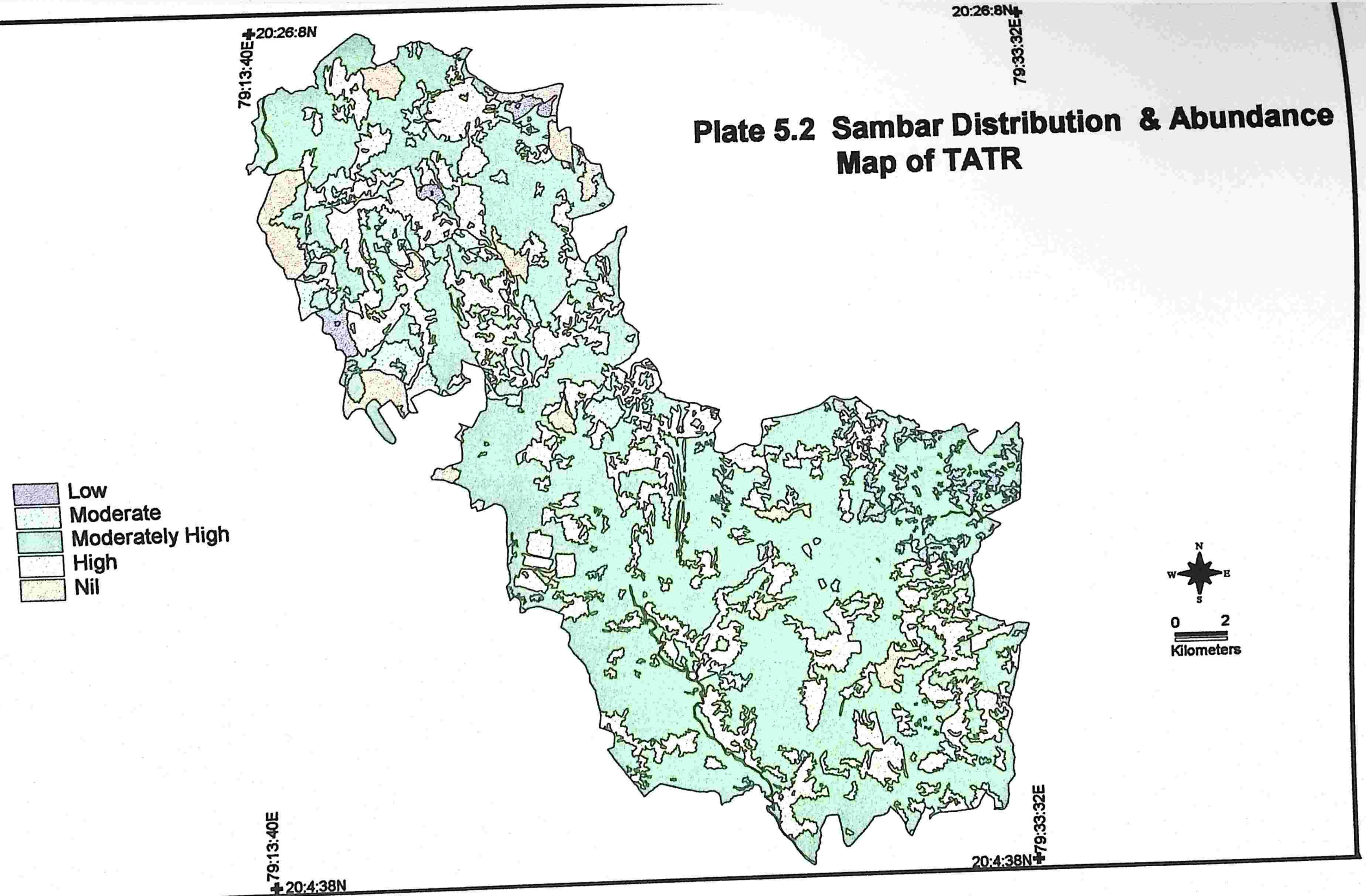


Plate 5.2 Sambar Distribution & Abundance Map of TATR

Plate 5.3 Wild Pig Distribution & Abundance Map of TATR

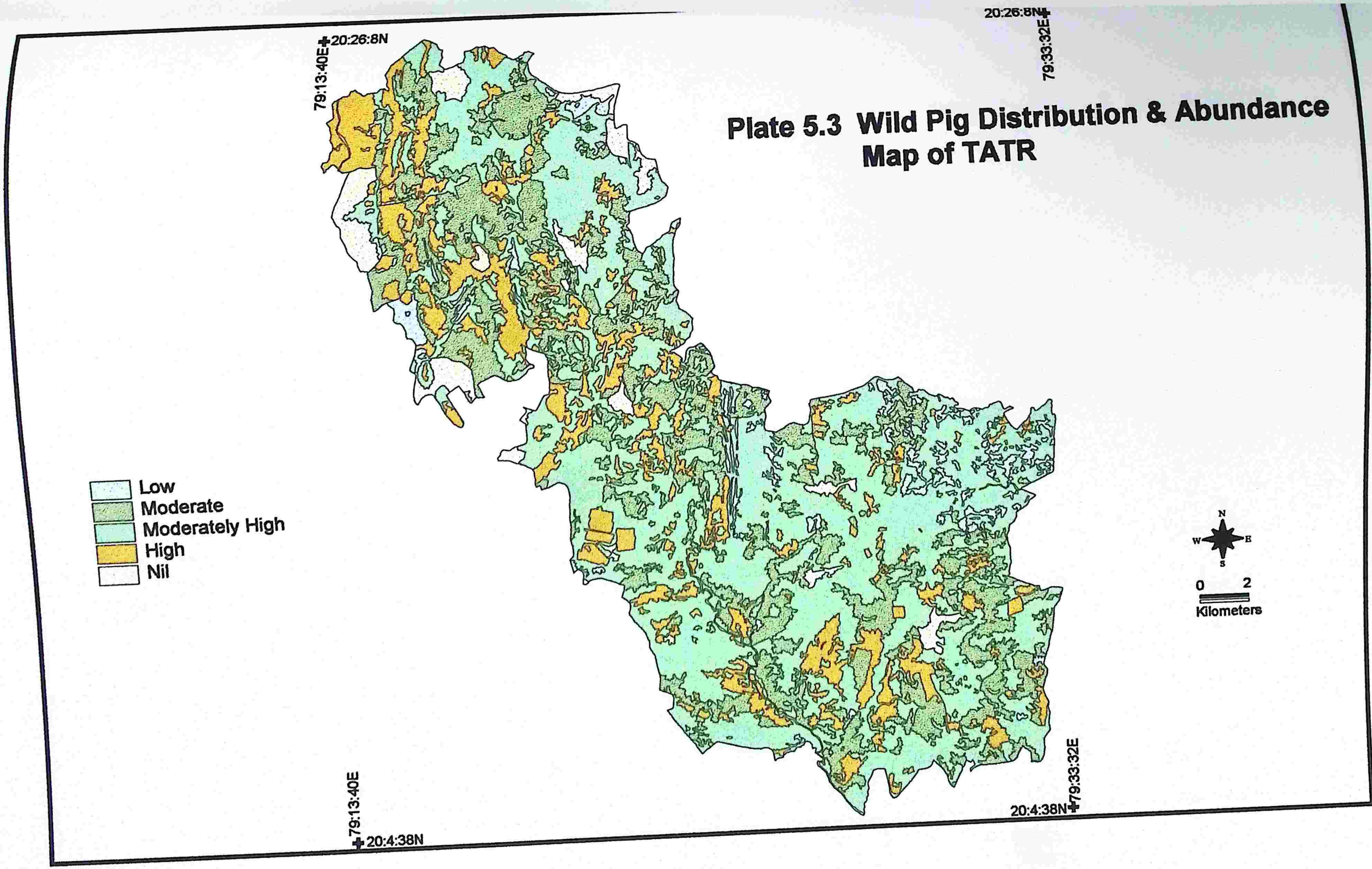


Plate 5.4 Gaur Distribution & Abundance Map of TATR

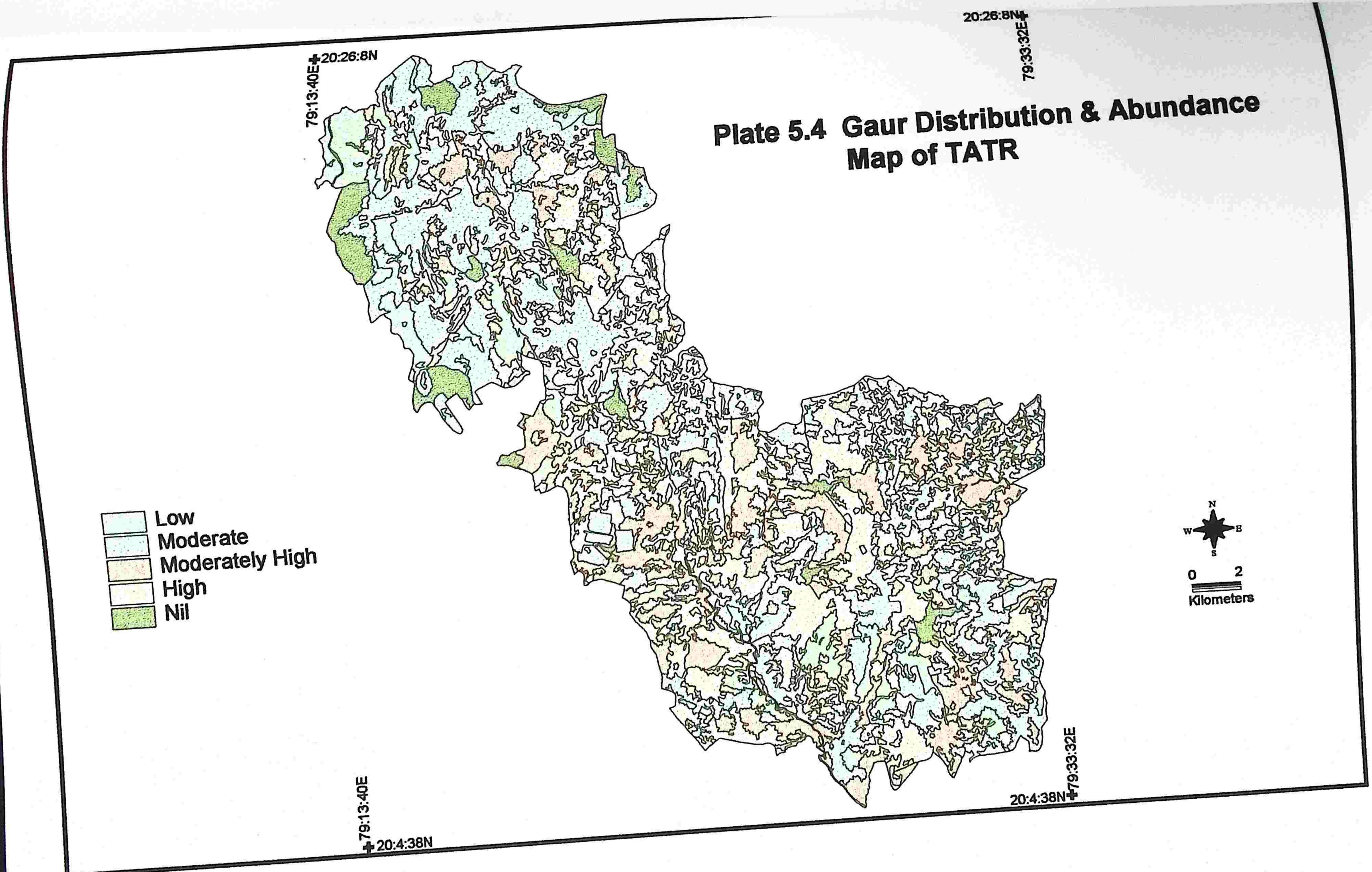


Plate 5.5 Barking Deer Distribution & Abundance Map of TATR

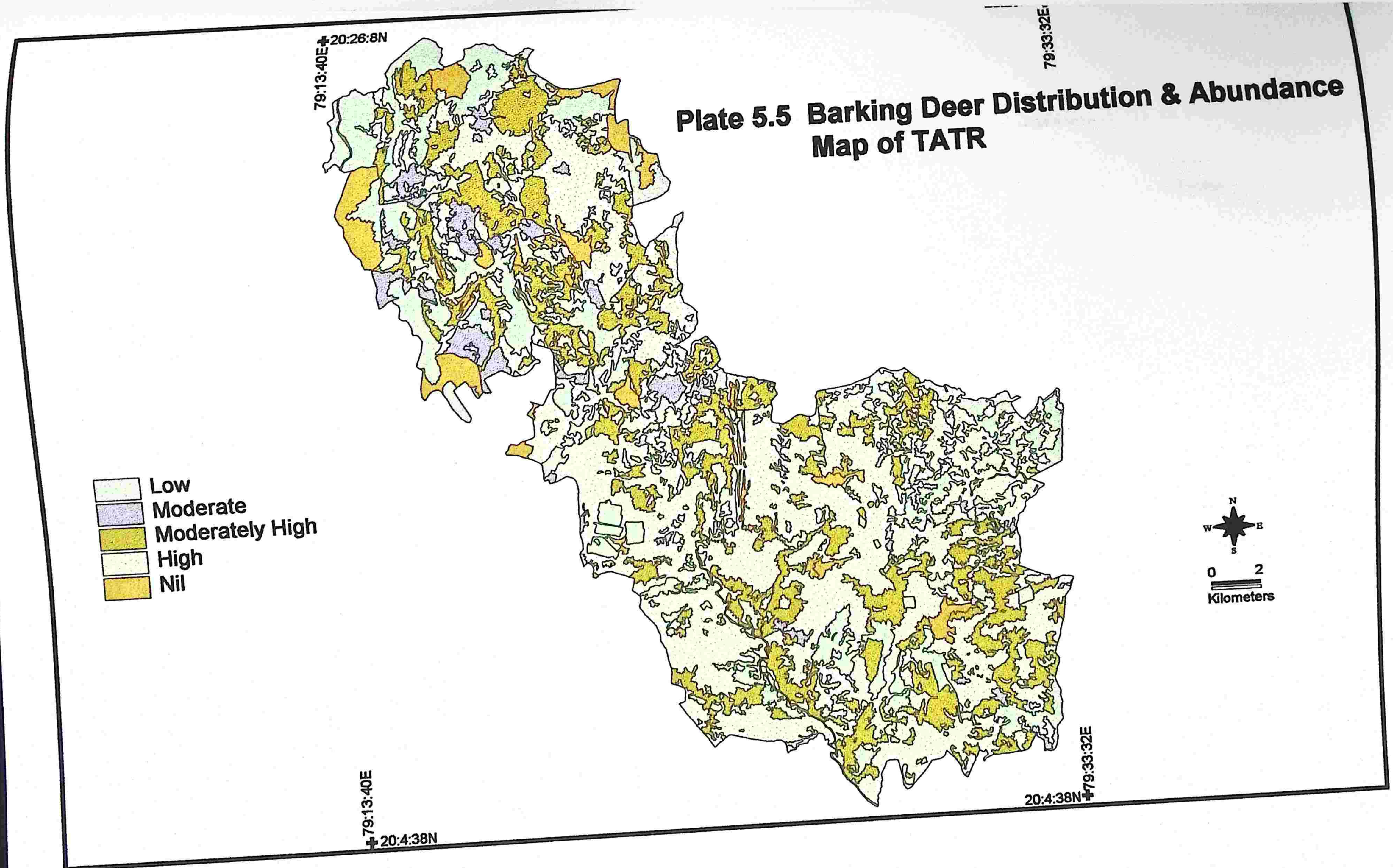
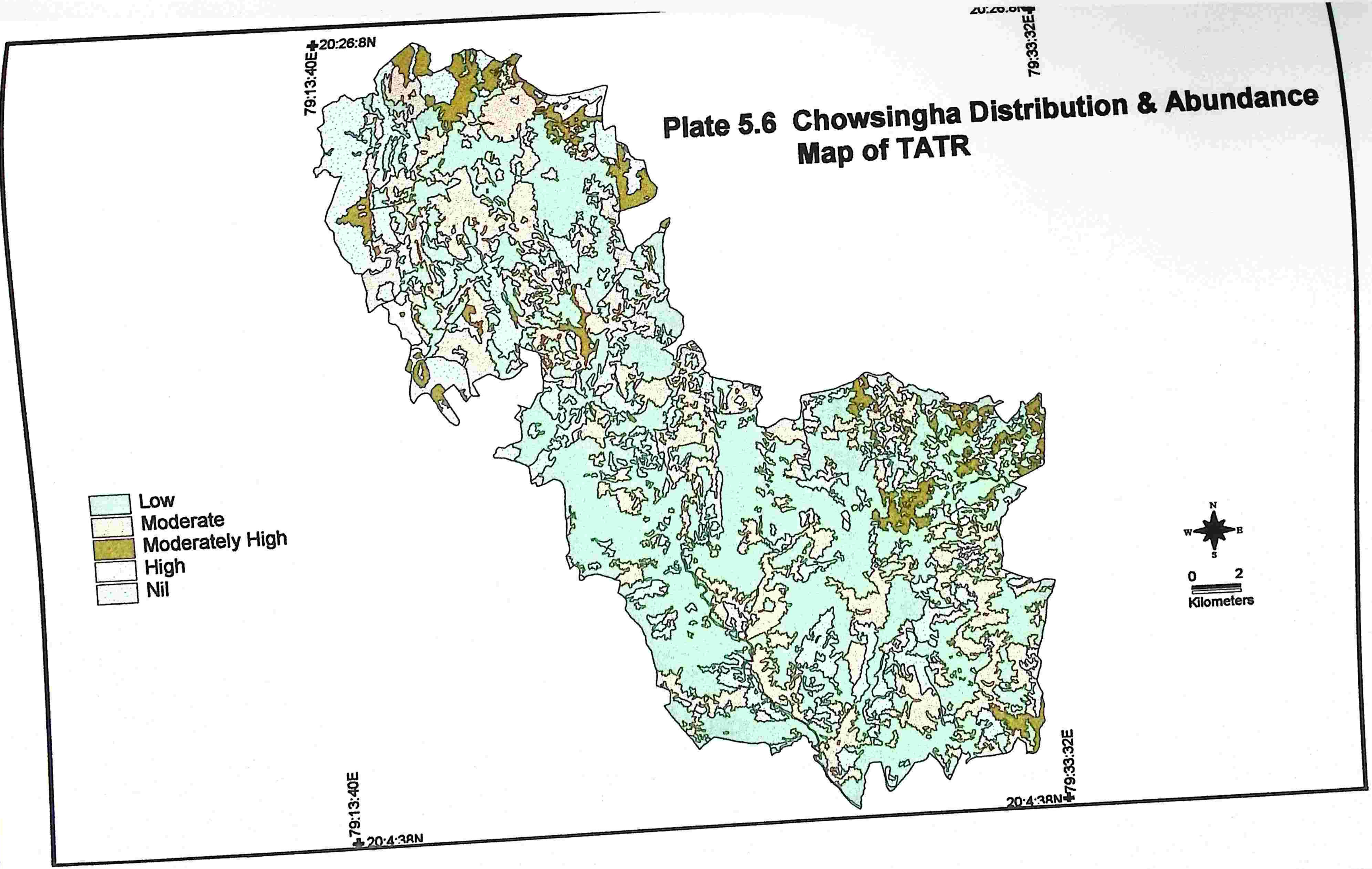


Plate 5.6 Chowsingha Distribution & Abundance Map of TATR



5.4.2. Biomass

The differential patterns of ungulate biomass levels can be explained on the basis of habitat requirements and feeding strategies. Chital, Sambar and Gaur contribute nearly 86.66% of the total biomass which reveals the importance of these species in forming major prey base in the area. Biomass when compared with other studies in central India reveals similarity in results. In all these studies three species contributed nearly 75% of the total biomass. The contribution of over 75 % to the total wild prey biomass by three species indicates the occupancy of uniform position in the ecosystem, in areas of comparable habitats (Mathur, 1991). Table 5.12 summarises the information on total number of species and the biomass contribution by few dominant species in wildlife reserves of India, South Asia and Africa. Mckay & Eisenberg (1974) put forth the argument that highly mobile species contribute most to the biomass. The reason being their better response to proximate conditions of rainfall and forage availability leading to their ability to maintain high density levels. But this explanation may not always hold good as has been pointed by Mathur (1991). .The high levels of biomass and abundance of three species in TATR cannot be solely due to mobility but may be due to the absence of a wide spectrum of competing species and also due to their efficient resource exploitation. MacArthur and Wilson (1967), Pianka (1974) and Cody (1974) have stated that low resource abundance and low environmental predictability are conditions which favour the generalist over specialist in the context of environmental exploitation strategies. Chital, Sambar and Gaur are all generalist and are possibly better exploiters of resources than other species.

5.4.3. Sex Ratio and Population Structure

Population structure of various species have been studied by different workers. A comparative account of those studies is given in Table 5.7. The sex ratio for all the species except for barking deer are heavily skewed towards females (Table 5.6) when compared with other studies. Schaller (1967) reported sex ratios for Chital in Kanha as 60 males:100 females, in Corbett Tiger reserve it was 71 males:100 females, in Keoladeo Ghana Sanctuary 79 males:100 females and from West Bastar 69 males:100 females. Looking at the results of Schaller the sex ratios in TATR are quite heavily skewed towards females.

However Seidensticker (1976a) from Royal Chitawan National Park reported the sex ratio for chital as 115 males:100 females and for sambar it as 102 males:100 females. Ables (1977) reported a sex ratio of 73 males:100 females for introduced chital in Texas. Tamang in one study from Chitawan reported sex ratios of 54 males:100 females and 55 males:100 females for chital and sambar respecitvely. Based on a study in Bandipore Tiger Reserve, Johnsingh (1983) found sex ratio of chital to be 68: 100 and for sambar 38:100. Karanth & Sunquist (1992) reported sex ratios of 72:100 for chital and 42:100 for sambar. Dinerstein (1980) reported a heavily skewed sex ratio in favour of males for Nilgai while in TATR and other studies it is strongly skewed towards females. The results of this study are comparable with sex ratios obtained from Gir Lion Sanctuary by Chellam (1993) and Pabla (1998). The sex ratio of sambar was comparable with most other studies.

Several arguments have been given by different workers to explain the skewed and biased sex ratios prevailing in wild populations. Karanth & Sunquist listed (I) solitary habit of males (ii) proneness to injuries from intra-specific aggression (iii) oblivious behaviour during mating season and (iv) dispersal behaviour as four major reason responsible for rendering male ungulates more prone to predation and hence a skewed sex ratio. Patel (1992) explains it in light of biased predation of males owing to their large body size through which predators maximize the yield of meat for every successful hunt.

It is quite evident that there is a great deal of variation in the population structure of ungulates from area to area and species appear to be able to evolve a unique population structure depending upon the availability of resources, predation, disease, competition and intrapopulation dynamics. The overall results of this study are within the range of variation cited in literature.

5.4.4. Group size and composition

The concept of group perceived here is similar to that used by various workers (Walther 1972, Esser 1980, Taylor 1982, Underwood 1982 and Barrette 1992) i.e. a group is any number of animals associating with each other and forming an unbroken unit, spatially as well temporally.

The size of the group is more likely the result of various ecological parameters such as habitat structure, spatio- temporal distribution of food, predation pressure and reproductive strategy (Barrette 1991, Khan and Vohra 1992, Miquelle *et al.* 1992). The predation pressure may induce many ungulate species to live in herds, and spatial availability of their food limits the maximum size the herd can achieve (Horn 1968, Jarman 1974, Khan and Vohra 1992). Group formation in an open area can be interpreted as an anti predator strategy, animals most likely using each other as cover in areas devoid of cover (Hamilton 1971, Altmann 1974, Jarman 1974, Triesman 1975,Berger 1978, Bertram 1978, Pulliam and Caraco 1984 and De-Ruiter 1986).

Various descriptions of group size have been used. Barrette (1991) discussed and compared eight descriptions of group size . He found Typical group size (g), described first by Jarman (1974), to be the best description of group size. (g) being an animal-centred value, it describes the experience of the animal itself rather than of the observer. Most of the measures tend to be observer-centred (e.g. mean) which are inadequate in describing the experience of the animal. Typical group size is a biologically more significant measurement as natural selection acts on individuals, but in this study Mean Group Size has been used. The optimal group size is determined by the decision of the animal to surround itself or forage with such number of animals which is the most beneficial to it.

Jarman (1974) classified African antelopes based on their grouping tendencies into five social classes. Most of the ungulates in TATR, except barking deer and chowsingha are gregarious to varying degrees and would fall in social class B to D as per the classification given by Jarman (1974). Barking deer and Chowsingha fall in category Class A of solitary animals living singly or in pairs, feeding selectively in one small home range and living inconspicously.

Gaur and wildpig resemble class D in which groups of 6 to a few hundred animals can be seen which feed on grass and may migrate seasonally. Sambar and Nilgai show close resemblance to class B where 3 to 6 individuals occur in a group which feed selectively on specific plant parts and use a mix of freeze and flee anti predator strategies. Chital as per this classification would fall in class C of gregarious animals forming groups of 6 to 60 animals, feeding on a range of grass and browse, and using a wide variety of anti predator strategies.

The mean group size (MGS) calculated in this study are comparable with other studies conducted in India (Table 5.9). There was no significant variation in MGS across winter and summer although there were some minor differences in MGS (Fig. 5.5).

Highest mean group size was observed in langur owing to its social behaviour. Chital had the next highest mean group size. Since chital occupies mostly the open habitats and edges it exhibits high mean group size. It is also evident from Table 5.18 that chital mean group size is highest in Teak 1 and Meadow. Mean group size of sambar was more or less constant in all cover types.

5.4.5. Habitat utilization

Habitat utilization by ungulates shows some amount of discrepancy as measured through indirect and direct observations. Habitat utilization as measured by indirect observations varied less in comparison to the results obtained through direct observation.

The chital pellet groups and sightings were high in habitats with higher browse availability. Chital sightings were more in habitats which had more of *Zizyphus mauritiana* and *Zizyphus enoplia* species. Habitats like Meadow, Teak II and Teak I and grassland on plateau supported more of such plant species apart from grass to graze. These habitats had less cover and formed an edge with other habitats. Scrub forest, though close to human habitation showed indirect evidence of use because of *Zizyphus mauritiana*. There were no animal sightings in this habitat, which suggests that the habitats were not used during day time owing to the disturbance but were used during night when human disturbance was less. Miscellaneous open forests were completely avoided because of non availability of water and forage presence of high degree of disturbance.

Difference in habitat utilization by Sambar was observed when measured through pellet group density and animal sightings respectively. This more or less solitary animal was seen more in dense habitats with good cover, forage and away from human disturbance. The pellet groups were more or less uniformly distributed which suggest the animals took shelter in dense habitats during the day, away from human disturbance but used almost all habitats during night when human disturbance was least. There is a large difference in animals seen and pellet groups observed in Teak I. This was mainly due to the location of pure teak forest close to the Tadoba lake which is the centre of tourism activity. Teak I was strongly avoided during day time by animals due to disturbance but heavily used during night, owing to water and browse availability. Miscellaneous open forest was completely avoided. The reason being same as that for chital. Pellet density also indicates that cover is not very important for sambar at night.

Direct and indirect observations of wild pig also showed large differences in habitat utilization. Dense habitats which were used during day time were avoided during night possibly as predator avoidance strategy. Habitats with less cover showed uniform use as shown with direct observation and pellet groups.

Not much discrepancy in habitat utilization was observed through direct observation and pellet groups in case of Gaur. It used all habitats uniformly. Since gaur is a large bodied animal and does not go for selective feeding it, exhibited use of almost all habitats. its predation risk also not being so high, as would be in case of other animals, this species did not show much of variation in the habitat use pattern. Gaur avoided areas with human disturbance. Scrub habitat was marginally used in national park area because of water availability.

Direct sightings suggest that barking deer used habitats with dense cover only. But pellet groups suggest the use of other habitats also only marginally. Pellet groups were high in dense areas as compared to habitats with low cover. The animal being solitary restricted to dense habitat types with its specific feeding demands. Not much is known about the habitat use pattern of this species.

Chowsingha and Nilgai showed complete avoidance for dense habitats and preference for open habitats. Nilgai records were observed in crop fields in vicinity of protected area whereas chowsingha avoided the crop fields.

Chapter 6

PREDATION ECOLOGY OF TIGER

6.1. INTRODUCTION

Large felids are specialized carnivores. Their predation ecology is governed by a wide range of ecological conditions, of which the most important one relates to the prey species. The abundance, distribution and size of the prey influence the predation by large cats (Chellam, 1993). Habitat factors like availability and distribution of ambush cover, terrain and availability of water also play a vital role in predation ecology of large cats.

One of the major requirement for the presence of a flourishing predator population is a good prey base. Chapter 5 gives the details of abundance and distribution of various prey species and their sex ratios. This chapter exclusively discusses the diet and food habits of the Tiger in TATR.

Scat analysis has been widely used for food habit studies of carnivores because they are easy to collect and are non destructive in nature (Joslin 1973, Johnsingh 1983, Norton *et al.* 1986, Palmer and Fairall 1989, Windberg and Mitchell 1990). Cuticular and medullary patterns of hair have been widely used for identifying prey species consumed from scats by many workers (Joslin 1973, Perrin and Campbell 1979, Keogh 1983, Palenik 1983, Mukherjee *et al.* 1994). Few studies have attempted to identify Indian mammals based on their hair structure. Joslin 1973, used cross sections of hair to examine the medullary pattern for identifying prey remains in carnivore scats. In other studies cuticular and medullary characteristics were studied (Koppikar and

Sabnis 1976) and distribution of hair keratin (Rajaram and Menon 1986) in some Indian mammals. In this study both cuticular and medullary characteristics were studied to produce information on food habits of Tiger.

6.2. METHODS

Data on the diet of the Tiger and its predation ecology was collected by two methods:

1. Collection and analysis of scats.
2. Examination of kills made by Tiger.

6.2.1. Scat collection

Tiger scat were collected as and when encountered during the course of field work. All scats were collected in zip lock polythene bags and associated information on location (compartment. No.) was collected. The scats were collected from April, 1994 to June 1997 covering three summers and three winters. In all 230 scats were collected out of which 140 randomly chosen samples were analyzed for the study.

6.2.2. Scat analysis

Scats collected were washed in running water using a sieve and prey remains like hair, bones, hooves and feathers were retained. The washed scats were then subjected to oven drying for 48 hours. Twenty hair sample based on Mukherjee *et al.* 1994 were randomly drawn from each scat and mounted on gelatin to study the cuticular pattern for identification of prey species. 20 hair from each scat were washed in alcohol and mounted on DPX solution to study the medullary pattern for identification of prey species. The identification was done with the help of binocular microscope. The results are expressed as percentage occurrence. Percent occurrence was preferred over frequency of occurrence because the former provides a better measure of the relative frequency with which each item has been consumed and it also accounts for scats with multiple prey remains (Ackerman, Lindzey and Hemker, 1984; Chellam, 1993).

6.2.3. Examination of kills

Apart from analysis of scats for determining food habits of tiger, data from kills was also collected. This was done to enable and provide information on various other aspects which would strengthen the understanding of predation ecology of tiger in TATR. Collection of data from kills has been considered important in other studies also (Schaller, 1967,1972, Sunquist 1981 and Johnsingh 1983).

Kills were located through random encounters while doing routine field work and through search made by forest staff. Since major scavengers like vultures are not present detection of kill was totally incidental. Further, as leopard is also present in the area identification of the predator became very important. Indirect evidences were searched for in and around kill site and in some cases the kills were observed to confirm the predator involved. A total of 77 tiger kills were observed throughout the study period (April 1994 to June 1997).

Data on sex , distance from water source and cover condition was also collected at each kill site. The actual kill site was located with the help of drag trails. The habitat type in which the kill was made was also noted.

6.2.4. Livestock kills

Livestock kill were very difficult to trace as the kill was immediately removed by the locals. For livestock kill, information collected by field staff was analyzed compartment wise to generate a livestock kill distribution map. This map enhanced the understanding of the spatial nature of livestock kill pattern and the extent of livestock interference in the reserve.

6.2.5. Carnivore distribution

Data was also collected on the location of scats, kills, pugmarks, scrape marks and claw marks for tiger and leopard as and when they were encountered. This helped in generating a spatial distribution pattern of these two species of large cats in the study area. Data on all the above mentioned parameters was aggregated to develop an index for distribution in terms of low, medium and high categories, in GIS domain using ARC/INFO.

6.3. RESULTS

6.3.1. Scat data

140 scats were analyzed for determining food habits of tiger. Occurrence of prey species form scat data revealed that 91.99% of scats contained single prey remains, 7.29% contained two prey remains of two species and 0.72% contained remains of three species. Scat data from

summer showed only 2.85% containing remains of two species while winter data suggested 11.9% scats containing remains of two species and 1.5% scats containing three species. Seven species of ungulates were reported from the scats. The results obtained from scat analysis and kill data are reported species wise.

Analysis of pooled scat data revealed that chital contributed a maximum of 38% to the diet of tiger (Fig. 6.3). There was a significant seasonal difference in chital occurrence in scat in summer and winter (KW X^2 = 16.1 p<0.05, n=57). In summer chital contributed 26.38% of total diet (Fig. 6.1) and in winter 48% of total diet (Fig. 6.2). There was no significant variation within seasons between months.

Sambar was the next highest contributor to the diet of tiger (32%) (Fig. 6.3). Choice for sambar as reflected in scat analysis also differed significantly in summer and winter (KW X^2 = 3.88, p<0.05, n=48). Sambar contributed 26.38% (Fig. 6.1) and 36.7% (Fig. 6.2) of total diet in summer and winter respectively. Variation in sambar occurrence within season was not significant.

Wild pig contributed 16% to the total diet of tiger (Fig. 6.3) based on scat analysis. Wild pig occurrence in scats differed significantly between seasons (K-W X^2 = 4.5, p<0.05, n=24). In summer, wild pig constituted 23.6% of the total diet (Fig. 6.1) and in winter it dropped down to 8.8% (Fig. 6.2). Differences within seasons were not significant.

Gaur, the largest body sized prey contributed only 2% to the total diet (Fig 6.3). Gaur occurrence did not differ significantly between summer and winter. In summer, gaur contributed 2.77% (Fig. 6.1) and in winter 1.26% (Fig.

6.2) of the total tiger diet. No significant difference was observed within seasons.

The occurrence of Langur in scats was 8.6% (Fig. 6.3). In summer the percent occurrence of Langur in scat was observed to be 15.27% (Fig. 6.1) and in winter it fell to 2.53% (Fig. 6.2). The seasonal difference in Langur occurrence in scat was significant (K-W X^2 = 18.25, $p<0.05$, n=13). No significant difference was observed within seasons.

The occurrence of barking deer and chowsingha in tiger scats was 1.32% and 0.66% respectively (Fig. 6.3). Barking deer constituted 1.38% in summer (Fig. 6.1) and 1.26% in winter (Fig. 6.2). Chowsingha contributed 1.38% in winter (Fig. 6.2) and none in summer. There were no significant seasonal differences in barking deer and chowsingha occurrence in tiger scats.

Nilgai yet another large bodied antelope contributed only 2% to the total diet (Fig. 6.3). Nilgai occurrence in scats in summer was 4.16% (Fig. 6.1) and in winter it was none.

6.3.2. Kill data

A total of 77 tiger kills were encountered during the study period. 32.96% of total kills were of chital followed by sambar (29.8%), wildpig (14.28%) and langur (9.09%). Gaur and nilgai occurrence in kills was 7.79% and 6.49% respectively (Fig. 6.6).

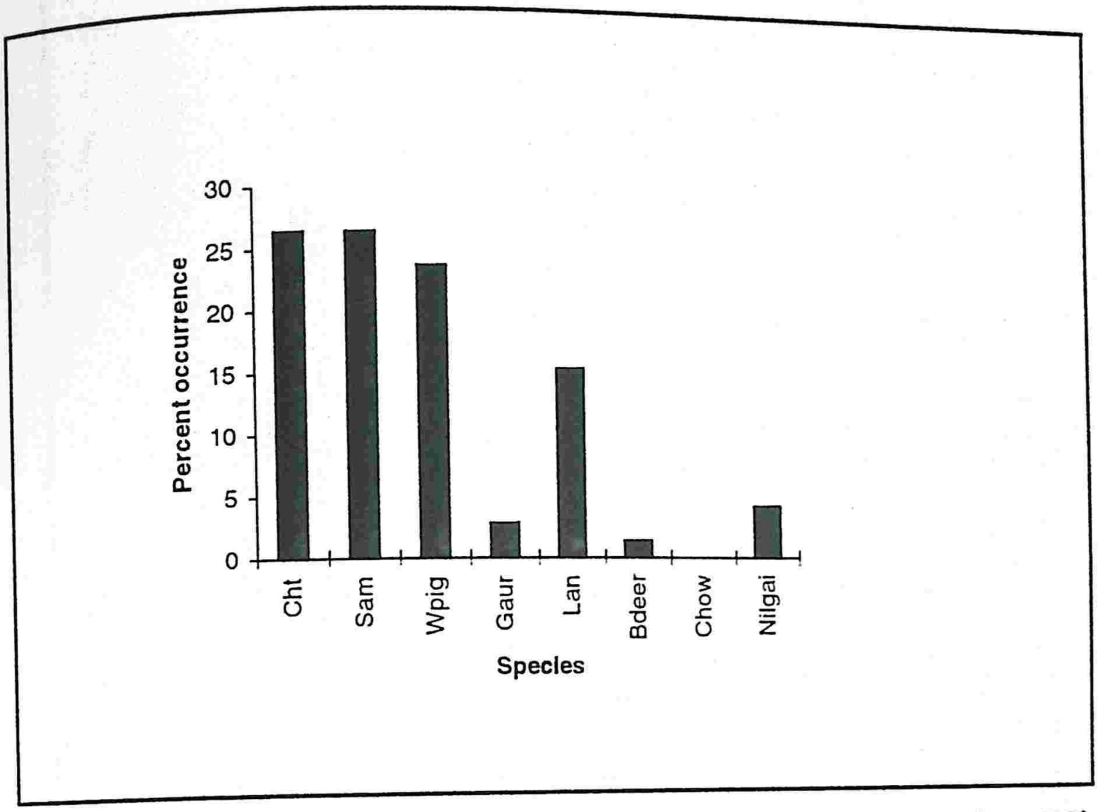


Figure 6.1. Prey species occurrence in scat in summer (n = 70)

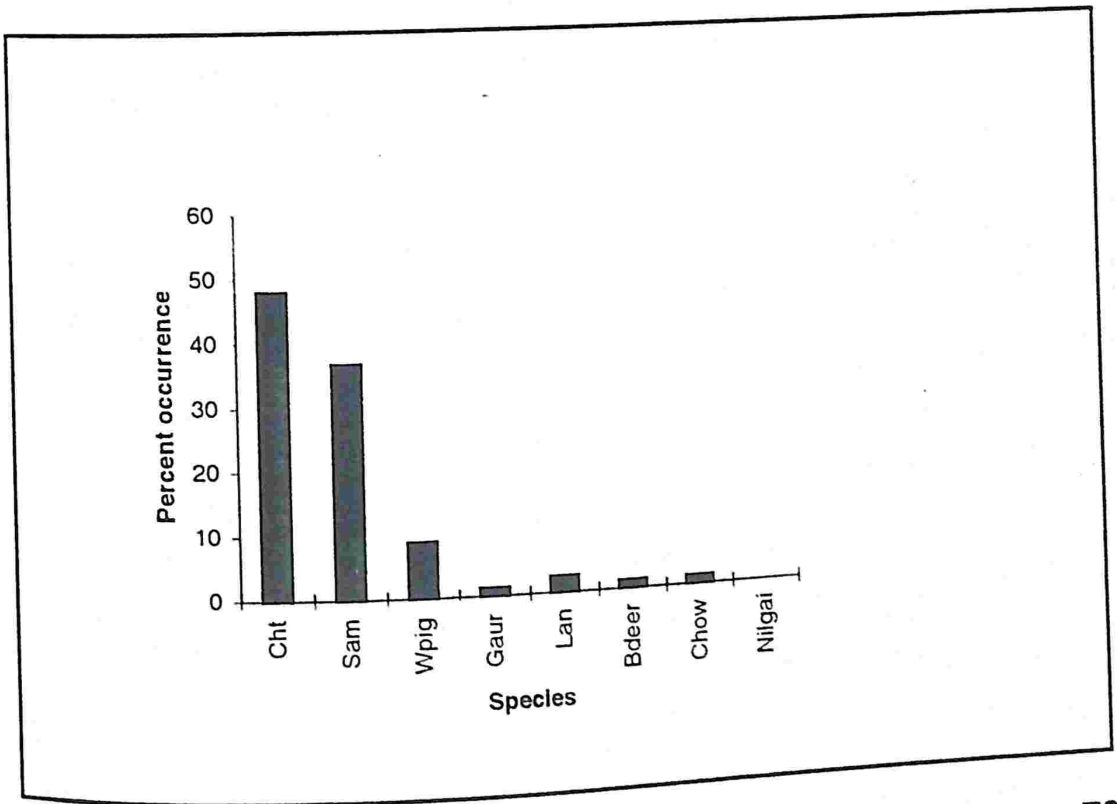


Figure 6.2. Prey species occurrence in scats in winter (n = 70).

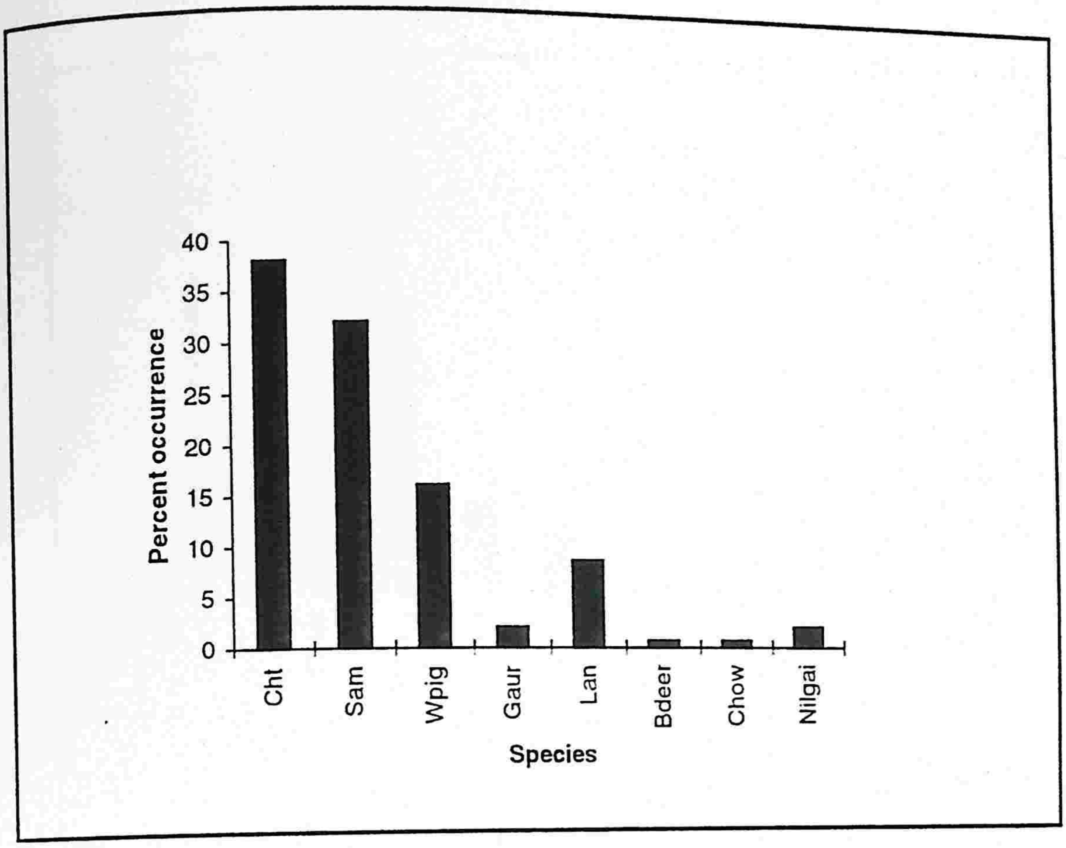


Figure 6.3. Overall prey species occurrence in scats, n = 140.

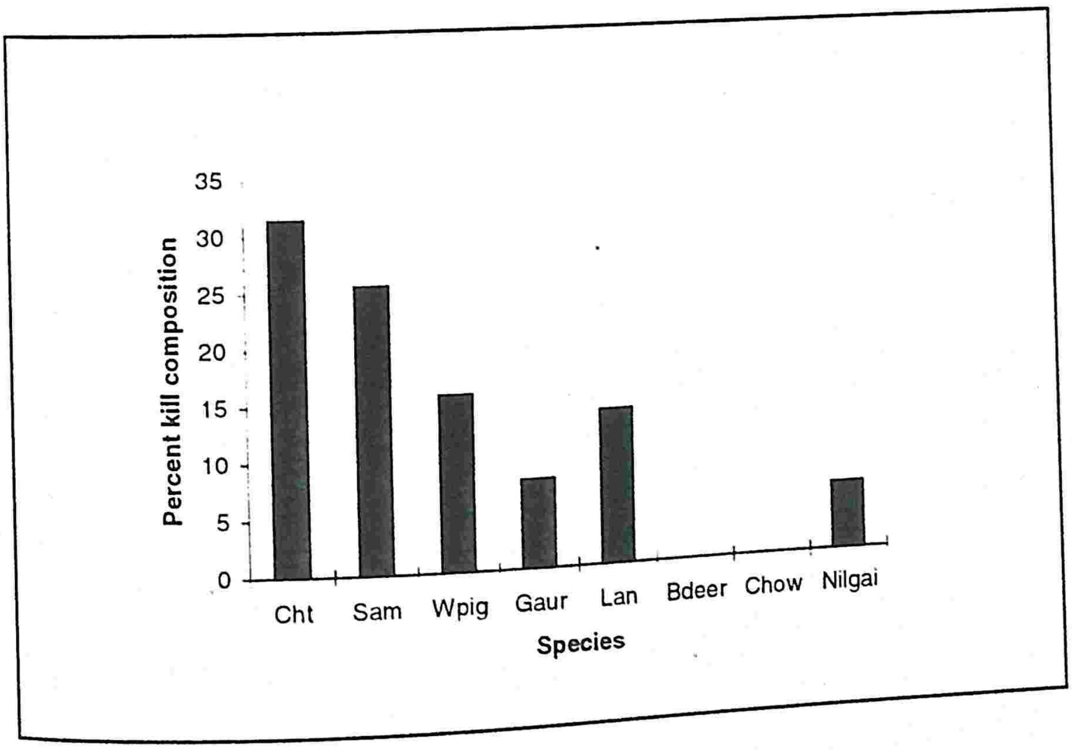


Figure 6.4. Kill composition in summer (1995-1997), n = 51.

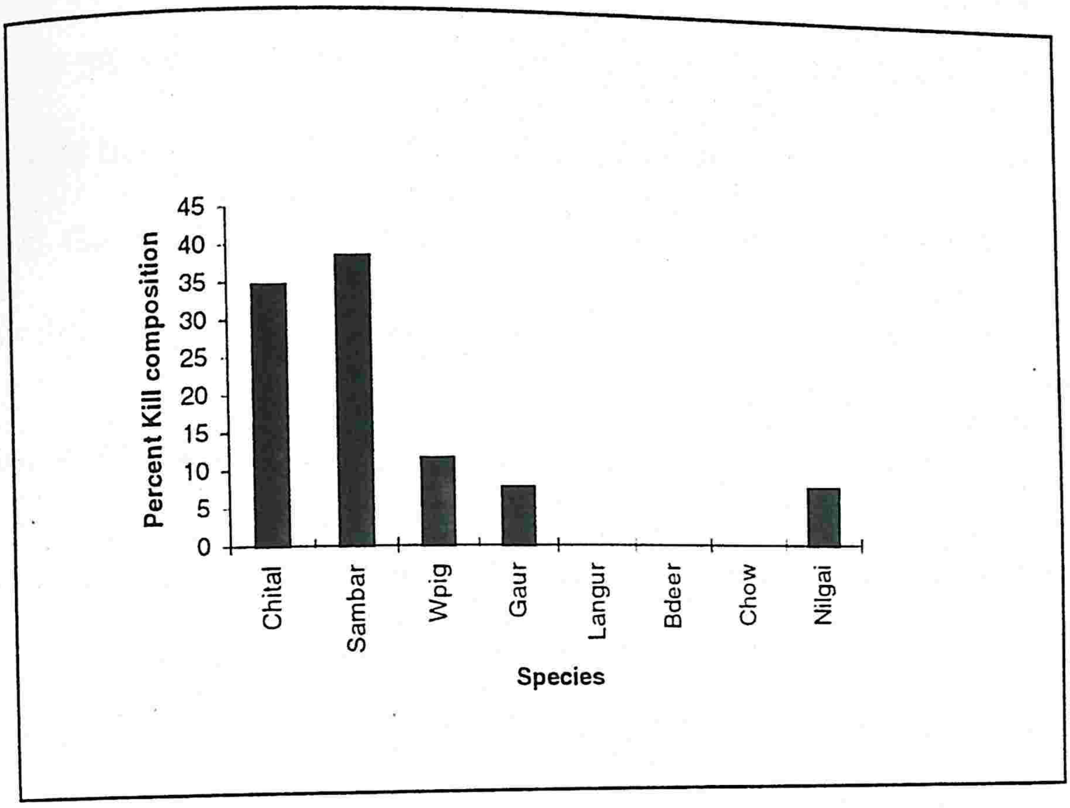


Figure 6.5. Kill composition in winter (1995-1997), n = 26.

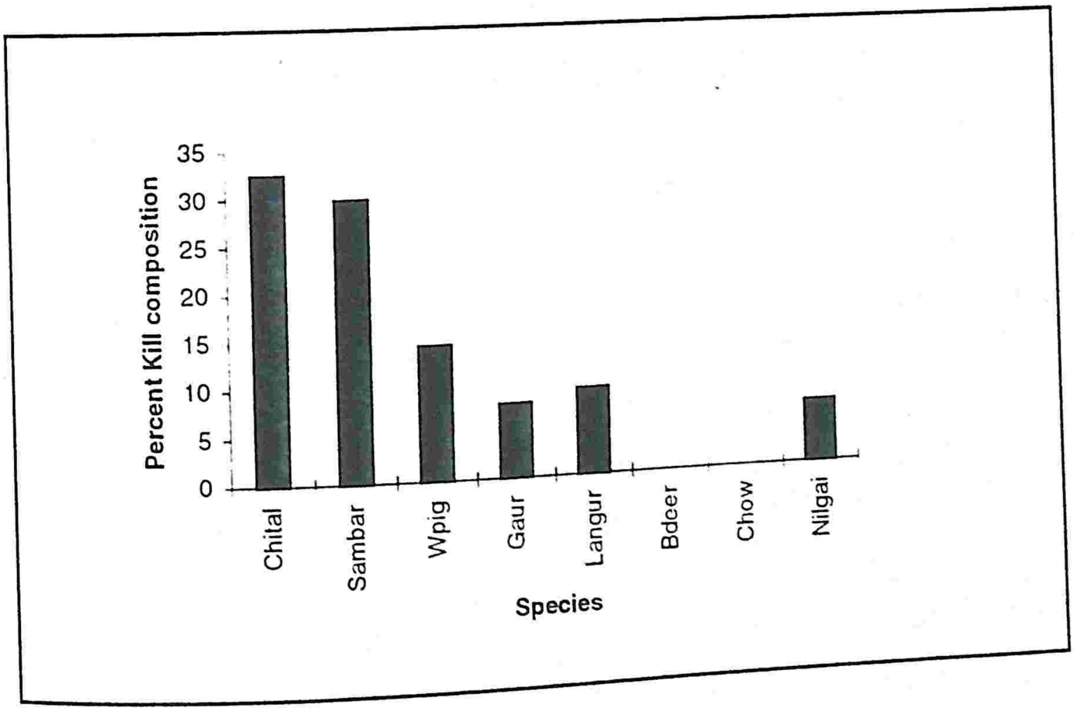


Figure. 6.6. Overall kill composition based on kill data (1995-97).

The kills made in summer and winter of different prey species did not differ significantly except in the case of sambar (K-W X^2 = 14.48, p<0.05, n=23). A maximum of 31.36% kills of chital were observed in summer whereas a maximum of 38.46% of sambar kills were observed in winter (Fig 6.4 and Fig 6.5). No kills of barking deer and chowsingha were observed during the entire study period. Gaur and nilgai showed a higher representation in kill data than the results obtained from scat analysis.

6.3.2.1. Sex ratio of kills

The predation pattern by tiger showed a large bias towards males especially chital, sambar and wild pig (Table 6.1). In case of gaur the ratio was biased towards females. The predation of nilgai also showed a bias towards males. In summer, predation on only males was observed in the case of wildpig (Table 6.1). Predation on langur and nilgai was observed only in summer (Table 6.1).

Table 6.1. Sex ratio of kills made by tiger in TATR.

Species	Summer Males:100 F	Winter Males:100 F	Overall Males:100 F
Chital	300:100	50:100	257:100
Sambar	333:100	150:100	229:100
Wildpig	–	50:100	450:100
Gaur	34:100	–	20:100
Langur	–	–	–
Barking deer	–	–	–
Chowsingha	–	–	–
Nilgai	200:100	–	150:100

n=23). A maximum of 31.36% kills of chital were observed in summer whereas a maximum of 38.46% of sambar kills were observed in winter (Fig 6.4 and Fig 6.5). No kills of barking deer and chowsingha were observed during the entire study period. Gaur and nilgai showed a higher representation in kill data than the results obtained from scat analysis.

6.3.2.1. Sex ratio of kills

The predation pattern by tiger showed a large bias towards males especially chital, sambar and wild pig (Table 6.1). In case of gaur the ratio was biased towards females. The predation of nilgai also showed a bias towards males. In summer, predation on only males was observed in the case of wildpig (Table 6.1). Predation on langur and nilgai was observed only in summer (Table 6.1).

Table 6.1. Sex ratio of kills made by tiger in TATR.

Species	**Summer Males:100 F**	**Winter Males:100 F**	**Overall Males:100 F**
Chital	300:100	50:100	257:100
Sambar	333:100	150:100	229:100
Wildpig	–	50:100	450:100
Gaur	34:100	–	20:100
Langur	–	–	–
Barking deer	–	–	–
Chowsingha	–	–	–
Nilgai	200:100	–	150:100

6.3.3. Weight class of kills

Kills were classified into different weight classes. 46.75% of kills were made in weight class 51-100 kg. followed by 44.15% in weight class >100kg. only 9.09% kills belonged the weight class <25kg. No kill were observed in weight class 25-50 kg. In summer also pattern was more or less same with 47.05% prey in 51-100 kg. class and 39.3% in >100 kg. class. 13.75% prey fell in weight class <25 kg and no prey in 26-50 kg class. In winter the category <25 and 26-50 did not have any prey. Weight class >100 had 53.84% prey and Weight class 51-100 had 46.15% prey (Table 6.2).

Table 6.2. Weight class of kills made by tiger (n = 77)

	Weight Class			
Tiger kills	**< 25 kg**	**26-50 kg**	**51-100 kg**	**> 100 kg**
Summer (n=51)	n = 7 (13.75%)	–	n = 24 (47.05%)	n = 20 (39.2%)
Winter (n=26)	–	–	n = 12 (46.15%)	n = 14 (53.84%)
Overall (n=77)	n = 7 (9.09%)	–	n = 36 (46.75%)	n = 34 (44.15%)

6.3.4. Ambush cover

The ambush cover was qualitatively assessed in all 77 sites where kills were made. Ambush cover appears to be very crucial and important in capturing the prey. 63.63 % of kills were made in areas with high ambush cover. 22.07 % kills were in areas with medium ambush cover and 14.2 % kills were in area with low ambush cover. Data was also analyzed species wise for ambush cover condition of kill site (Table 6.3). It is evident that most of the kills were made in area with high ambush cover except for nilgai where all kills were made in areas with low ambush cover.

Table 6.3. Ambush cover at kill sites (n = 77).

SPECIES	Ambush cover categories		
	Low	Medium	High
Chital	3 (3.89%)	5 (6.49%)	17 (22.07%)
Sambar	1 (1.29%)	3 (3.89%)	19 (24.67%)
Wildpig	2 (2.59%)	7 (9.09)	2 (2.59%)
Gaur	–	1 (1.29%)	5 (6.49%)
Langur	–	2 (2.59%)	5 (6.49%)
Barking deer	–	–	–
Chowsingha	–	–	–
Nilgai	5 (6.49%)	–	–
Total	11 (14.2%)	17 (23.37%)	49 (62.33%).

6.3.5. Habitat types of kill sites

Table 6.4 presents the data for prey species killed in various habitat types. 52% of chital kills were observed in Meadows whereas 60.86% of sambar kills were observed in Miscellaneous bamboo I habitat type. 81.8% of wild pig kills were observed in riparian forest and 83.3% of gaur kills were observed in Miscellaneous bamboo I. 60% of nilgai kills were observed in scrub forest and 40% in Miscellaneous open forest.

6.3.6. Influence of water

To see whether proximity to water sources played any important role in predation ecology of tiger the distance to nearest water source from kill sites was measured for all 77 kills observed. The data is presented seasonally (Table 6.5). Out of 16 chital kills observed in summer 12 were made <25m from water source and 3 between 26-100m from water. This constitutes 95.75% of total chital kills observed during summer. Out of 13 sambar kills during summer 53.84% were in <25m category and 30.76% in 26-100m category. This constitutes 84.6% of total sambar kills in summer.

All wild pig kill in summer were in <25m category. Out of 4 gaur kills observed only 1 (25%) was made in category <25m and 3 (75%) were made in category 101-300m. All langur kills in summer were made in <25 m category. Out of 3 kills observed in the case of nilgai in summer 1 (33%) was made in Category <25 m and 2 (67%) in category 26-100m. This form 100% kills within 100m from the nearest water source.

Table 6.4. Habitat types in which different prey species were killed by tiger based on kill data (n = 77).

Species	T I	T II	TB	TMB	Misc.	MB I	MB II	Rip.	Meadow	GP	Misc.Open	Scrub
Chital	3	–	–	2	3	–	–	4	13	–	–	–
Sambar	1	–	–	1	–	14	5	–	–	–	–	–
Wildpig	–	–	–	–	1	–	–	9	1	–	–	–
Gaur	–	–	–	–	1	5	–	–	–	–	–	–
Langur	–	–	–	1	–	–	–	6	–	–	–	–
Nilgai	–	–	–	–	–	–	–	–	–	–	2	3
Total	4	–	–	4	5	19	5	19	14	–	2	3

Table 6.5. Distance of kill sites from water sources (n=77)

Season	Distance from water source (in meters)				
	< 25	26-100	101-300	301-500	> 500
Chital (n=25)					
Summer	12	3	0	1	0
Winter	0	1	1	4	3
Sambar (n=23)					
Summer	7	4	2	1	0
Winter	2	3	4	0	0
Wild pig (n=11)					
Summer	8	0	0	0	0
Winter	0	0	1	2	0
Gaur (n=6)					
Summer	1	0	3	0	0
Winter	0	0	0	0	2
Langur (n=7)					
Summer	7	0	0	0	0
Winter	0	0	0	0	0
Nilgai (n=5)					
Summer	1	2	0	0	0
Winter	0	0	1	1	0

Table 6.6. Kill composition (in %) based on scat analysis in other studies

Species	This study (1998) Tadoba, India	Schaller (1967) Kanha, India	Mcdougal (1977)	Sunquist (1981) Chitwan, Nepal	Kotwal (1987) Kanha, India	Rabinowitz (1989) HuaiKha Khaeng, Thailand	Johnsingh (1992) Bandipur,India	Stoen (1994) Bardia, Nepal	Karanth (1995) Nagarhole, India
Chital	38 %	52.2 %	33.3 %	–	46.6 %	–	39 %	77 %	31.2 %
Sambar	32 %	10.4 %	29.3 %	20 %	10.2 %	7 %	30.5 %	–	24.9 %
Wild pig	16 %	0.8 %	10.6 %	3.6 %	8.5 %	4 %	5.5 %	8.8 %	9.4 %
Gaur	2 %	8.3 %	–	–	2.5 %	–	–	–	17.4 %
Langur	8.6 %	6.2 %	5.7 %	3.6 %	12.9 %	–	–	2.3 %	3.9 %
Barking deer	1.32 %	–	4.1 %	–	2.2 %	42 %	–	–	6.1 %
Chowsingha	0.66 %	–	–	–	0.3 %	–	–	–	–
Nilgai	2 %	–	–	–	0.9 %	–	–	1.9 %	–

Table 6.7. Kill composition in other studies

Species	This study (1998) (n=77)	Johnsingh (1992) (n=19)	Karanth (1995) (n=154)
Chital	32.96 %	26.3 %	10.4 %
Sambar	29.8 %	36.8 %	28.6 %
Wild pig	14.28 %	21 %	14.3 %
Gaur	7.79 %	0	44.8 %
Langur	9.09 %	0	0
Barking deer	0	0	0
Chowsingha	0	0	0
Nilgai	6.49 %	0	0
Others	0	15.9 %	0

6.3.7. Livestock predation

Livestock predation data was spatially mapped in GIS domain using ARC/INFO software. There was no occurrence of livestock hair in scat although livestock kills by tiger were observed. This is probably because livestock owners prevented the tiger from consuming the carcass The kill site became disturbed which led to tiger abandoning the prey. In TATR Livestock do not contribute much to the tigers diet. Spatial analysis of livestock kill data revealed that maximum livestock depredation (14.52%) occurred in areas which were mainly close to the villages (Plate 6.3).

6.3.8. Carnivore distribution

Data collected from direct sightings by the researcher and field staff along with, pug marks, scrape marks, claw marks and scats were pooled together and mapped in spatial domain for tiger and leopard. The overall tiger distribution appeared to be more or less clumped. Tiger distribution based on the above information when mapped revealed the population to be distributed in 69.8% of the total geographical area of the reserve (Plate 6.1).

Leopard population on other hand was distributed in only 48.6% of the total geographical area of the reserve. The areas which were under heavy use by tigers were avoided by leopards. Leopards in TATR mainly take respite in peripheral areas and close to villages inside the reserve (Plate 6.2). Leopard movement was substantially less in the areas of high tiger use. Leopards rarely frequented roads and trails in such areas.

6.4. DISCUSSION

6.4.1. Scat and Kill data

Analysis of scat and kill data reveals that several ecological factors such as abundance of prey, their distribution, size, sex and anti predator strategies employed by them govern the predation by tiger in TATR. Chital being the most abundant species was preyed upon more than others. Chital were killed more in winter than summer. Since winter supports high ambush cover in nearly all habitat types it becomes easier for tiger to ambush the animals. However more kills were observed in summer than winter. The reason for this could be

Plate 6.1 Tiger Distribution Map of TATR

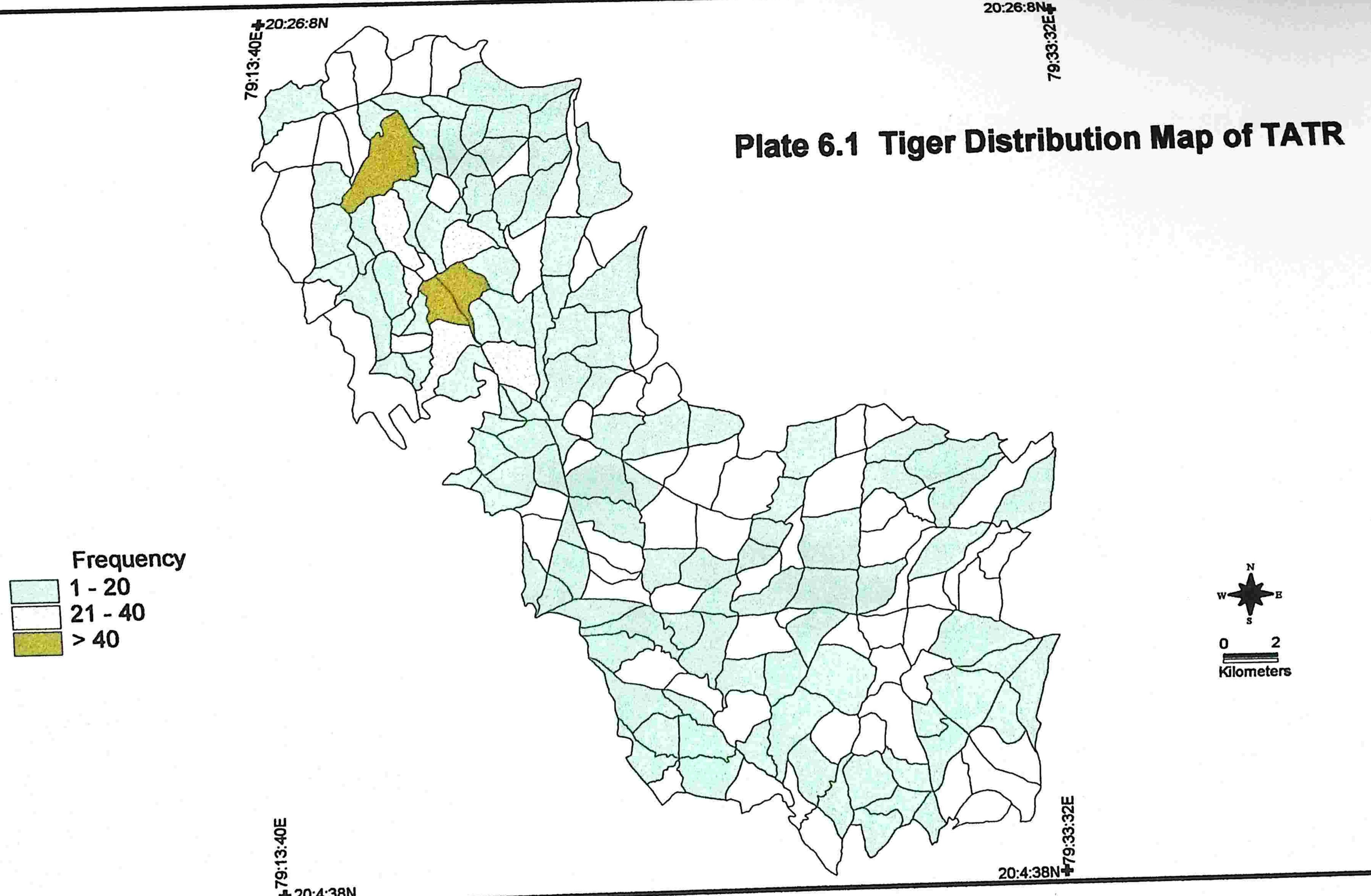
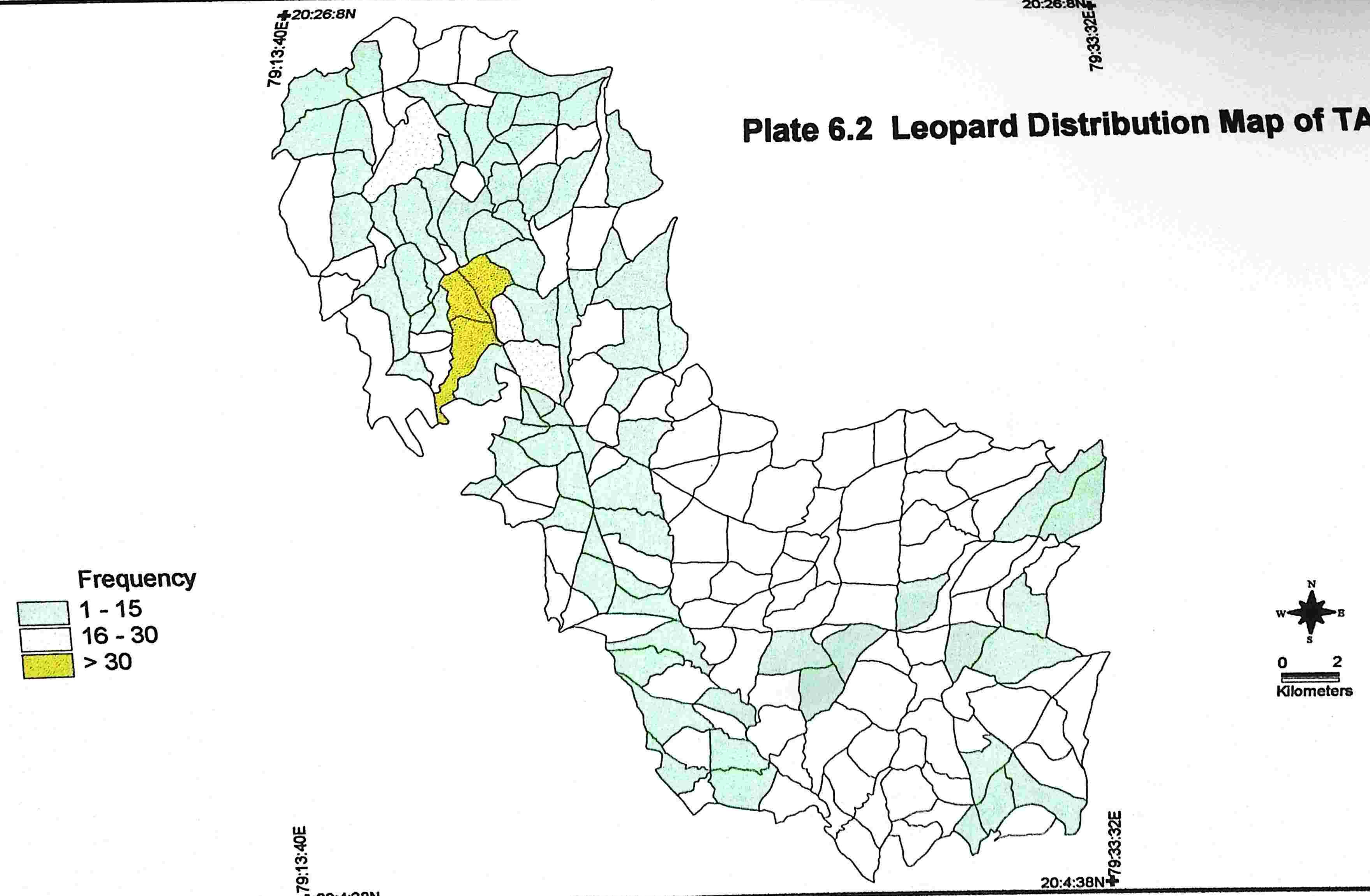


Plate 6.2 Leopard Distribution Map of TATR



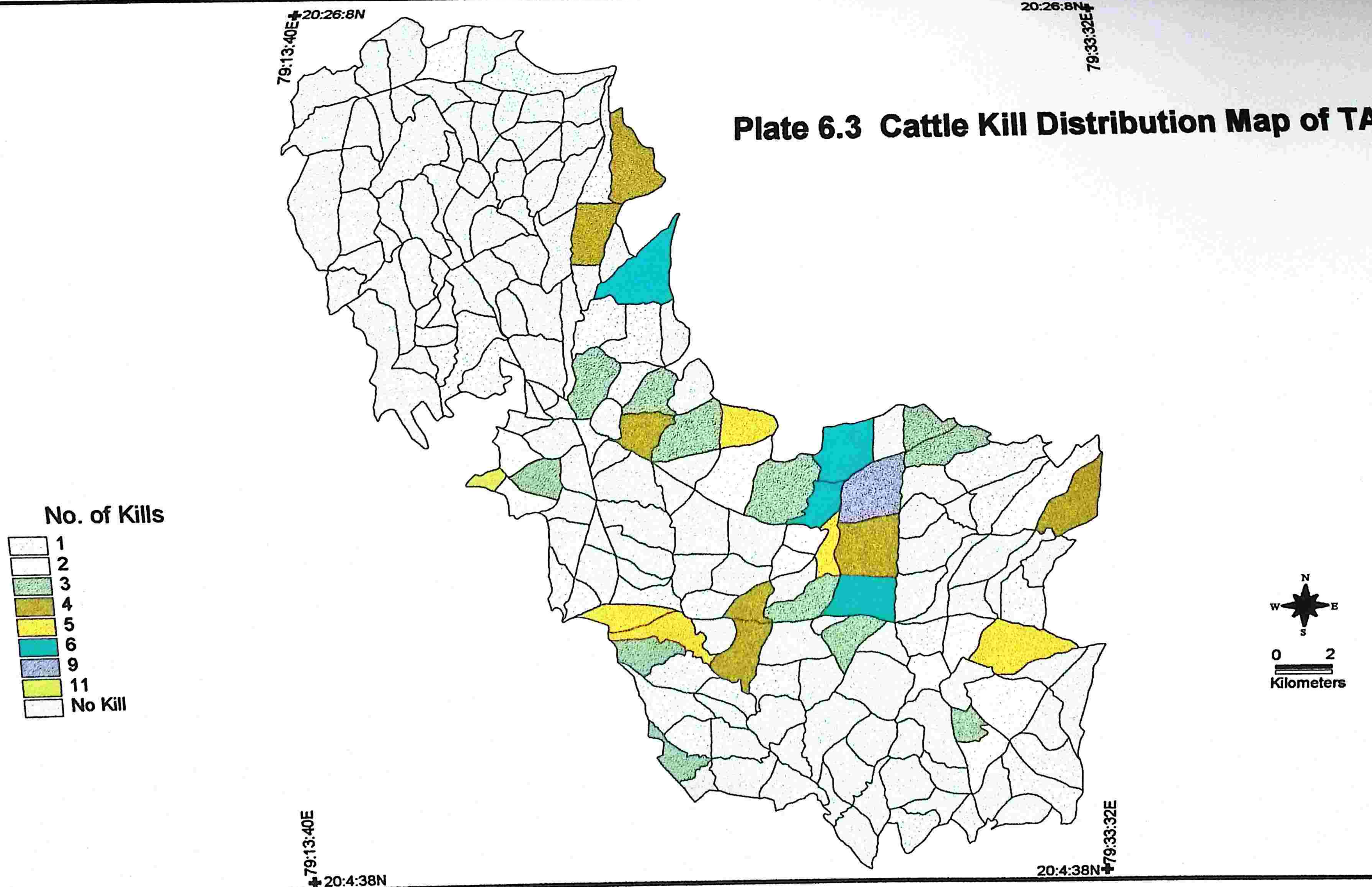


Plate 6.3 Cattle Kill Distribution Map of TATR

attributed again in terms of cover and detection ability as in the absence of major scavengers it becomes difficult to locate kills in winter.

Sambar also revealed similar trend as that shown by chital. More number of kills were made in winter than summer. Cover played a major role in predation of sambar and chital by tiger. As it is evident from Table 6.3, maximum kills of chital and sambar occurred in area with high ambush cover.

Wild pig was third largest contributor to the tigers diet. Maximum wild pig occurrence in scat was in summer. Wild pig remains in wallows for longer time than any other animal in summer. Most of the kills of wild pig were made close to the wallows where animals lie in puddles completely oblivious to the danger of predation.

Similar trend emerged in case of langur. In summers, the langur troops keep themselves close to the water sources. There have been several observations in summer when whole troop would be sitting with their heads tucked inside bamboo culms in riparian habitats so as to avoid heat and remain oblivious of the predator on sprawl. Good ambush cover in habitats like riparian forest and Miscellaneous bamboo forest facilitates tiger predation. In winters, langur troops keep themselves away from dense cover and hence there was little predation observed in winter. Kill data also confirmed to similar trends.

Gaur though a large bodied animal did not contribute much to the tigers diet unlike the results obtained by Karanth & Sunquist, 1995, where Gaur contributed as much as 44.8% in kill data and 17.4% in scat data. Rabinowitz, 1989 in his study in Thailand did not find any evidence of gaur and banteng being preyed upon by tiger. Other studies in central Indian highlands especially kanha Tiger Reserve by Kotwal, 1987 reveal similar results, as obtained from this study. Johnsingh ,1983 in his study in Bandipur did not observe predation on gaur by tiger. From the results of this study it appears that in TATR prey selection is governed not only by body weight of prey but prey detection and predator evasion strategies by prey species might also play an important role. Other reason could be low density of gaur as compared to principal prey species like chital, sambar and wild pig.

6.4.2. Sex ratios of kills

Males are known to be more susceptible to predation. Territorial contest (Estes & Goddard 1967; Kruuk 1970; Schaller 1972), post rut fatigue (Hornocker 1970) are some of the factors which make males more susceptible predation. Data from TATR indicate that chital, sambar and wild pig males are more prone to predation than females. In his study Schaller, 1967 found tigers killing more sambar males (120 males:100 females, population ratio 30:100). A similar trend was observed by Chellam, 1993 in Gir where lions killed more males than females in case of chital and sambar. Gaur being a large body sized animal escaped the skewed predation. Large size bulls escaped predation as it might be difficult for tiger to drag and handle the prey, which is nearly five times its own weight. Karanth & Sunquist, 1995 however reported heavy predation on adult gaur in Nagarhole National park. Curio, 1976 reviewed a series of factors which might explain the vulnerability of certain prey categories to predators. The strong male biased predation in TATR may be explained in light of such factors. For species like sambar and wild pig, the tendency of males towards being more solitary may substantially increase their chance of encountering predators (Karanth & Sunquist, 1995) and decrease their chance of guarded by groups shared vigilance (Taylor, 1976). The absence of male biased predation in gaur may be attributed to very low number of solitary bull. In the case of chital which occur in large groups the spacing behavior of males and their tendency of warding off from herd of and on makes them more prone to predation as observed in gazelles (Fitzgibbon, 1990). Male deer roam widely when they are in rut and in doing so they also increase their probability of encountering predators. The results shown in Table 6.1 clearly show a predation bias highly skewed towards chital, sambar and nilgai males. Summer forms the major rutting season in central India and males become more susceptible to predation.

6.4.3. Weight class of kills

Table 6.2 shows that tiger selected large prey. Weight class 51-100 kg was selected more because of higher availability of chital followed by weight >100 kg which include species like sambar and gaur. Larger species as stated by Mcnab, 1963 mainly depend on energy sources that occur in large food items unless they are capable of killing smaller prey efficiently. Carnivore usually prey upon mammals which are of about their own size and weight (Bourliere, 1963). Preference of prey like sambar and gaur in TATR by tiger can be explained in the light of optimal foraging theory (MacArthur and Pianka, 1966; Schoener, 1971). Tigers in Chitwan killed more sambar than chital predicted on the basis of their availability which suggests that the sambar was selected for against smaller but more abundant chital. Similar trend was observed in the present study.

6.4.4. Livestock predation

Livestock killing are quite common throughout country (Sawarkar, 1986). Livestock depredation data over from 1993 to 1997 was mapped in spatial domain. Cattle kill incidences are common in areas with low prey density and in areas with considerable cattle intrusion (Sawarkar, 1986). TATR does not fall in either of these. The total livestock population of reserve as per census conducted during this study in 1995 was 2066. These figures are quite low as compared to other areas in similar geographic location. Livestock were not represented in tiger scats collected from TATR. Tiger in almost all the instances could not eat anything from the kills. The kill sites are disturbed by the villagers and the tiger is forced to abandon the site. Owing to this reason livestock kills were excluded from kill data also as livestock in real terms did not contribute anything to tigers diet. Quite a few times 4-6 livestock were simultaneously killed by tiger on a single day but none was eaten. Livestock were often killed during summer when water sources frequented by tiger were subjected to high disturbance. Mass killing of livestock on single occasion could be due to that. In doing so the livestock avoid moving to such areas. Cattle kill incidences and field observation in summer in TATR supports this idea.

6.4.5. Carnivore distribution

Evidences of unharmonious coexistence of tiger and leopard have been reported from earlier studies (Schaller, 1967,1972). In areas where both the predators occur, they often partition the habitat spatially and temporally (Seidensticker, 1976). Leopards in such a scenario tend to adapt themselves to a more nocturnal and less terrestrial existence than tigers (Eisenberg & Lockhart, 1972; Muckenhirn & Eisenberg, 1973) and avoid roads and major trails frequented by tiger (Seidensticker, 1976). Leopards in TATR also showed their avoidance in areas of high tiger occurrence. Scant leopard pug marks on roads and trails are also indicative of reduced use. Leopard found respite in areas close to habitation which were not heavily used by tigers. More than two third of the total area was used by tigers.

Chapter 7

UNIQUE HABITATS

7.1. INTRODUCTION

Wildlife habitats are very often identified only with the vegetation communities, but there are some habitats where vegetation association is not obvious. These are called as unique habitats. These habitats are represented by geomorphic features with special functions not provided in plant communities or their successional stages (Thomas 1979). These habitats do not occur as frequently as the vegetative habitats but nonetheless add to the diversity of the environment, which otherwise is largely dominated by plant communities. Little or no attention has generally been paid on these lesser known and lesser occurring habitats, their usefulness in management and their role in enriching the wildlife diversity of the area. These features show a very clumped distribution and are restricted only to certain areas as their formation depends solely on geomorphology of the area.

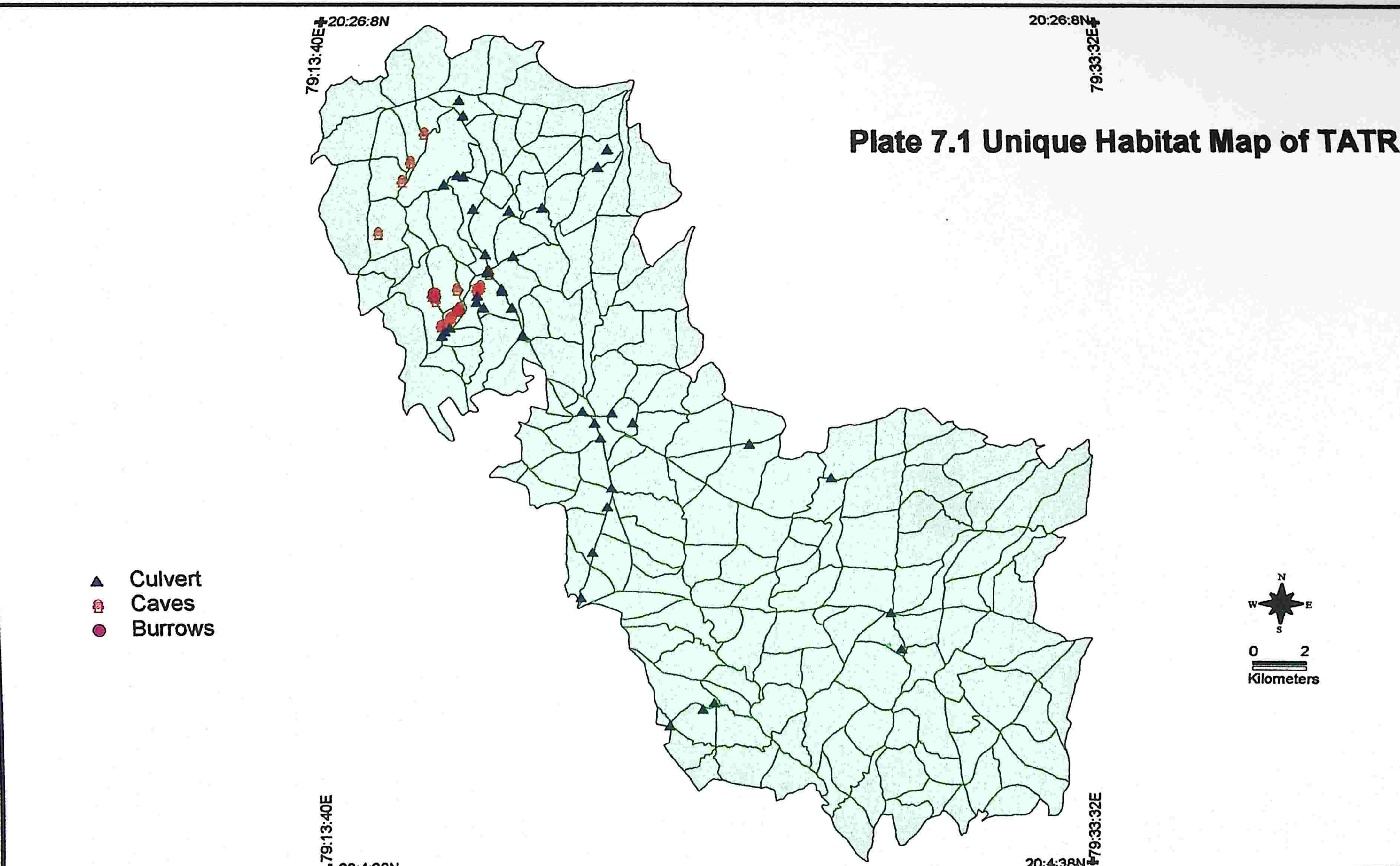
Mainly two kinds of unique habitats were identified in TATR *viz.* Caves and Cliffs. These features have abrupt, relatively stable edges and a predictable air flow pattern (Maser *et al.* 1979). These habitats occupy relatively very small part of the total land base in the reserve but harbour a varied range of wildlife. Another feature, which though man made has also been considered as unique habitat in this study. These are Culverts. Culverts are built on roads where either a nallah or stream crosses the road. Cylindrical pipes are used to create these features. During the initial investigation it was observed that these culverts also offer resting sites for large carnivores. Apart from offering resting sites they also offer disturbance free passage to lesser vertebrates to move from one side of the road to other. Culverts in protected areas and elsewhere have perhaps never been built with the purpose of providing respite to many species and to act as passage through which animals can pass safely. They have been built only to facilitate the flow of water across roads in monsoons and provide accessibility. No attention has so far been paid in India on these structures in their new role. Elsewhere also very little attention has been paid to the use of culverts as wildlife passage or resting sites (Camby & Maizeret, 1985; Hunt *et al*, 1987).

7.2. METHODS

7.2.1. Caves & Cliffs

Caves are defined as natural underground chambers that are open to the surface (Thomas, 1979). The caves may be shallow or deep depending on the geomorphic formation and are mainly found in igneous, metamorphic or sedimentary rock formations. In this study all forest compartments were surveyed for ascertaining presence of caves based on information already existing with Forest guards. New ones were also found during the survey carried out as part of this study. These caves were then marked and later on mapped with the help of Global Positioning System (**GPS**) Unit. Data was collected over a period of one year from these caves on their use by the dependent species, based on direct and indirect evidences. Each cave was sampled once in a month. Scats, pugmarks, footprints were mainly the indicators used in the indirect evidence category. A total of 17 caves were located and mapped (Plate 7.1). On each visit

Plate 7.1 Unique Habitat Map of TATR



temperature was measured inside and outside the cave.

Cliffs were easy to mark from the 1:50,000 S.O.I toposheets. These areas were initially marked on map and later surveyed to check for availability of burrows and talus. These areas are very few in TATR. They were also checked periodically for the presence of any indirect evidences. Data on use of these areas could only be obtained for porcupines and reptiles.

7.2.2. Culverts

There were 42 culverts spread all over TATR. All culverts were sampled twice a month for twelve months during 1995 - 1996. These structures were also mapped using GPS (Plate7.1). On each visit data was gathered on use of culverts by observing animal track signs. After the visit the sand substratum was levelled off so as to erase the previous signs. All culverts were also measured for Culvert Length (CL), Culvert Width (CW), and Culvert Height (CH), which basically helped in calculating openness (ON) using the formula ON = CW X CH/CL (Yanes *et al* 1994). There was some difficulty in differentiating the track signs of lesser vertebrates. So they were grouped into categories *viz.* birds, reptiles, small carnivores, rodents. Large carnivores like tiger, leopard and sloth bear were easy to identify. On each visit temperature was also measured inside and outside the culvert.

7.3. RESULTS

7.3.1. Caves

Evidence from caves showed a high use by bats. Almost all caves visited had big colonies of bats. The highest frequencies were of bats 57.52 % of the total evidences, sloth bear 21.7 %, reptiles 15% and tigers 5.6 %, n = 18.

Tiger use was observed only in months of April, May and June. The highest use of caves by tiger was observed in month of June..Sloth bears were also more or less regular users of caves. Reptiles used caves quite often. Evidence of use was observed in quite a few caves all round the year. Major reptiles using caves were python, lizards, and geckos. Figure. 7.1 shows the use of caves by the tiger, sloth bear, reptiles and bats in different months.

Temperature difference inside and outside the caves makes the cave environment more conducive for animals to use. Summer season showed a high degree of use by animals. Temperature difference inside and outside caves was markedly high (Figure. 7.3).

Talus were distributed only along cliffs and these areas were very small in terms of the total geographical coverage. These areas showed high use by porcupines and reptiles. Among reptiles, geckos and skinks were the most common.

Table 7.1. Percent use of caves by different animals

MONTH	TIGER	SLOTH BEAR	REPTILES	BATS
January	0 %	61 %	38 %	94 %
February	0 %	44 %	33 %	89 %
March	0 %	55 %	22 %	100 %
April	22 %	72 %	27 %	100 %
May	33 %	67 %	27 %	100 %
June	39 %	61 %	39 %	84 %
September	0 %	0 %	0 %	100 %
October	0 %	0 %	17 %	89 %
November	0 %	0 %	22 %	100 %
December	0 %	0 %	22 %	100 %

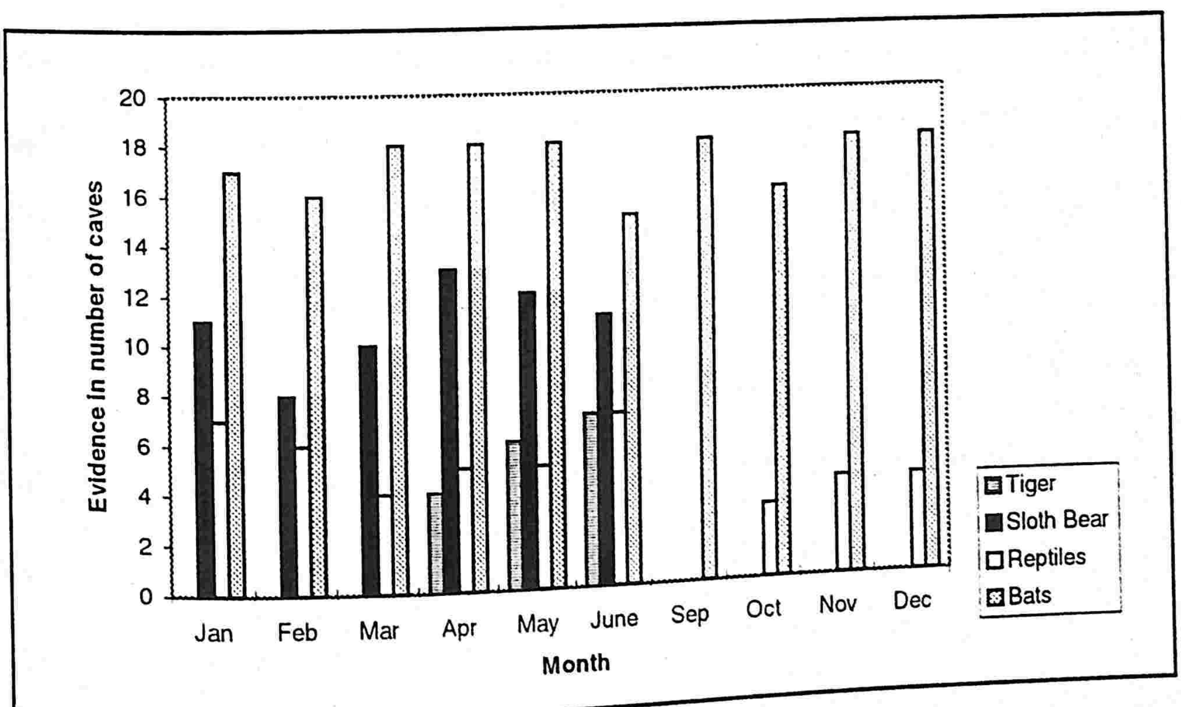


Figure 7.1. Evidences of cave use by different animals

7.3.2. Culverts

Use of culverts was determined by means of the animal tracks and droppings found inside them. In all, 734 tracks were recorded in culverts. The average for all vertebrates pooled together was 2.4 tracks per culvert per observation day. The highest frequencies were of lesser carnivores 32.15 % followed by birds 29.2 %, tigers 19 %, reptiles 10 % and sloth bear 9.4 %, (n = 42). Among the lesser carnivores the prominent ones were the common palm civet, small Indian civet, 3 species of mongoose and lesser cats. Civets and mongoose were the most frequent user in this category. Ground birds like quails, grey jungle fowl, spurfowl and pea fowls used the culverts quite frequently. Reptile crossings through culverts were frequent only in case of lizards with some exception of snakes. There were five direct observations of python crossing through culverts. Among large cats tiger used the culverts almost throughout the year. Tiger showed the highest use in June, 54 % followed by April and May with 50 % and 48 % use respectively. Tiger showed regular use of culvert except for the monsoons. Sloth bear did not use the culverts frequently. Table 7.2 and Figure. 7.2 show the culvert use by different animals. The dimension of the culvert is considered as one of the important factors affecting the permeability for animals (Ulbirch, 1984; Ballon, 1986). In Tadoba the dimension of culverts were fairly large to allow the passage for big animals like tiger and sloth bear. They not only served as passage for the large cat but also provided shelter from high temperatures during summer. This was indicated by the presence of bedding sign. There was one instance in 1995 when a tigress had littered in one culvert and used it almost for three months with two cubs. Culverts were used more in summers by all group of animals (Figure. 7.2).

Temperature difference was considerably high in and outside the culvert which is shown in (Figure. 7.3).

Table 7.2. Percent use of culverts by different animals

MONTH	TIGER	SLOTH BEAR	LESSER CARNIVORES	BIRDS	REPTILES
January	43 %	26 %	43 %	29 %	21 %
February	26 %	19 %	40 %	24 %	17 %
March	45 %	33 %	57 %	76 %	38 %
April	50 %	31 %	64 %	71 %	26 %
May	48 %	21 %	73 %	81 %	21 %
June	54 %	33 %	86 %	81 %	24 %
September	0 %	0 %	24 %	0 %	0 %
October	21 %	0 %	45 %	43 %	12 %
November	29 %	0 %	67 %	50 %	7 %
December	19 %	0 %	62 %	57 %	10 %

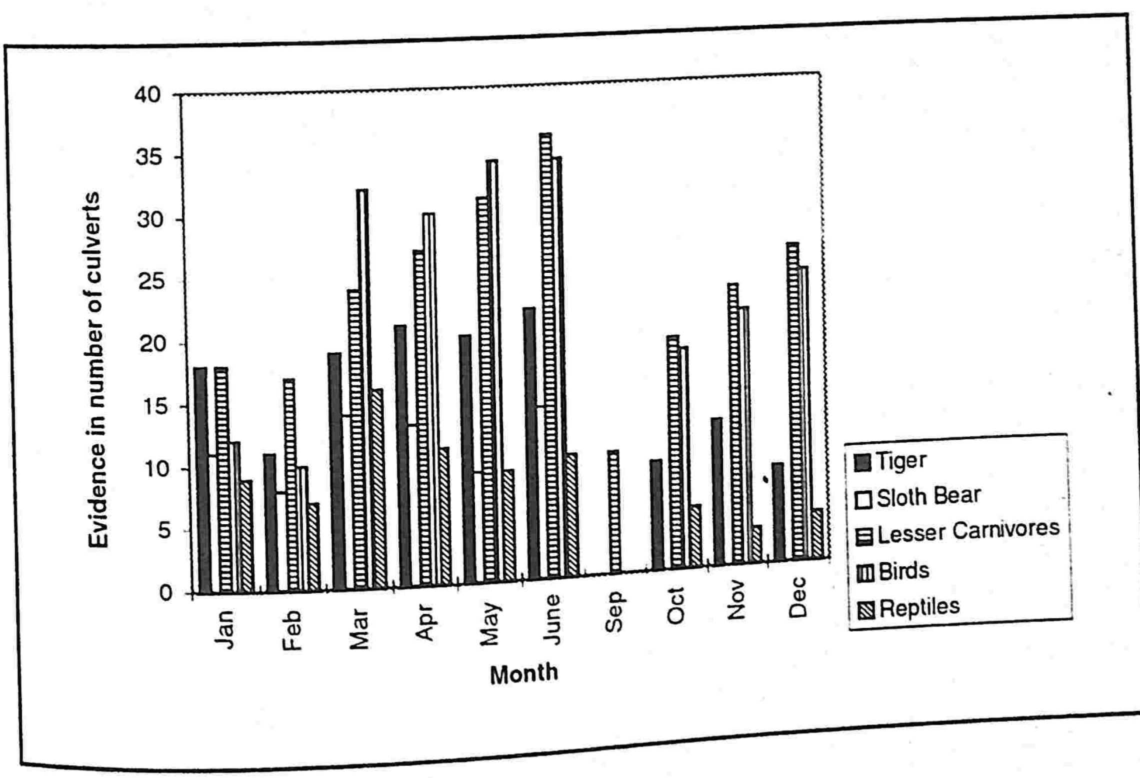


Figure7.2 Evidence of culvert use by different animals in TATR

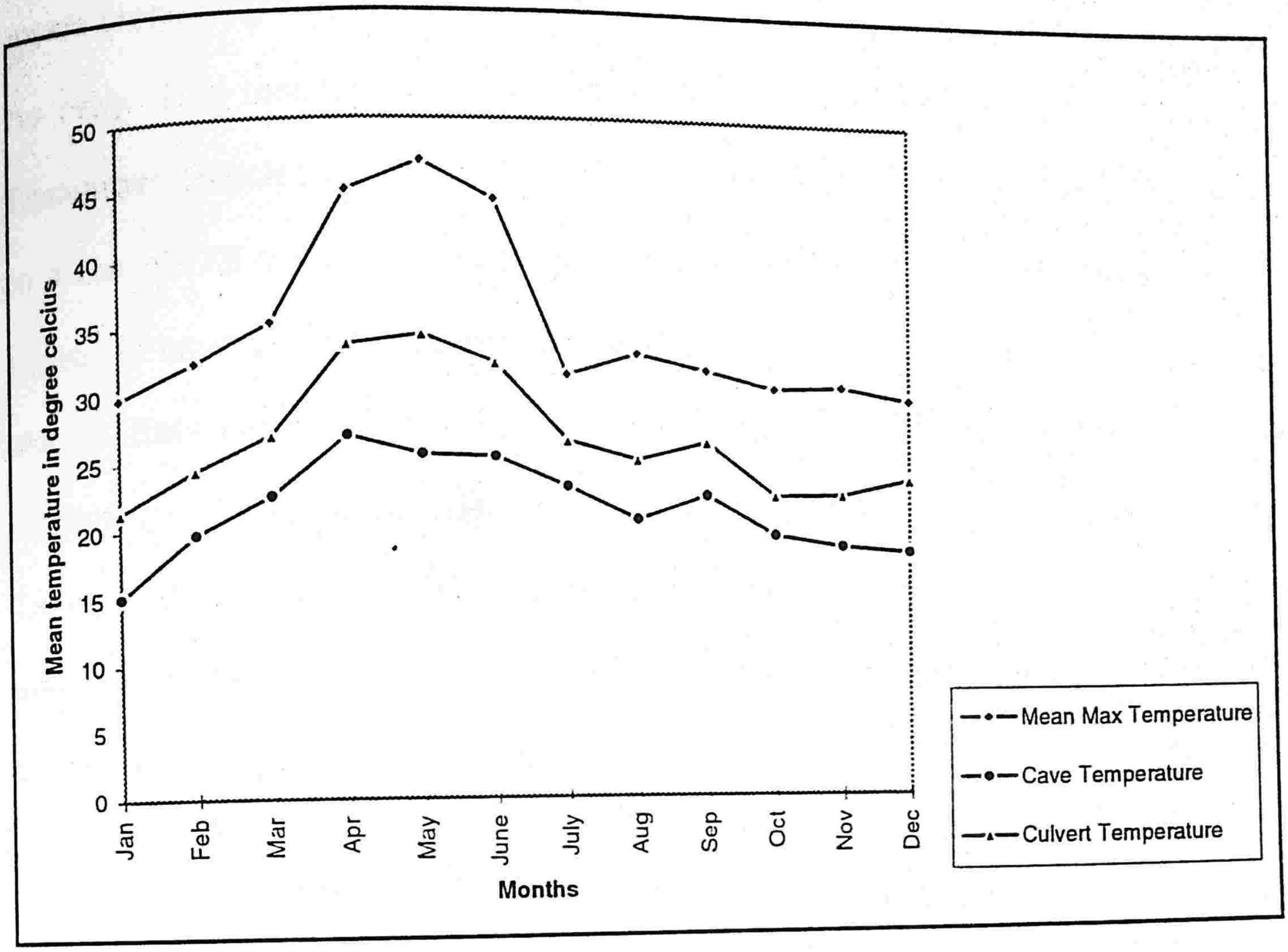


Figure 7.3. Mean temperature outside and inside caves and culverts in TATR

7.4. DISCUSSION

The results suggest that the caves, talus, and culverts are used by a wide range of animal species. Bats and sloth bear were the most frequent user of caves. Huge colonies of bats inside the caves suggest that the environment is suitable for them. Caves in tropical countries are known to fulfil the physiological demands of the adult and young ones besides providing security from predation pressure and for new born. Sensitivity to day light, sociological consideration and morphology are some of the which are fulfilled by caves (Findely 1993). Bats were found as deep as 22m characteristics inside the caves. Sloth bears used the caves most from January to June. In winter, caves were not checked deep inside presuming that the bears might be inside and therefore any intrusion could be risky. This resulted in no data for bears in the months of September to December. Reptiles use was detected almost round the year. Pythons were seen in 4 out of 18 caves. Apart from python several other reptiles were observed using the cave environment like other snakes, lizards, calotes, rock agama and skinks. Bats did not show any seasonal variation in cave use. Likewise for reptiles and sloth bear also there was no marked seasonality in the use of caves. Tiger did show a clear seasonal pattern. The use of caves by tiger was restricted only to summers, when ambient temperature rose high and the large cat needed cool and shady place to rest.

Talus are very important for smaller vertebrates. The highest use of talus was observed for reptiles. In these areas there were lots of burrows also and most of them confirmed use by porcupines through indirect evidences.

Culverts showed a very interesting use pattern by a wide variety of animals. Among large vertebrates tiger and sloth bear emerged as the main users. Tiger used the culverts almost throughout the year with the highest usage in summer. In summers, the culverts were not only used as passage but also as resting sites during high temperature regime of the day. Sloth bears were not as frequent users of culverts as were the tigers possibly because of their habit of being more nocturnal than tiger, and in nights the roads are disturbance free thus unrestricted use is possible. Lesser carnivores were the most frequent users of all the animals observed in the culverts. Use of culverts by lesser carnivores was observed throughout the year. Lesser carnivores also showed a seasonal variation in culvert use. The use was high in summers than during winters

Many ground birds were also the potential users of culverts. For birds like quails and spur fowls culverts offered an excellent passage from one side of the forest to the other which otherwise is restricted by presence of road. Reptile presence in culvert was frequent only in case of geckos and agamas (10 % of the total vertebrate crossing). It is quite evident that the unique habitats provide some important functions outside vegetation cover for wide range of animals and animal groups. Results indicate that structures like caves, talus and culverts offer diversity to the environment which is otherwise dominated by vegetative communities. Though small in amounts, these features constitute important micro habitats.

Chapter 8

FOREST FIRES AND FIRE HAZARD MAPPING

8.1. INTRODUCTION

Forest fires are a major concern in India, especially in the dry zones of the country, because of the environmental losses they cause. They are mainly caused by the local land use practices and other anthropogenically related factors, unlike boreal forest fires of Northern America (Edward, 1992) where lightening is the major cause. Most of the protected areas in the dry zones of the country witness huge fires which are devastating in nature and which degrade the environment and diminish the natural resources. A spreading fire is a complex combustion process in which the flaming front is heating and then igniting unburned woody and herbaceous fuel. In this heating process the moisture in the fuel is first evaporated. Since a fire spreads initially in ground fuel, any determination of spread requires consideration of both the ground fuel layer and the rapidly changing weather conditions through a series of wetting and drying process in the ground fuel layer. Forest fires spread primarily by heat transfer from flaming combustion (Edward, 1992). Periodic information on fire events at both local and national scales are required for the better understanding and documentation of the extent of their occurence in time and space (Flasse & Ceccato, 1996). In a developing country like India this information is not available on a regular basis. The risk of forest fires is a major problem in most of the tropical countries (Maselli *et al* 1996). The presence of a long dry season produces a long period of stress for vegetation, which leads to low moisture content and results in increasing the susceptibility towards high flammability (Chuvieco & Salas, 1996). These fires generally lead to increased concentration of various gases, high aerosol and reduction in evo-transpiration (Matson & Holben, 1987). Burning of forests not only, does environmental damage but also kills most of the ground and middle storey flora which otherwise provides forage as well as shelter for all herbivores. Animals have tendency to avoid those areas which has no re-growth after the fire have occurred. Effects of fire on vegetation and subsequently on large herbivores has been a matter of study (Hopkins, 1965; Philips, 1965; West 1965, 1971; Skovlin, 1971; Rodgers, 1979; Edroma, 1981; Choudhary, 1986; Sawarkar, 1986). It is known that burning stimulates the sprouting of plants even in dry seasons (Vesey-fitz gerald, 1971), which is, however, dependent on the availability of moisture in soil and atmosphere. Fire occurrence and behaviour is influenced by (i) climatological factors *viz.* rainfall, temperature and humidity (ii) physical factors *viz.* topography and (iii) vegetation types.

Operating an effective fire management programme in national parks and sanctuaries requires both financial and manpower resources. It is therefore necessary to prioritise the fire prone areas and then devise fire control measures. Fire prone areas are the points which have a high probability of fire start and possibility of spread of fire to other areas. Prioritising fire prone areas and developing fire danger index involves taking into account a wide range of factors such as weather, fuel and topography (Deeming *et al*, 1978). While dealing with all such variables it is important to be able to integrate them spatially which can be effectively done using Geographical Information System (GIS), where both analytical and geographical relations can be accounted for (Chuvieco & Salas, 1996). GIS has the capability of spatially integrating several variables like vegetation, topography and fire history. Not much GIS based applications have been used in India in analysis of wildfire threat mapping, but in countries like Australia, major studies have been carried out in the last one decade or so. Kessell & Good, 1985; Musto & Stubs, 1985; Bishop & Cutler 1986; Muller 1993 have used GIS concepts to integrate multiple data layers to provide a true insight in fire risk assessment. Vegetation plays a pivotal role in the fire assessment.

Remote sensing has also an important role to play in fire hazard mapping. Satellite data has been used since 1972 to derive land cover information. Apart from this, satellite data has been effectively used to study and monitor the forest fires in India (Abhijit *et al.*, 1996). Forest fire research has a wide and genuine GIS application. Very few studies have been done in India on fire using GIS. The factors which affect the beginning and spread of fire are extremely diverse in nature and hence dictate the use of integrated analysis approach (Chuvieco & Congalton, 1989). Since the phenomenon of fire is intrinsically dynamic, the use of remote sensing also provides an extremely valuable support system in these kind of studies. Remote sensing gives a quick picture of vegetation status and their types and extent. It also give an idea about the extent of area burnt. Any GIS package can only serve as a tool for storing, collating and displaying multiple spatial data layers. Further, it cannot prevent either ignition or spread of fires. However, it has the capability to model the fire risk and its impact thus allowing effective planning. In other words it makes it easier to combine and integrate several variables in a profound and efficient way. Most of the studies on fire hazard mapping do not deal with fire hazard modelling. These studies have mainly focused on the fuel classes derived from remotely sensed data and topographic information which were computed together to generate standard fire hazard rating system (Burgan & Shasby, 1984; Agee & Pickford, 1985; Root *et al*, 1986). In other studies work has been done on deriving source variables (Vegetation, topography and fire history) but attempts have not been made to integrate these variables into a single fire hazard index (Cosentino *et al*, 1981; Yool *et al*, 1985). Brass *et al*, 1998 developed a qualitative model based on spatial layers from vegetation and slope characteristics in four classes (Low, Moderate, High and very High). In this study I have attempted to integrate the spatial data layers in a single fire hazard index, which has been later used to develop the fire hazard map. This study component mainly deals with fire hazard mapping in terms of the fuel availability and does not take into account the fire risk models. Result of this study has improved the knowledge base about areas, which are susceptible to fire in dry season from different causative factors.

8.2. METHODS

A stratified random sampling approach was used to obtain the fuel content value in different, homogenous stands of vegetation, derived from the visual interpretation of IRS-LISS II satellite data. Details of vegetation map prepared have already been discussed in chapter 4. In each vegetation type 20m X 20m (N=225) plots were laid to describe the species composition and community structure. 1m X 1m quadrat were laid in each of these 20m X 20m plot to quantify the surface fuel which chiefly included leaf litter, twigs and broken branches. The total fuel content (fuel load) per unit area (kg/sq.m) was calculated from this. The middle storey fuel was quantified by counting the total number of shrubs in the main 20m X 20m plot and then length, breadth and height was measured for each shrub to obtain the total shrub volume.

All fire incidences were recorded individually and the habitat in which they occured was recorded. Rate of spread (r) is the distance perpendicular to the moving flame front per unit time (Edward, 1992). It is not the increase in perimeter or length of fire (Vaan Wagner, 1965, 1977; Tangren, 1976). Rate of spread of fire is an easily measured variable. On each fire occurrence rate of spread was measured from five different random locations with the help of a stopwatch and measuring tape. One point was marked and then after a minute the point where fire had reached was marked and it was then measured. These five values were later averaged to calculate the Rate of Spread (ROS) for each individual fire incidence for all habitat types in which fire occurred.

The fire history data available with the Forest Development Corporation of Maharashtra (FDCM) was obtained compartment wise with date and area burnt on each fire incidence.

The fire behaviour is mainly influenced by the topography. The effect of elevation, slope and aspect are widely reported in the literature (Brown & Davis, 1973 , Artsybashev, 1983). The digital elevation model was prepared by the weighted average interpolation of the digitised contours lines at an interval of 20 m. The elevation data was derived from SOI 1:50,000 scale toposheets. The slope and aspect were later computed from the DEM. Slope was computed at four different scales *viz.* 0-5°, 5 - 25°, 25 - 45°, > 45°, representing gentle, moderate, steep and very steep.

Firelines are important feature in the area which are cut and maintained every year. This also help in reducing the fire risk. Firelines are generally 20m wide clearings in the forest. Understorey and middle storey is cut every year on these lines in the month of December followed by burning the dry material by the end of first week of February. Firelines were digitised on 1:50,000 scale from the 1": 1 mile map provided by the Maharashtra Forest Department.

Roads, trails and drainage are also important while describing the fire hazard mapping. These physical features were obtained from the 1:50,000 SOI toposheets and digitised using Geographical Resource Analysis Support System (GRASS).

Damage ratings were developed for different vegetation strata using weighted scale method. 239 sample plots of 20m X 20m were randomly selected and marked. These plots were monitored over one fire season i.e from February 1997 to June 1997. Data was collected on the area being subjected to fire or not. Plots falling in burnt category were subjected to ocular estimation for damage in terms of cover loss. Damage ratings were assigned on a four point scale with respect to extent of fire in terms of loss of vegetation cover along the vertical strata. Table 8.1 shows the criteria used for assigning damage ratings.

Table 8.1. Damage rating criteria

Vertical Strata Burnt	Damage Rating Score
SF	1
SF + LMS	2
SF + LMS + MS	3
SF + LMS + MS + US	4

SF= Surface Fuel, LMS= Lower Middle Storey, MS= Middle Storey
US= Upper Storey

Data was also collected on two meteorological parameters namely temperature and rainfall pattern from one meteorological station in the National Park. It was assumed that the average meteorological conditions would more or less remain uniform for the entire area.

8.3. RESULTS

8.3.1. Vegetation

Vegetation structure and characteristics are the key factors in determining the fire intensity and behaviour. They also influence the spread of fire. A vegetation map was developed in GIS domain using IRS-LISS II data. FCC were visually interpreted and 15 categories of land cover were delineated. Both overstorey and understorey are important as they represent the total fuel content available for fire. IRS - LISS II, FCCs were used to derive land cover maps which categorize the vegetation into homogenous stands. The land cover map was treated as fuel map in the context of fire and henceforth referred as fuel map in this unit. The fuel map is shown in Plate 4.1.

8.3.2. Litter

Mean litter weight was highest in grassland on plateau fuel type and lowest in scrub fuel type (Figure 8.1). Mean litter weight was observed to be significantly different amoung different fuel types (K-W X^2 = 37.05 P < 0.05, n=239). Mean litter weight was also found to be significantly different in fuel types across different months (K-W X^2 = 16.64, P < 0.05, n=239) (Figure 8.2).

8.3.3. Bamboo density

Bamboo density was assessed qualitatively in different fuel types on a four point scale which is shown in Table 8.2.

Table 8.2. Bamboo density rating in different fuel types in TATR.

Fuel Type	Bamboo Density Rating
Teak 1	1
Teak 2	2
Teak Bamboo	3
Teak Miscellaneous Bamboo	4
Miscellaneous	1
Miscellaneous Bamboo I	4
Miscellaneous Bamboo II	3
Riparian	1
Meadow	1
Grassland on Plateau	1
Scrub	1
Miscellaneous Open	1

1 = Low, 2 = Moderate, 3 = Moderately high, 4 = High

8.3.4. Human Induced Risk

Human habitations inside TATR are a causative factor for fire occurrence. All human habitations were spatially mapped and using a distance analysis utility, a buffer of 1000 m perimeter was created around these habitations. For this purpose the habitations were marked as point data. Table 8.3 show the criteria for buffering. Fire risk decreases by the increment of 1000m from the village boundaries (Plate 8.2). A buffer of 1 km was also created on the north - western periphery of the reserve which is surrounded by villages (Plate 8.1).

Table. 8.3. Human Induced Risk around habitations

Distance	Risk
< 1000 m	High
1000 - 2000 m	Moderately high
2000 - 3000 m	Moderate
≥ 3000 m	Low

8.3.5. Roads & Firelines

A buffer distance of 100m on either side was established for roads (Plate 8.2). These buffered areas were assumed to be likely areas having high probability of acting as ignition points owing to their accessibility and high human movement. A buffer of 50m was created on either side of fire lines (Plate 8.3) as fire lines are not so frequented as roads.

Plate 8.1 Human Induced Risk Map of TATR

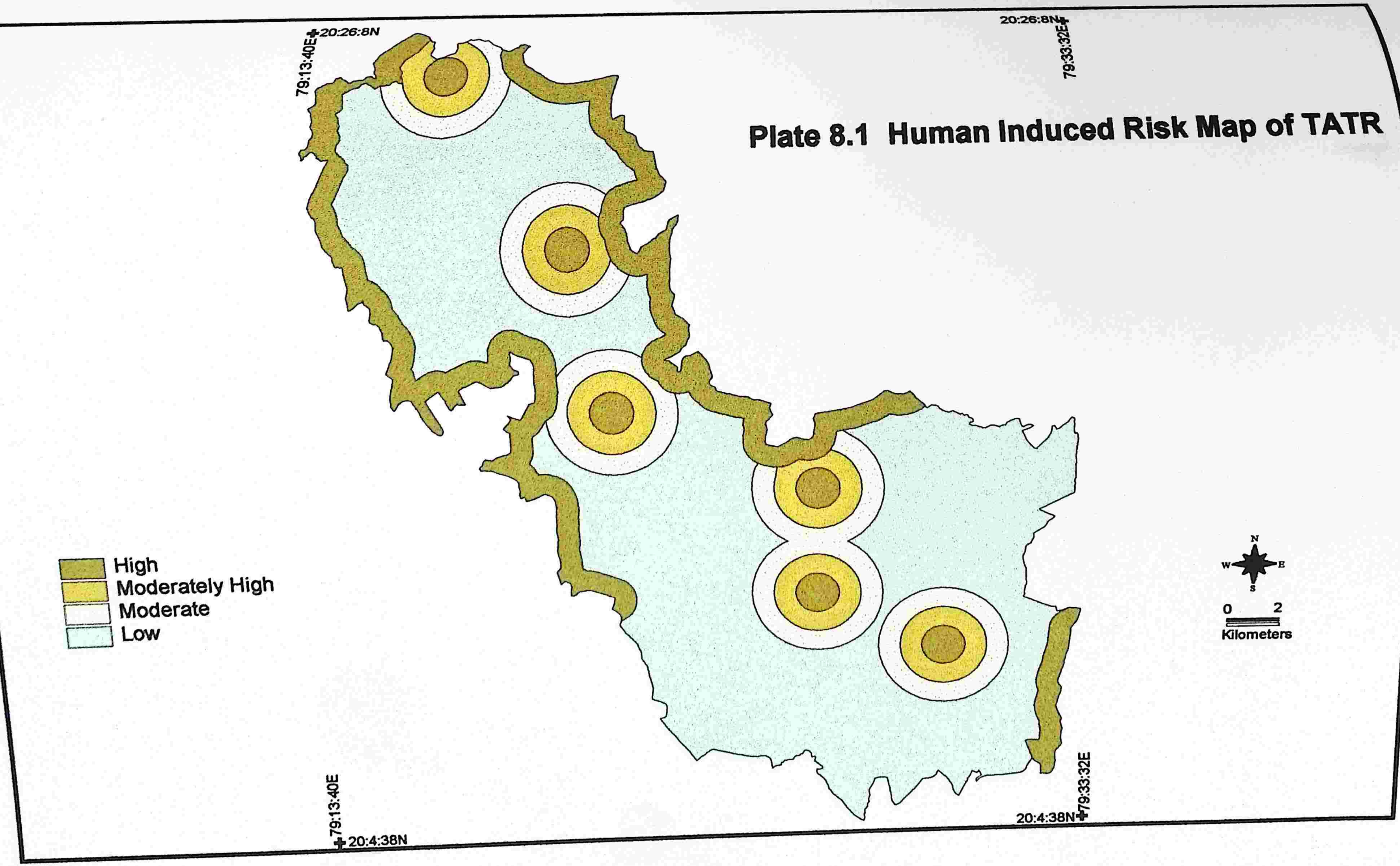


Plate 8.2 Road Induced Risk Map of TATR

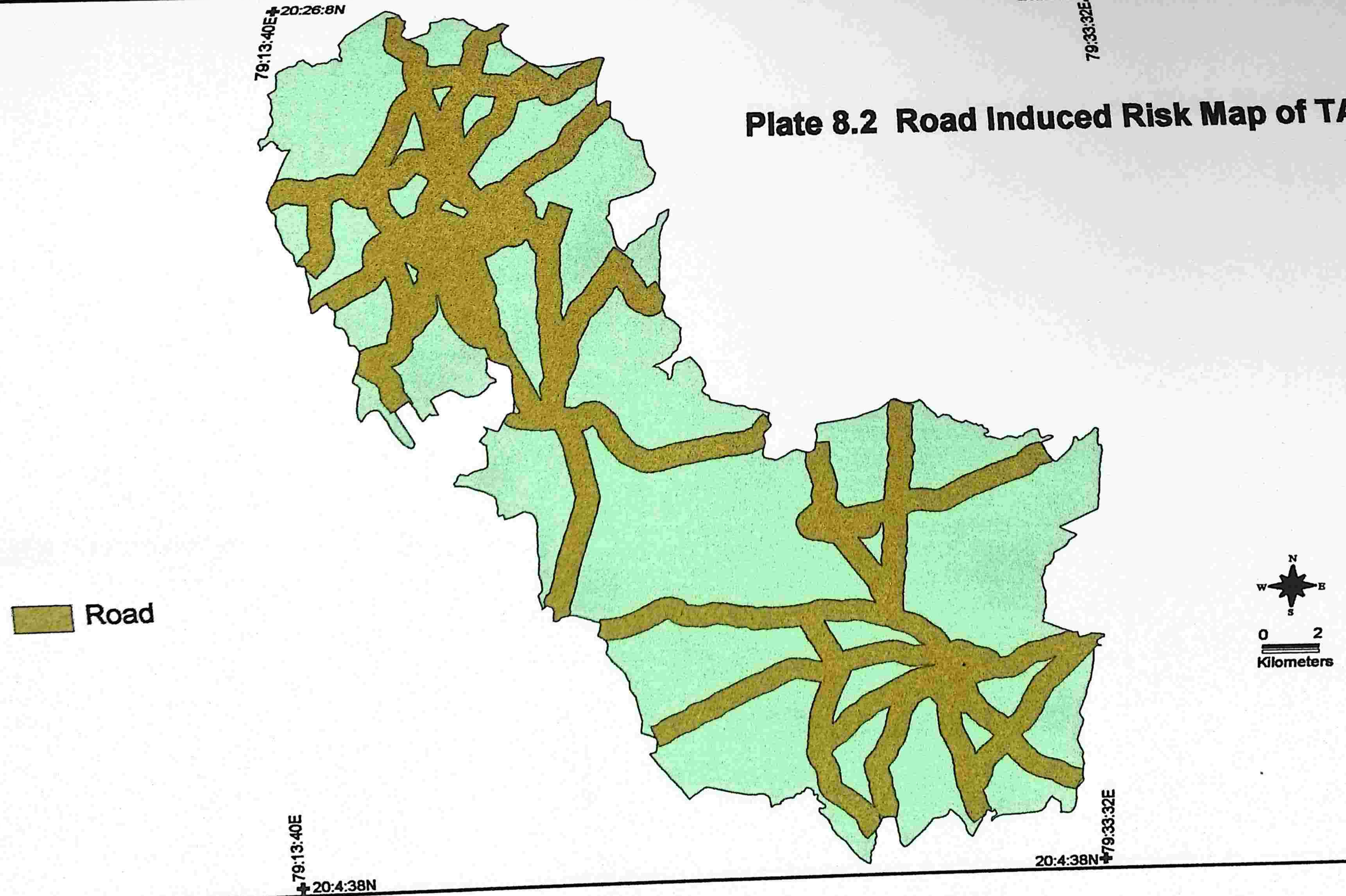
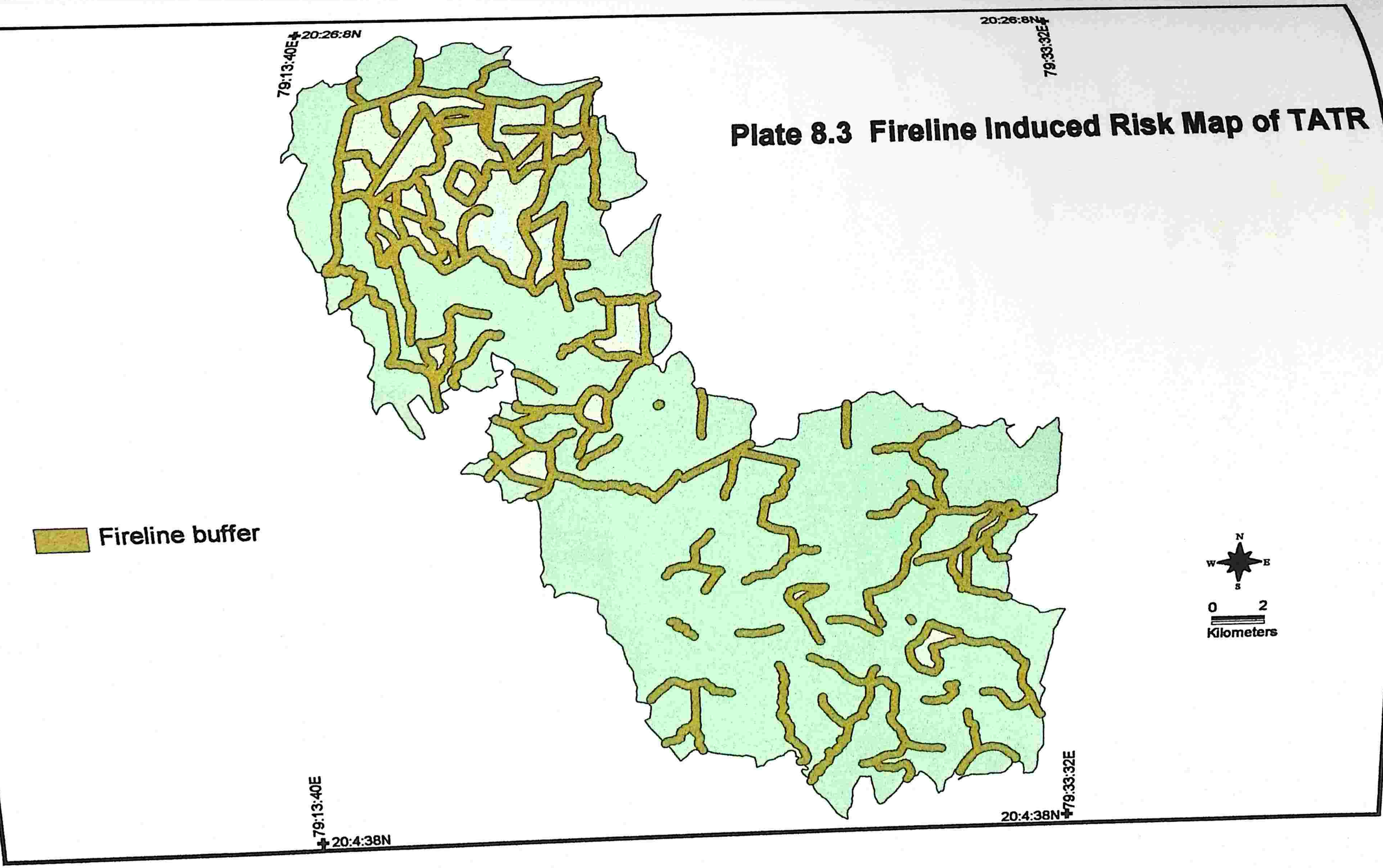


Plate 8.3 Fireline Induced Risk Map of TATR



8.3.6. Rate of Spread (ROS)

Fig.8.3 shows the mean rate of spread of fire in metres/minute in different fuel types. Mean rate of spread was observed to be highest in grassland on plateau followed by meadow and MB I & MB II. It was lowest in riparian and scrub fuel types.

8.3.7. Probability of Ignition (PI)

Based on mean litter load and the number of fire occurrence in different fuel types probability of ignition was established as an index on a ten point scale (Fig. 8.4). Probability of ignition was highest in Grassland on plateau, Meadow, Miscellaneous bamboo I, Miscellaneous bamboo II and Teak Miscellaneous Bamboo fuel types, because of fuel compactness and contiguity.

8.3.8. Slope & Aspect

Slope was computed from digital terrain model (DTM) and later graded in four classes, *viz.* $0^\circ - 5^\circ$, $5^\circ - 20^\circ$, $20^\circ - 45^\circ$, $> 45^\circ$ with low, moderate, moderately high and high fire hazard rating respectively (Plate 8.4). Aspect was also calculated from DTM (Plate 8.5)

8.3.9. Fire history

Data on fire history (Fig. 8.5) gives an account of fire incidences from 1986 - 1994. In 1994 there were a maximum (389) fire incidences while in the year 1987 a minimum (43) fire incidences. Pooled data month wise showed high number of fires occurring in the month of March and April with 460 and 332 fire

Plate 8.4 Slope Map of TATR

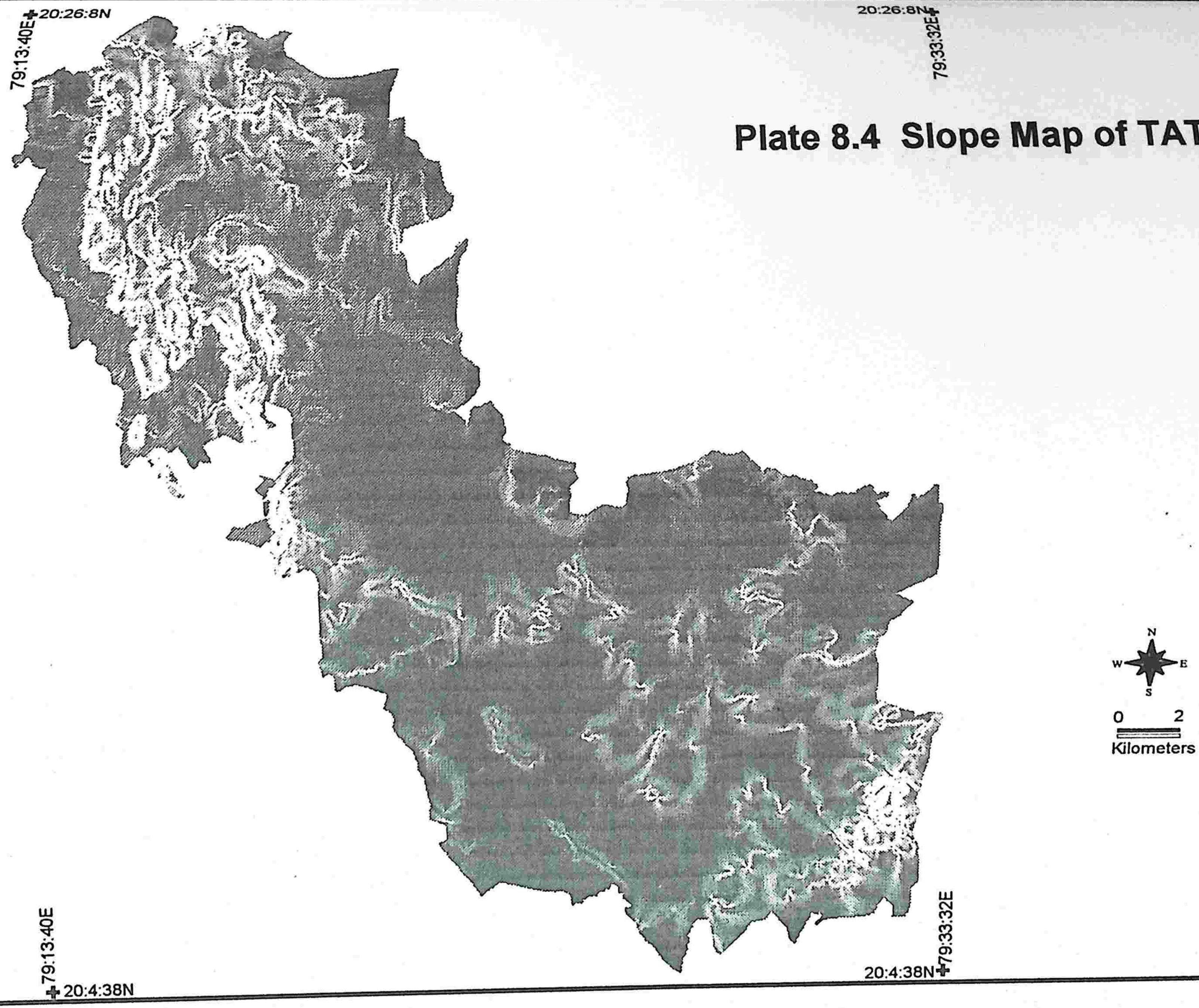


Plate 8.5 Aspect Map of TATR

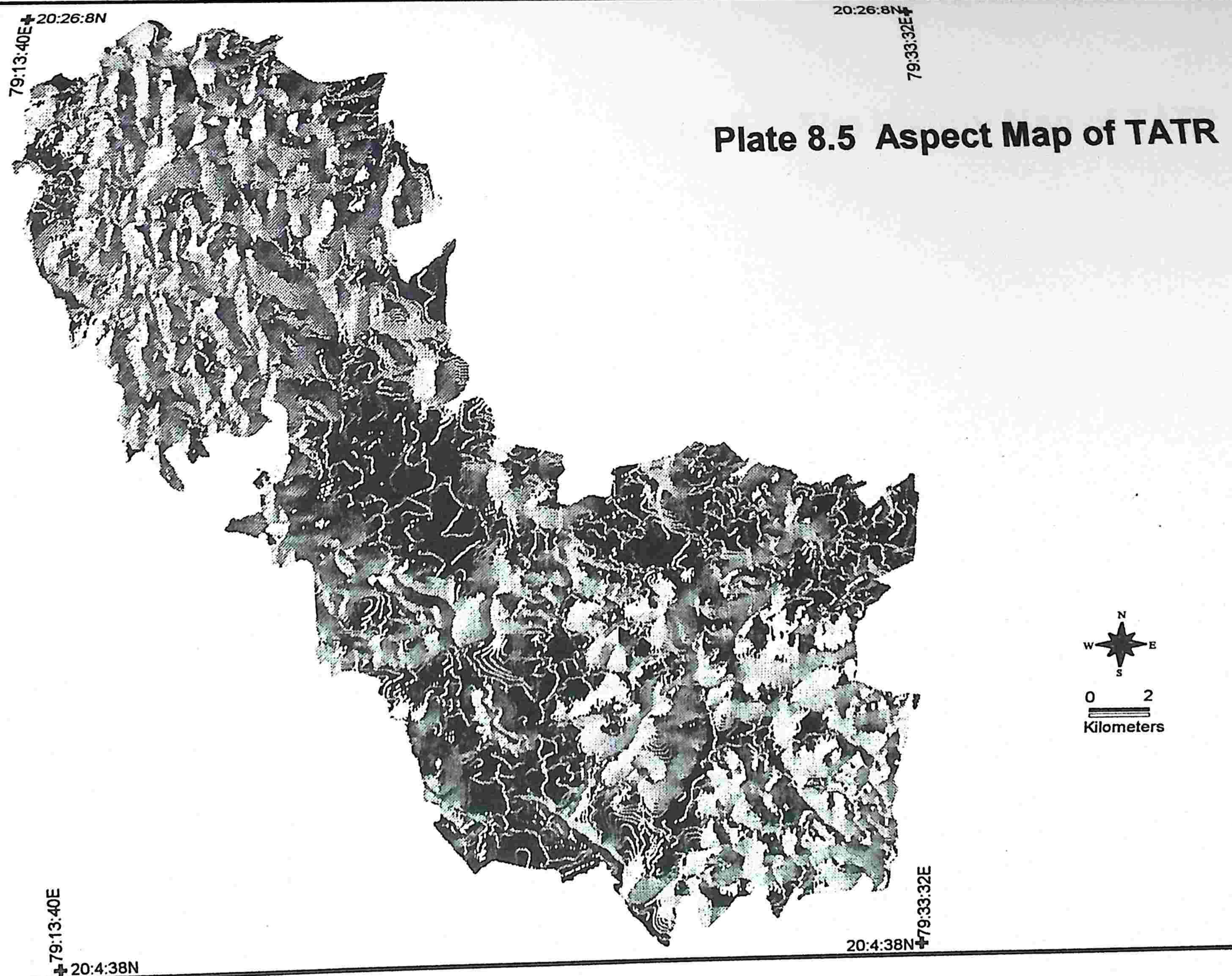
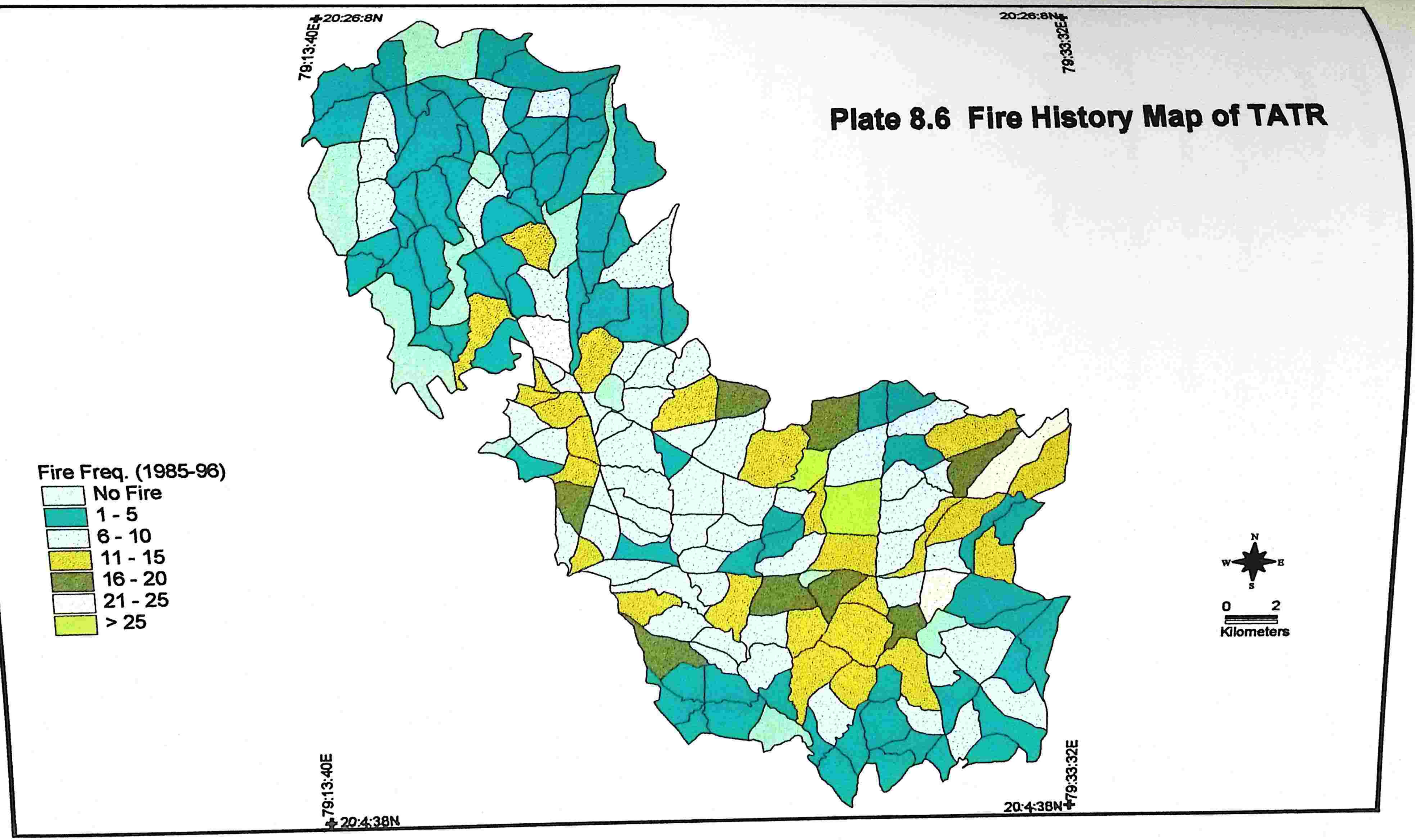


Plate 8.6 Fire History Map of TATR



incidences (Figure. 8.6). Figure. 8.7 and Figure. 8.8 show the area burnt (in ha) in past nine years in different months respectively.

Fire occurrence data was integrated with compartment map layer and a compartment wise fire incidence map was generated (Plate 8.6) showing compartments burnt under different fire occurrence regimes.

8.3.10. Fuel Load Index

Fuel load index was derived using information obtained from mean litter load and bamboo density in different fuel types (Table 8.4). Fuel load was high in Miscellaneous Bamboo I, Miscellaneous Bamboo II and Meadow, followed by Teak Miscellaneous Bamboo and Grassland on Plateau. Fuel load index was spatially integrated with fuel type map layer to derive a fuel load map for TATR (Plate 8.7).

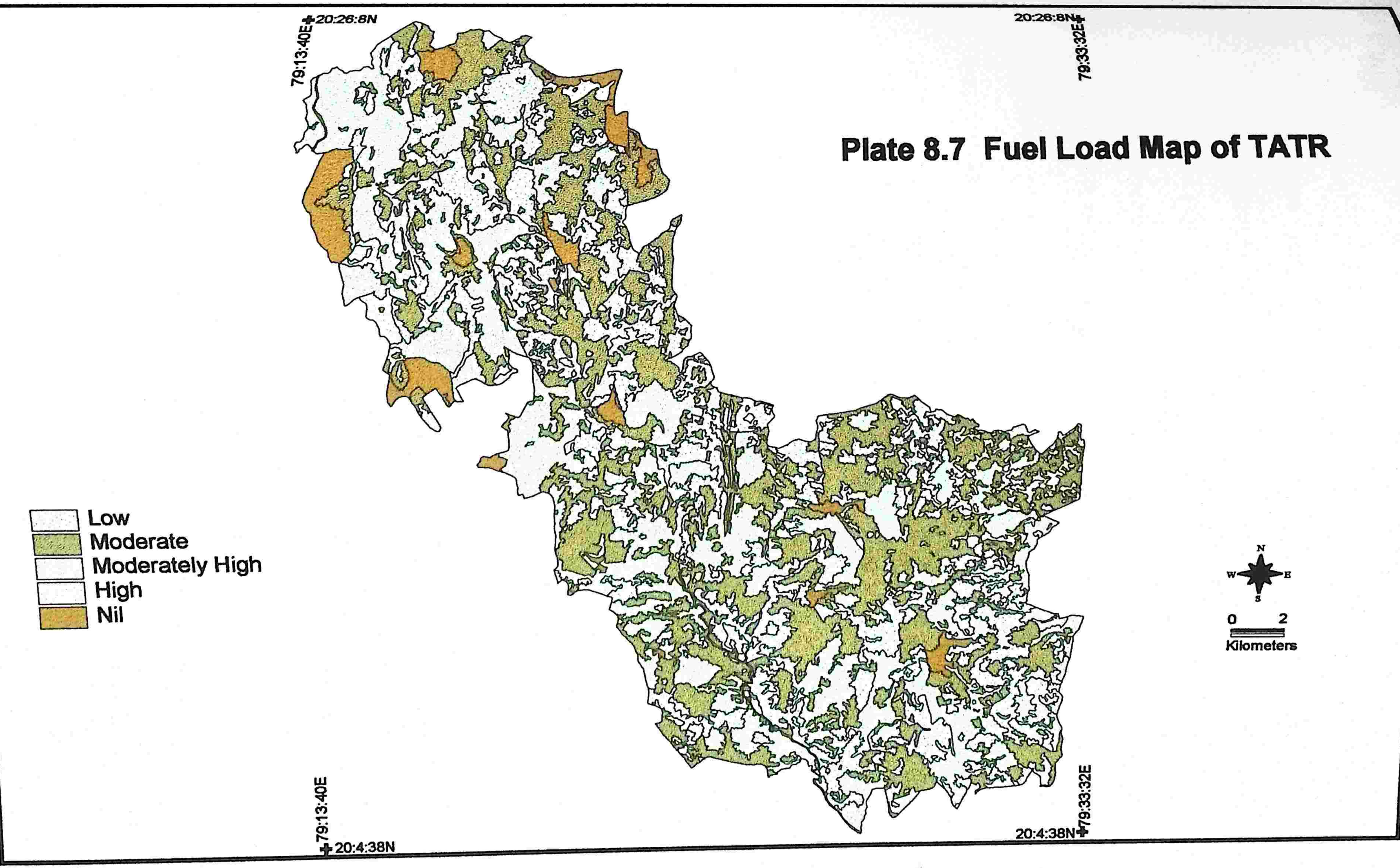
Table 8.4. Fuel load matrix

LOW	MODERATE	MODERATELY HIGH	HIGH	NIL
Misc	T 1	TMB	MB I	Agriculture
Rip	T 2	GP	MB II	Settlement
Scr	TB		Meadow	Water body
Misc.open				

Forest fire risk was established for each fuel type. To summarise the following formula was used:

$$FR= [\ 10\ LL_{I=1-10} + 5\ FF_{J=1-10} + 5\ BD_{K=1-4} + 3\ ROS_{L=1-10} + 3\ PI_{M=1-10}\ ]$$

Plate 8.7 Fuel Load Map of TATR



Where FR= Fire risk

LL= Litter load risk

FF= Fire frequency risk

BD= Bamboo density risk

ROS= Rate of spread risk

PI= Probability of Ignition risk.

Using the FR formula described above fire risk values were obtained for each fuel type, which resulted in establishing fire hazard index (Figure. 8.9). The hazard values were grouped according to their rating into five categories (Table 8.5). Table 8.5 was spatially integrated with the fuel map layer and finally a composite fire hazard map was prepared (plate 8.8).

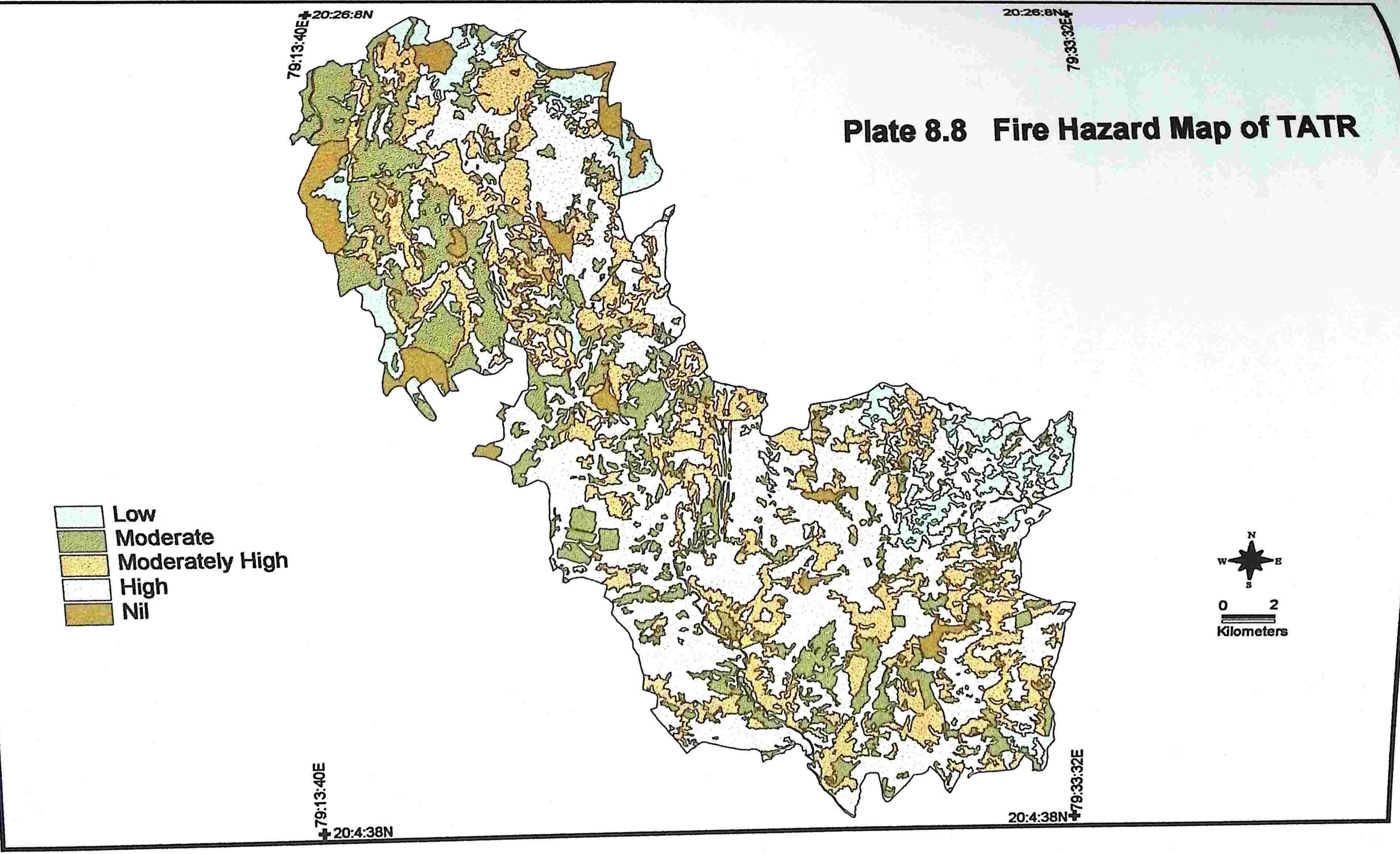
Table 8.5. Fire Hazard Matrix for TATR

LOW	MODERATE	MODERATELY HIGH	HIGH	NIL
T 1	T 2	TB	TMB	Agriculture
Rip	Misc	Meadow	MB I	Settelment
Scr		GP	MB II	Water body
Misc.open				

8.3.11. Damage

Damage ratings were established on a four point scale. All the damage ratings assigned to each fire incidence(based on the criteria described in Table 8.5) in different fuel type were pooled together to reclassify them on a four point scale. Analysis of qualitative data revealed that maximum damage occurred in MB I and MB II with the reclassified rating of 4 followed by TMB with the rating of

Plate 8.8 Fire Hazard Map of TATR



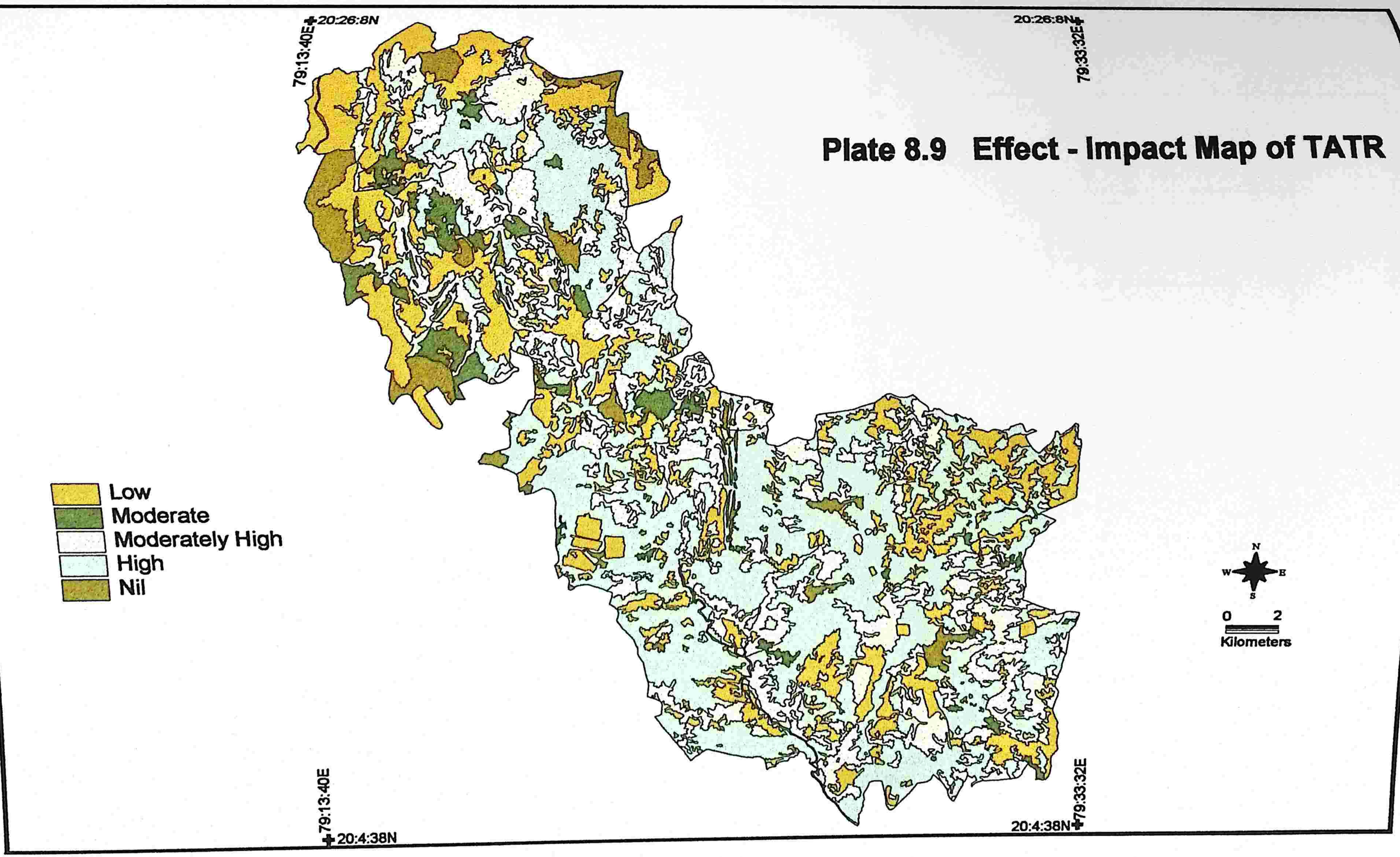
3. Minimum of 0 rating was observed in Riparian and Grassland on plateau fuel types (Fig. 8.9). Overall variation in damage in different fuel types was found to be significant (K-W $X^2 = 26.54$, $P < 0.05$, $n = 239$). Based on the damage rating index an EFFECT - IMPACT MATRIX was formulated (Table 8.6)

Table 8.6. Effect - Impact matrix for TATR

LOW	MODERATE	MODERATELY HIGH	HIGH	NIL
T 1	TB	TMB	MB I	Rip
T 2			MB II	GP
Misc.				Agriculture
Scr				Settlement
Meadow				Water body
Misc.open				

This effect-impact matrix was integrated with the fuel map layer to generate an Effect-impact map showing area affected by fire under different severity regimes (Plate 8.9).

Plate 8.9 Effect - Impact Map of TATR



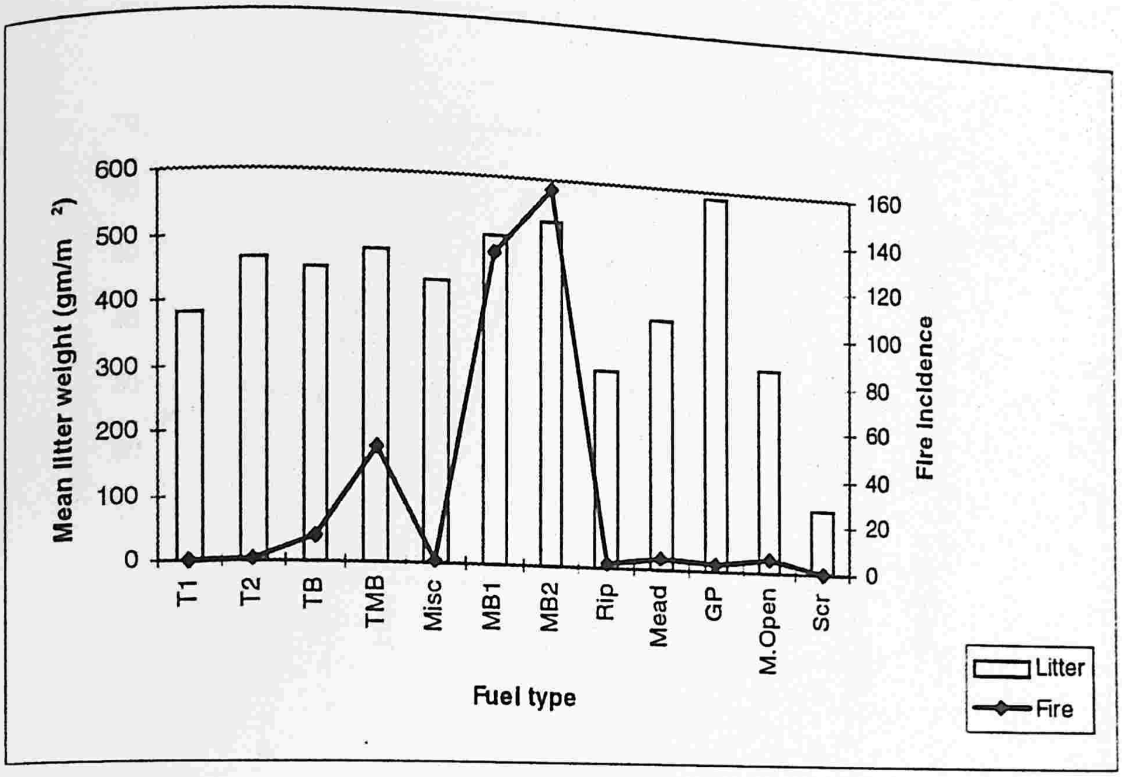


Fig. 8.1. Mean litter weight versus fire incidence in different habitat types in TATR

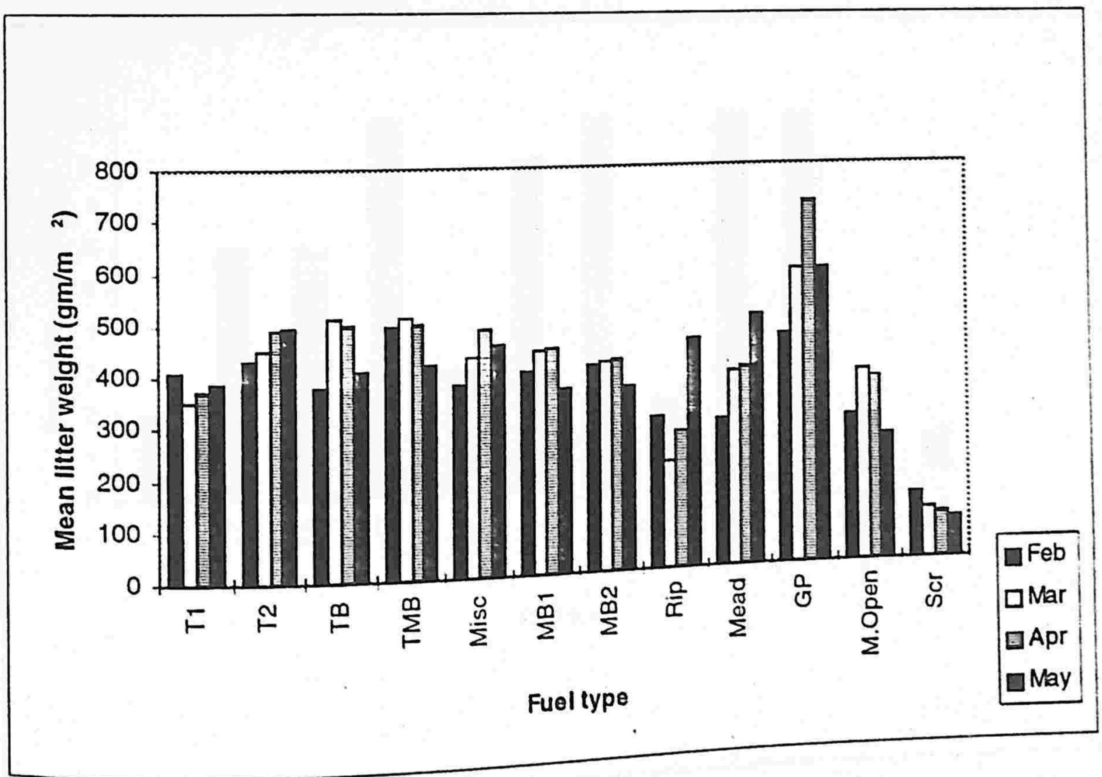


Fig. 8.2. Mean litter weight in different months in different fuel types in TATR

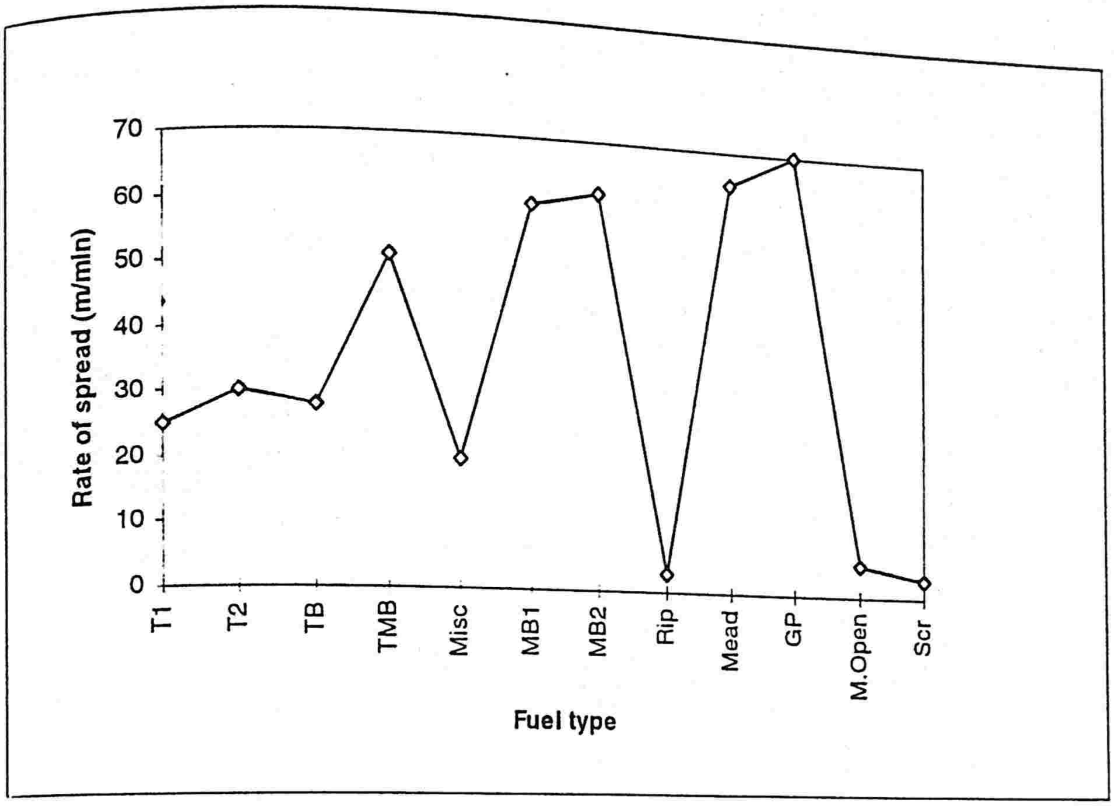


Fig. 8.3. Mean rate of spread of fire in different fuel types in TATR

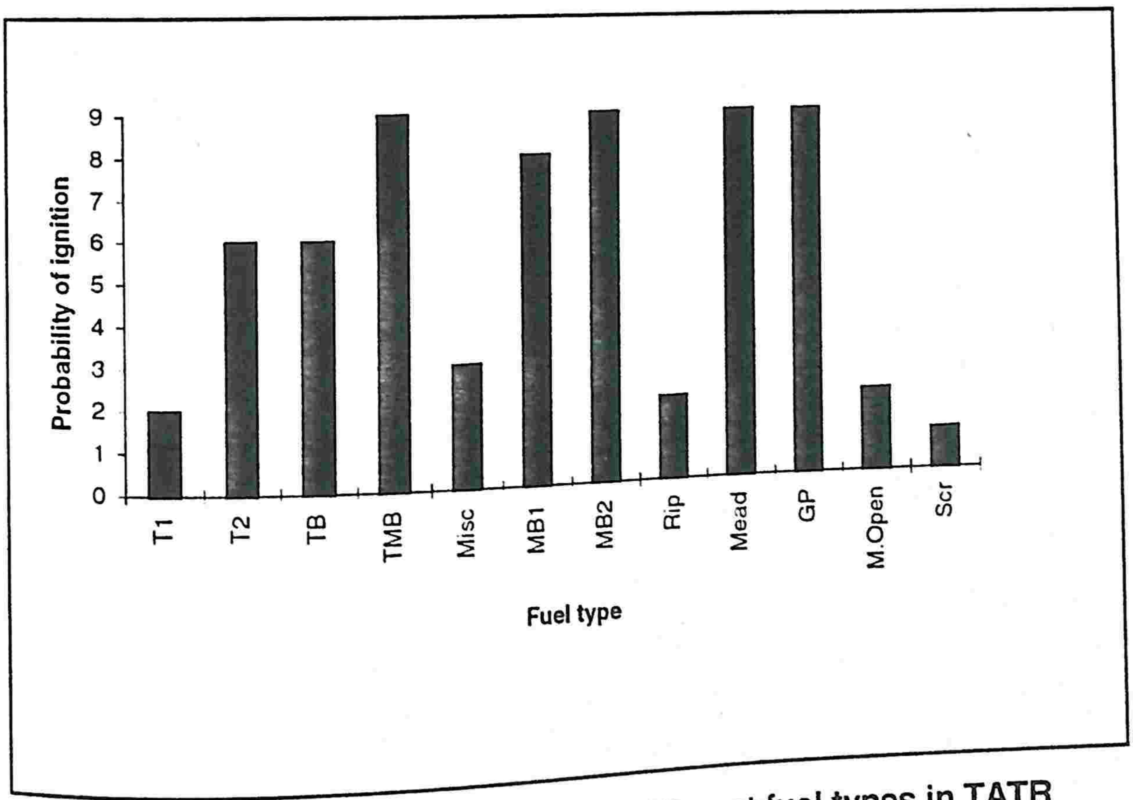


Fig. 8.4. Probability of ignition in different fuel types in TATR

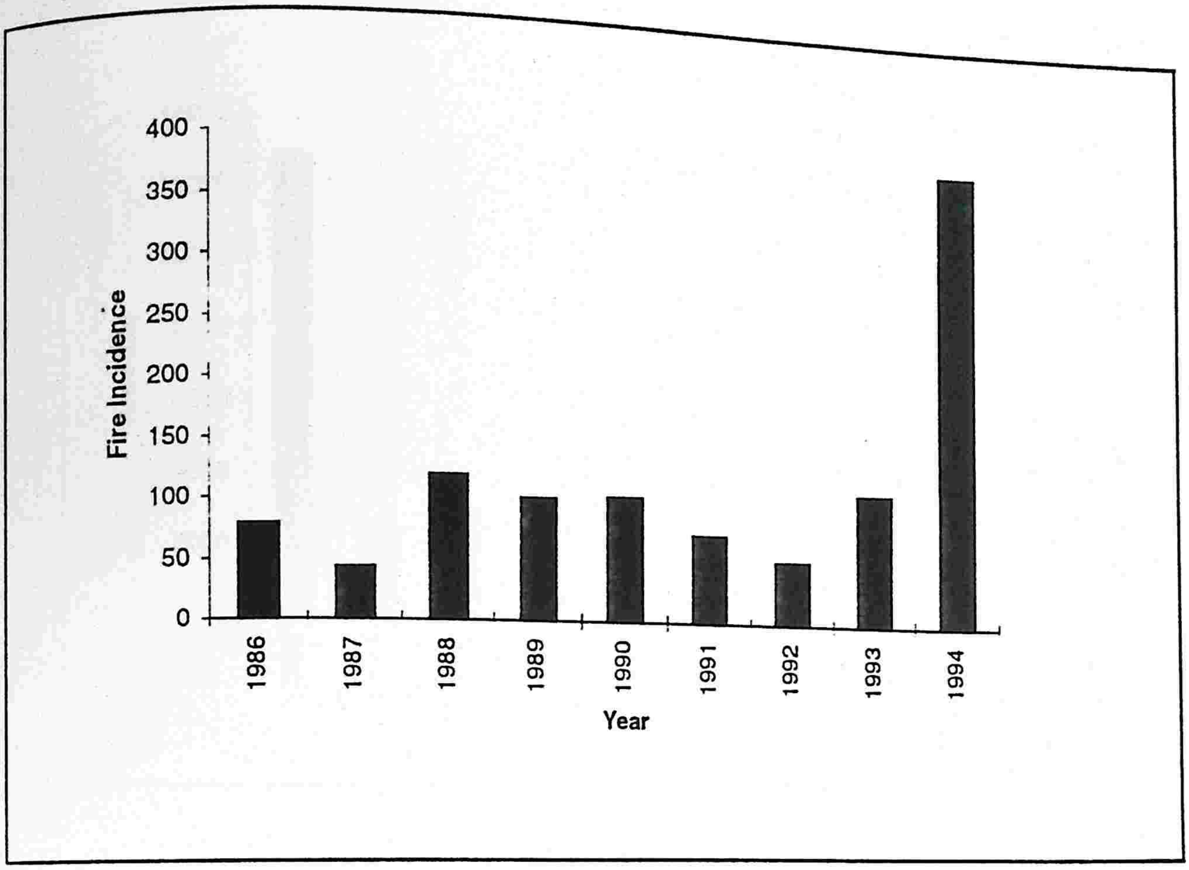


Fig. 8.5. Fire incidence in TATR between 1986 - 1994

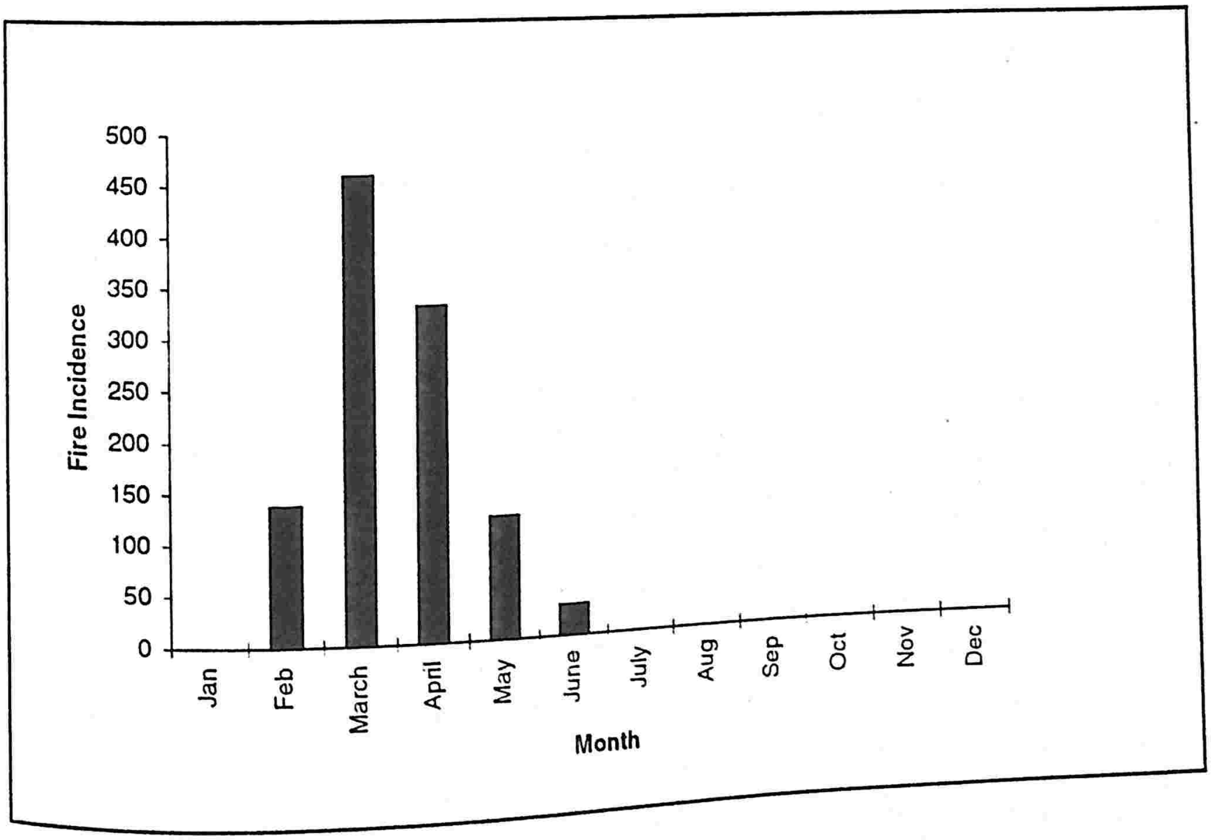


Fig. 8.6. Fire incidence in different months in TATR

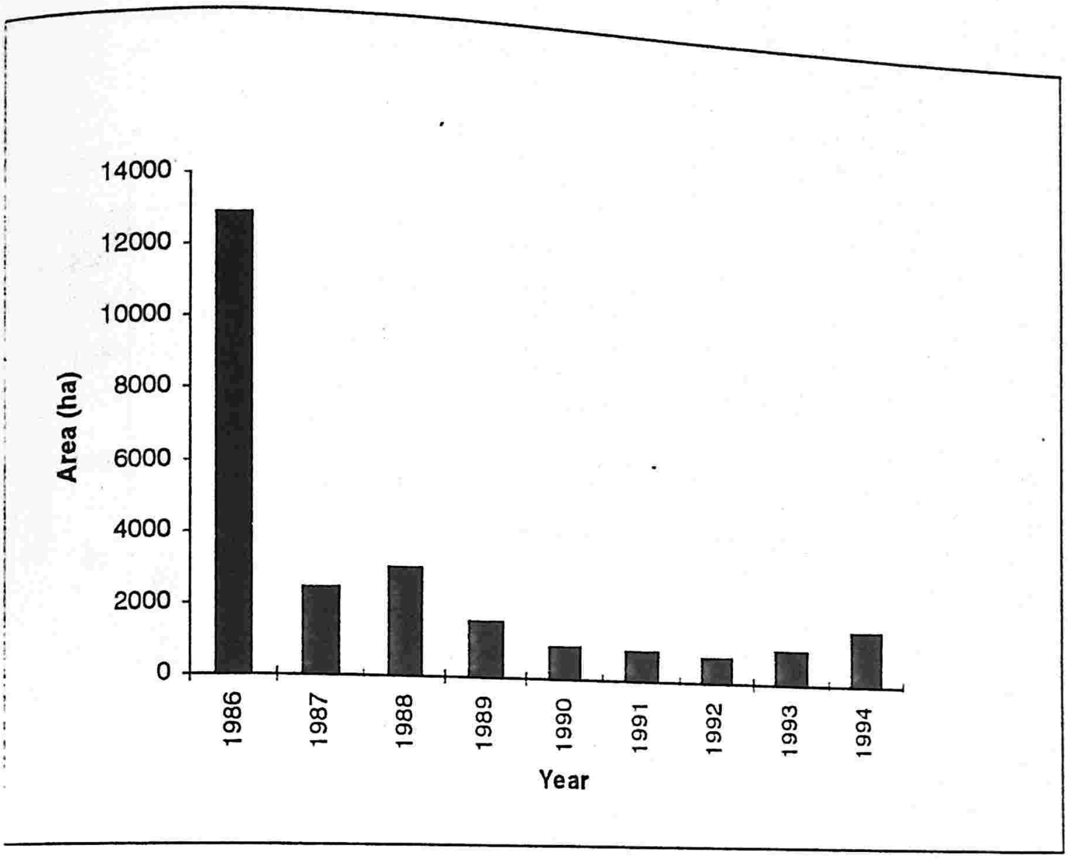


Fig. 8.7. Area burnt from 1986 - 1994 in TATR

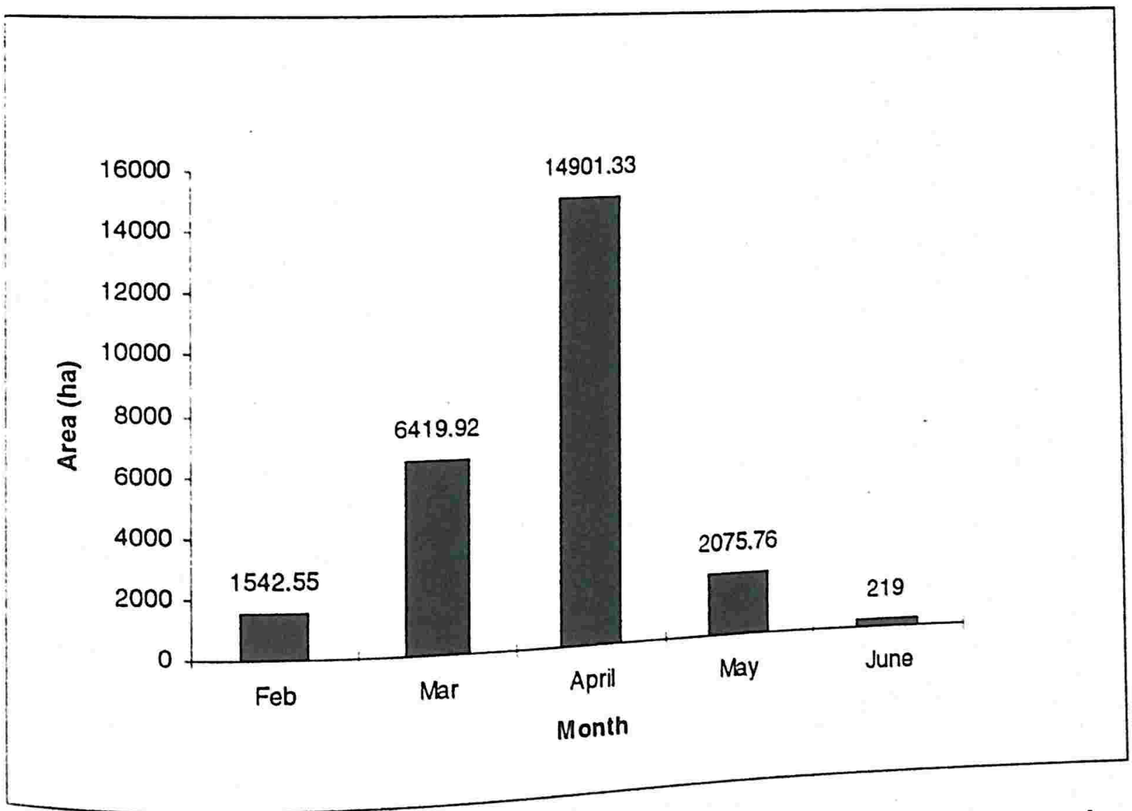


Fig. 8.8. Area burnt in different (cumulative total, 1986-1984) months in TATR

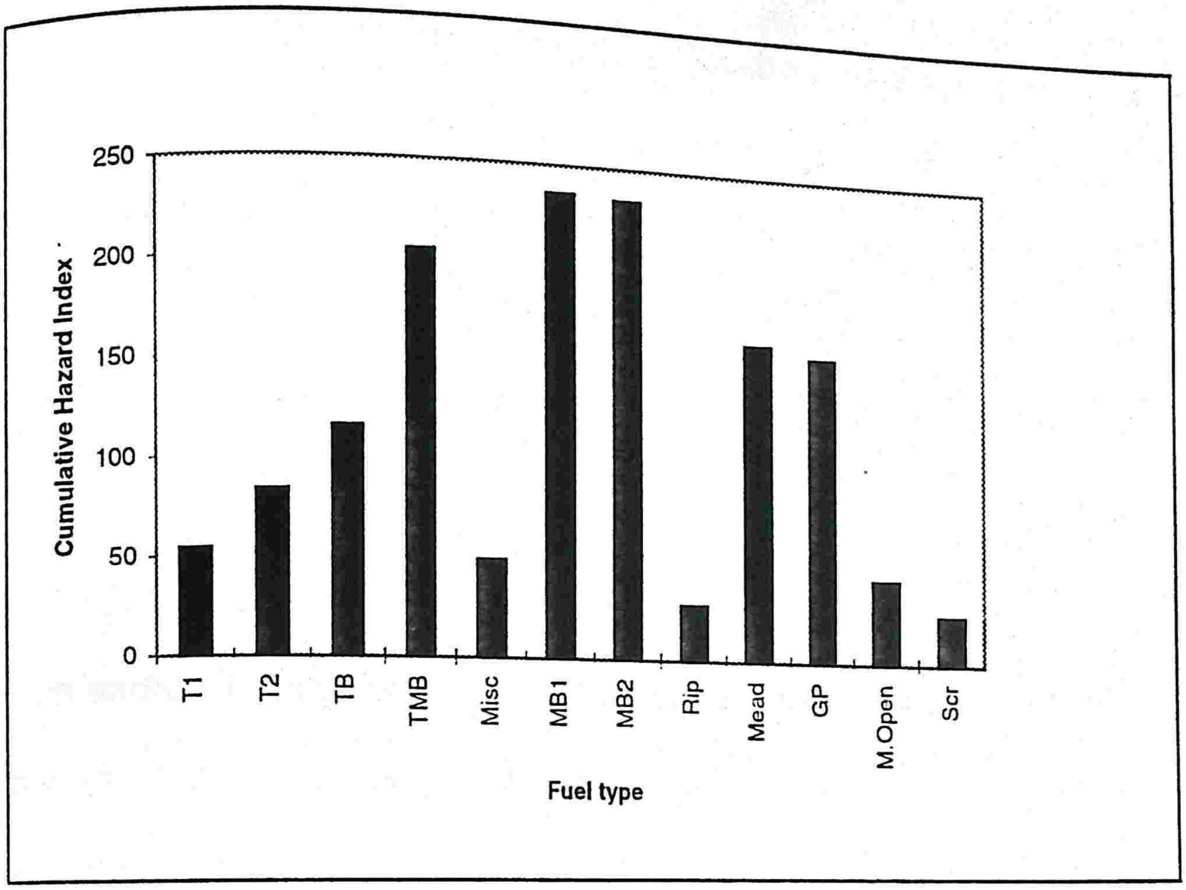


Fig. 8.9. Cumulative fire hazard index for different fuel types in TATR

8.4. DISCUSSION

The integration of the information obtained from remotely sensed data and other sources into a Geographical Information System (GIS) has been done to establish the fire hazard index for TATR and to map the fire prone areas. The effective use of Remote Sensing in studying, monitoring and detecting forest fires has been well established (Matson *et al.* 1984; Miller & Johnston, 1985; Muirhhead & Cracknell, 1985). Most of the remote sensing techniques used have been based on the thermal infrared band (3.55-3.93 µm) and the vegetation indices in order to map the high fire risk prone areas. Utility of Advanced Very High Resolution Radiometer (AVHRR) data has been tested by Miller and

Johnston to assess the critical fire risk period. Disturbance free IRS LISS II data procured for this study gave a good insight and facilitated the delineation of homogenous strands of vegetation. Vegetation forms the basic layer on which most of the analysis is based and furthermore even though the fire environment is favourable, forest fires will not occur if it is not supported by the vegetation types.

The amount of leaf litter present in each fuel types decides the intensity, duration and the length to which fire will move. Mean litter weight was highest in Grassland on Plateau (GP) followed by Miscellaneous bamboo II (MB II), Miscellaneous bamboo I (MB I) and Teak Miscellaneous Bamboo (TMB). Fire incidence when plotted against mean litter weight showed highest fire incidence in MB II, MB I and TMB, though the mean litter weight is highest in GP. The reason for this is the nature of fires i.e. they are all anthropogenic in origin. MB II, MB I and TMB fuel types have high density of *Bassia latifolia* and *Diospyros melanoxylon* and these are two major Minor Forest Produce (MFP) collected by tribal people. Because of thick layer of leaf litter in these fuel types in the month of March, Mahua flower collection becomes difficult as the heavy and juicy flower sink down in leaf litter. To facilitate the collection process the forest floor is subjected to fire and in the process owing to high fuel content value these fuel types witness large number of fires. Similarly, for Tendu leaf collection the areas having high Tendu density are put to fire to enhance the growth of new and fresh leaves. This also explains for the high number of fire incidence in the month of March and April (Figure 8.6).

Bamboo forms the middle storey fuel in most of the fuel types in Tadoba and where ever tree height or the first branching height reduces to as low as 5 to 6 m it also acts as ladder fuel to spread fire to canopy, though canopy fires are not very common in Tadoba. High number of fire incidence in fuel types MB I, MB II and TMB can also be explained in terms of Bamboo density.

Fuel load is the primary factor affecting fire occurrence and probability of ignition. Litter load and bamboo density were collated to generate the fuel load index. High fuel load index in MB I, MB II, and Meadow fuel types are explained by high mean litter load and Bamboo density.

Rate of spread of fire was estimated for each fuel type. Rate of spread is the function of wind velocity, wind direction and the total fuel available to burn. Wind velocity and direction could not be measured due to the dynamic nature of wind. Velocity and direction of wind change as it passes through different fuel types and different terrain features. So for this study average rate of spread was measured on each fire incidence. This rate of spread (r) is in general representative of local climatological conditions.

Probability of ignition (PI) is the chance factor which dictates the probability of a particular patch getting ignited. Probability of ignition (PI) is function of Fuel load and mean fire occurrences in a given fuel type. High PI in GP, Meadow, MB I, MB II and TMB is because of high fuel density, compactness and fuel contiguity.

. Since all fires are anthropogenic in nature and origin so human induced risk can not be neglected. Local land use pattern increases the fire risk in forest patches around the habitations. Factors like agricultural waste burning are the main cause of fires in areas adjoining villages.

Roads and fire lines act both as barrier as well as carrier of fires . They act as breaks for the spreading fire and at the same time since they provide accessibility to people thereby pose a threat of fire initiation .

Fire history of the area gives an insight into the number of times the area has been subjected to fire. Fire history data was collated compartment wise and the results are presented in the form of fire regime map. The fire occurrence maps are very important for devising fire management strategies.

Slope and aspect though do not influence probability of ignition but have a strong influence on fire behaviour, as they affect the rate of spread. The different slope classes were given weigthage according to the sensitivity of the fire spread after the fire ignition took place. Besides influencing fire behaviour it also plays an important role in fire suppression operations by making areas either accessible or inaccessible to the suppression crew.

All these factors were treated independently and all hazards were mapped separately. Vegetation is the most important component of fire risk, hence the final hazard map was prepared for different fuel types using litter load, fire frequency, bamboo density, rate of spread and probability of ignition as the major factors affecting the fire spread and behaviour.

Fire does cause damage to the system. MB I and MB II were damaged most in terms of cover and forage loss. These fuel types are high bamboo density areas and thus are compact and contigous and provide sufficient combustible material and so suffer maximum loss. Fire damages trees by a combination of crown, root and cambial damage. Deciduous trees resist fires better than evergreen trees, because their foliage contains more moisture and fewer organic compounds than the foliage of most evergreen trees. Further, the deciduous trees can grow new leaves every year.

Fire is also known to effect soil by changing the chemical composition. Nitrogen, Phosphorus, Potassium and Calcium can vaporise in severe fires. Fire can damage the soil by burning the humus layer that holds back the runoff. Such damages make erosion more likely.

Repeated fires can even alter the habitat structure in long run. After the fire animals move to other areas which are not affected by fire and in doing so at times animals move outside the protected areas into reserved forests where they are prone to poaching. The smoke released due to fire contains Carbon monoxide, particles of charcoal, ash and hydrocarbons which are lethal for living organisms. Special habitats like snags which are most prone to fires get destroyed completely and this causes habitat loss for those species, which are snag dependent.

An integrated analysis of spatial variables has proven very valuable for forest fire research. Remote sensing provides the source of fuel data , while GIS processing helps to generate fire hazard maps. The factors chosen for hazard mapping are important and are recognized as key variables in fire spread and fire prevention.

Chapter 9

PEOPLE, RESOURCE DEPENDENCY AND UTILIZATION

9.1. INTRODUCTION

Globally, the number of forest dependent people is over 500 million, of which around 200 million are tribal, many of whom reside in south and south east Asia (Lynch 1992). Many of the locally important goods and services in many parts of world are provided by forests. An estimated 1500 species of wild plants are used by local people in the tropics (Roche, 1989) and two thousand million people i.e nearly three quarter of the population of developing countries (FAO/ESCAP, 1983) depend on fuel wood for their daily energy consumption needs.

In India, forestry sector generates a substantial amount of direct employment to people (Dwivedi, 1993). An estimated ninety million cattle graze inside the forests, which is the main source of fodder (Lal, 1986) and an estimated 235 million m^3 of fuel wood is consumed, most of which comes from the forests (Dwivedi, 1993).

With the increasing human and livestock population, the per capita forest area in India declined from about 0.2 hectare in 1951 to 0.11 hectare in 1981 (FSI, 1987). According to Basu, (1987), almost 60 % population living in rural areas and 94 % of 100 million tribal population are completely dependent on forest resources to meet their daily needs and requirements for fuel, fodder, grazing and building material. Removal of woody plants for fuel and timber and high incidence of grazing by livestock has converted about two thirds of the

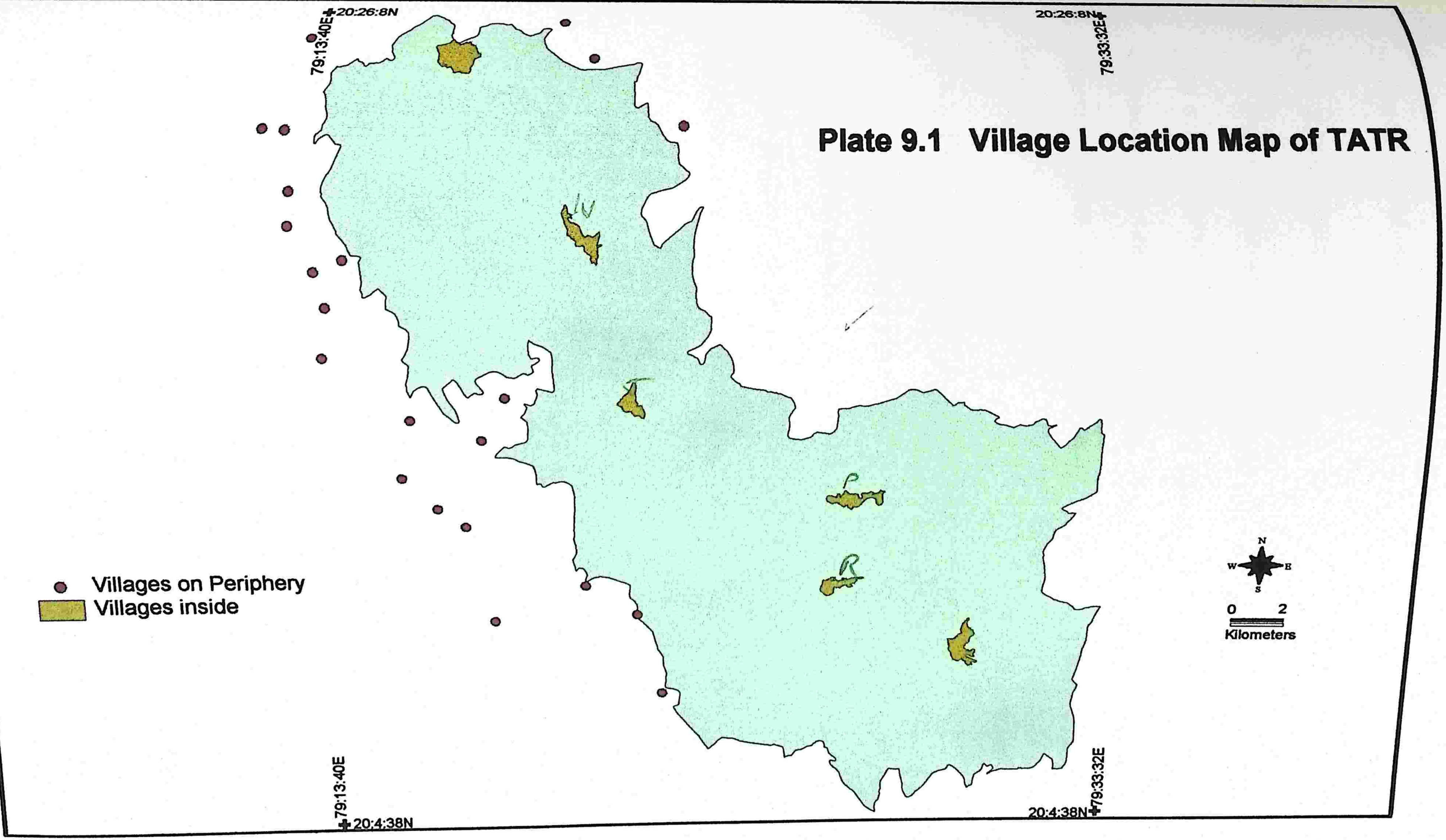
Indian potential productive land not under cultivation or human settlements, into barren lands (Dhaundiyal, 1997).

In a protected area situation it is important to constantly monitor the resource use pattern, to identify and prioritize the pressure areas which can be given additional management inputs to help reduce the biotic pressure. Tadoba Andhari Tiger Reserve has 6 villages inside and about 45 villages within 5 km radius from the periphery of the Reserve (Plate 9.1). The North western boundary of the reserve has a high concentration of villages. These villages are directly or indirectly dependent on the reserve resources for their daily needs. In this study definition of dependency is restricted to include the number of people using forest resources in form of timber, fuel and other forest produce for their personal consumption or sale. Dependence on forests can be of two types- primary and secondary. It is assumed that villages situated in vicinity of forest having primary subsistence or are economically dependent on forest are the primary dependents. Some villages situated at a greater distance from the forest also claim their rights and use forest resources periodically for the collection of firewood or fodder. These are secondary dependent villages. It is therefore important to have a complete update of socio-economic profile of these villages including detailed inventories of villages which lie inside the reserve.

9.2. METHODS

The study was conducted in six villages which lie inside TATR. The main aim of this study was to develop socio-economic profiles of these villages and to quantify their dependency on forest in terms of Minor Forest Produce collection and other resource utilisation patterns. The data for the study was collected from

Plate 9.1 Village Location Map of TATR



primary as well as secondary sources.

9.2.1. Primary Data

Primary data was collected by door to door survey of all the six villages using questionnaire method. The questionnaires were designed to collect data on demography, caste, land use pattern, livestock ownership, income generation patterns, sources of fuel wood and fodder and dependence of house hold on forest.

9.2.1.1. Estimation of dependency of villages

After reconnaissance of the study area six villages lying inside the reserve were selected for detailed socio-economic study and a rapid survey was done in 58 other villages to generate basic information regarding human and livestock population. After reconnaissance it was found that all north western villages, lying within a distance of 5 km from the reserve periphery, were dependent partially on forest. Forest compartments close to the periphery on north western fringe were monitored and qualitative data on biotic pressure was collected.

Villages falling inside TATR were subjected to detailed study. Each of these village was visited and rapport building exercise was carried out by mixing with the locals and becoming acquainted to their culture, customs and by participating in their local functions.

In second phase each of the six villages were visited and data on demography, caste configuration, priorities, land holding and use, income generation patterns, economic status of people, access to essential utility services, Minor forest produce (MFP), livestock ownership was collected directly by interviewing people.

9.2.1.2. Estimation of pressure

For estimating pressure and defining and delineating pressure zones, forest compartments in the Tiger reserve were surveyed while doing routine work and data on the presence of livestock, human, bamboo cutting signs, lopping signs and cattle dung encountered were collected. This data was later grouped and ranked to delineate pressure zones in four categories viz. low, moderate, moderately high, and high. Forest guards were also interviewed simultaneously to obtain information on pressure dispersion pattern.

9.2.2. Secondary Data

Secondary data was collected from Block headquarters, Village heads, Primary health centre and District information office.

9.3. METHOD OF ANALYSIS

The data collected was analysed using Statistical Package for Social Sciences (SPSS/PC+4.0). Attribute data on pattern of fuel wood collection, MFP collection and grazing was analysed in GIS domain using ARC/INFO software.

9.4. RESULTS

9.4.1. Demography

Analysis of data on population profile by comparing it with population in the year 1950 shows that populations have doubled (Figure 9.1). The population details of villages on periphery of the reserve are shown in Table 9.3. Total population of people residing inside the reserve was 2119 in the year 1994-95.

Mean family size was calculated to be 4.29 individuals per family. Male to female ratio was 1:1.01 which is almost near to the ideal sex ratio of 1:1. Demographic analysis was done for six villages which were intensively sampled. The results are given below:

1. Jamni

The total population of the village was 381 individuals. Mean family size was calculated to be 4.01 ± 0.142 individuals per family. The minimum and maximum family size was 1 and 7 individuals per family. Male to female ratio was calculated to be 1:1.01. Mean number of males and females per family were 1.98 ± 0.093 and 2.02 ± 0.122 respectively. 46.98 % of the total population was of people belonging to working age.

2. Nawegaon

This village has a total population of 420 individuals. Mean family size was 5.06 ± 0.24. The minimum and maximum family size observed were 1 and 16 members per family. Male to female ratio was 1: 0.88. Mean number of males and females per family were 2.68 ± 0.16 and 2.37 ± 0.15 respectively. People belonging to working age constituted 49.5 % of the total population.

3. Palasgaon

Total population of this village was 260 people with a mean family size of 4 ± 0.24 members per family. The minimum and maximum family size observed was 1 and 10 members per family respectively. Male to female ratio was 1:1.05. The mean number of males and females per family were 1.95 ± 0.15 and 2.06 ± 0.138. People belonging to working age constituted 55.4 % of the total population.

4. Botejhari

Total population of this village was 211 individuals. Mean family size was observed to be 3.836 ± 0.26 members per family. Minimum and maximum family size observed were 1 and 12 individuals per family. Male to female ratio was calculated to be 1:1.27. The mean number of males and females per family was observed to be 1.69 ± 0.11 and 2.15 ± 0.22 respectively. 56.39 % of the total population constituted the working age group.

5. Rantalodhi

Total population of the village was 383 individuals. Mean family size was calculated to be 4.03 ± 0.15 individuals per family. The minimum and maximum family size observed were 1 and 8 respectively. Male to female ratio was 1:0.89. The mean number of males and females per family were calculated to be 2.126 ± 0.11 and 1.9 ± 0.1 respectively. 53 % of the total population constituted the working age group.

6. Kolsa

Kolsa was the biggest of the six villages with a total population of 469 people and 100 house holds. The mean family size was calculated to be 4.69 ± 0.19 individuals per family. The minimum and maximum family size observed were 1 and 10 individuals per family respectively. Male to female ratio was 1:1.08. Mean number of males and females per family were 2.25 ± 0.12 and 2.43 ± 0.13 respectively. 50.53 % of total population constituted people belonging to working age group.

The overall population profile of all six sample villages for the year 1995 was compared with the census figures of the year 1950. Sample villages Rantalodhi and Jamni showed a increase of 227 % and 161 % respectively. Botejhari showed the lowest increase of 36.12 %. Nawegaon, Palasgaon and Kolsa revealed the population increase of 85 %, 69 % and 57 % respectively. The comparative population figures for the year 1950 and 1995 of all six sample villages are given in Fig. 9.1. Total population of sample villages in the year 1995 was 2119. Overall mean family size was calculated to be 4.29 people per family. Human density in forest came to 3.46 people per sq.km.

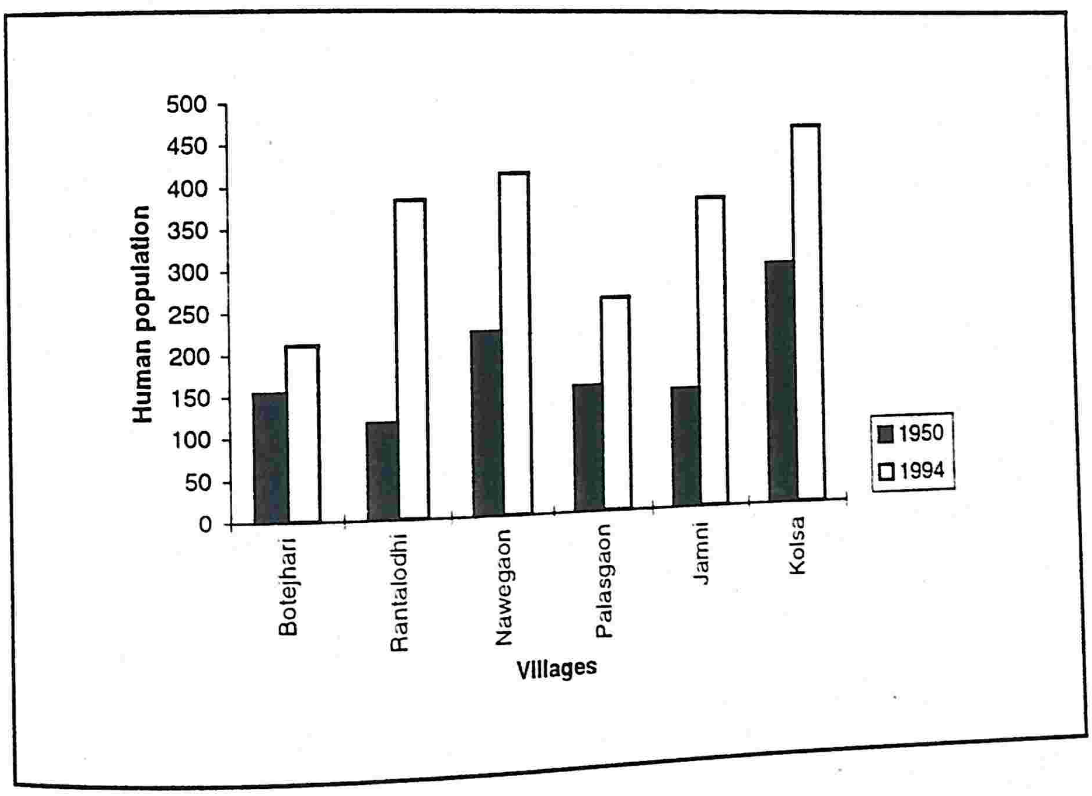


Figure 9.1. Population profile of sample villages

9.4.2. Literacy rate

The literacy rate was lower in Kolsa village (7.67 %) and Botejhari (8.05 %). Nawegaon and Palasgaon showed higher literacy rate of 17.14 % and 14.6

% respectively. Jamni and Rantalodhi had 11.28 % and 9.39 % literacy rate. The overall literacy rate was calculated to be 11.35 % (Figure 9.2). The highest educational standards were for village Nawegaon where 3 % of the literate population had studied beyond high school while the lowest rates were for Kolsa where only 0.25 % of literate population studied beyond high school. Other four villages also had a very low proportion of literate people.

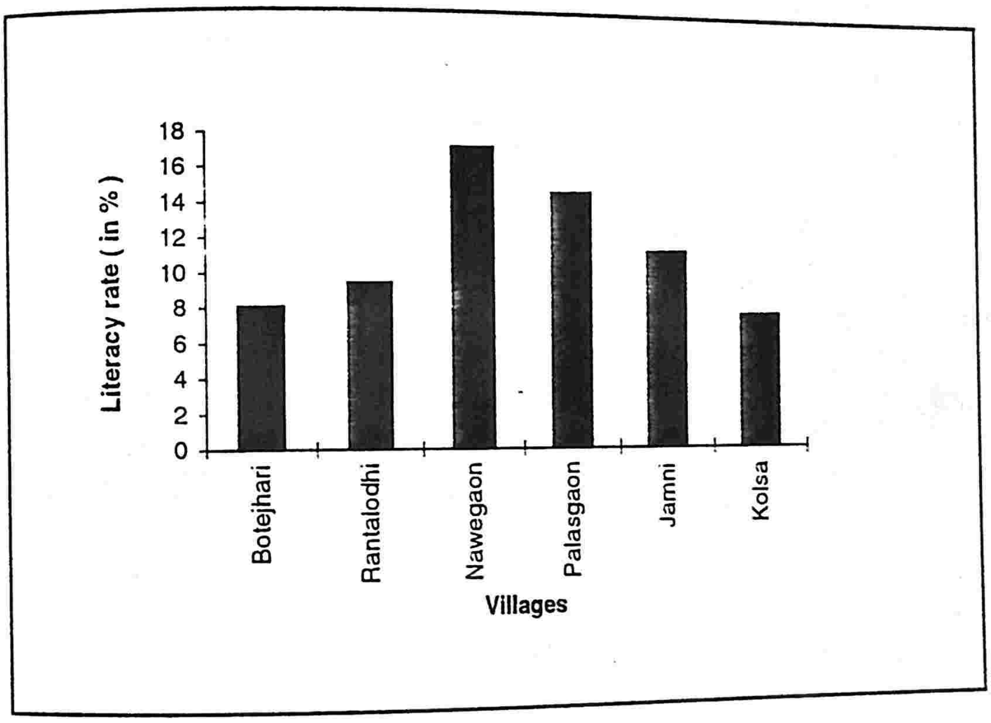


Figure 9.2. Literacy rate of sample villages

9.4.3. Caste configuration

The caste configuration of the area is not very complex. The area is primarily dominated by Gonds who constitute 66% of the total population. 17% of the total population are Manas and rest 17% includes other castes. Overall 11 castes were identified from the study area. Their percent proportion in each village is presented in Table 9.1. Castes other than Gonds and Manas are the ones who have immigrated over last few years to these villages. This sect of the population is completely dependent on forest resources for their day to day needs.

9.4.4. Occupational pattern

Agriculture formed the major occupation of the people in Kolsa, Nawegaon and Palasgaon (67%, 64.9% and 61.5% respectively), while in Botejhari 61.8% supplemented agriculture with labour works either in somebody else's field or with the forest department. Though agriculture formed the major occupation still percentage of people involved in labour works was also very high. Kolsa, Botejahri and Palasgaon showed highest number of people working as labours (93%, 92.7% and 87.7% respectively). Rantalodhi, Nawegaon and Jamni also had large proportion of people dependent on labour works (79.2%, 79.5% and 76.8% respectively). The people involved in service formed a very low proportion of total population ranging from a minimum of 6.2% (Rantalodhi) to a maximum of 11% (Kolsa) (Fig. 9.3). The occupation pattern changes dynamically over a period of time since it is dependent on cropping pattern and the total crop yield.

Table 9.1. Caste configuration matrix of villages inside the Tiger reserve.

Tribe	VILLAGES					
	Jamni	Nawegaon	Palasgaon	Botejhari	Rantalodhi	Kolsa
Gond	68.42	0	83.07	76.36	98.95	78
Mana	12.63	65.06	1.53	10.9	0	3
SC	10.52	1.2	0	0	0	0
Dhimmar	7.36	8.43	0	1.8	1.04	0
Pradhan	1.05	0	9.23	10.9	0	4
Lohar	0	13.25	0	0	0	12
Sonar	0	2.4	0	0	0	1
Mali	0	1.2	0	0	0	2
Guari	0	8.43	0	0	0	0
Rangari	0	0	6.15	0	0	0
Bharai	0	0	1.53	0	0	0

*** Figures in percent.**

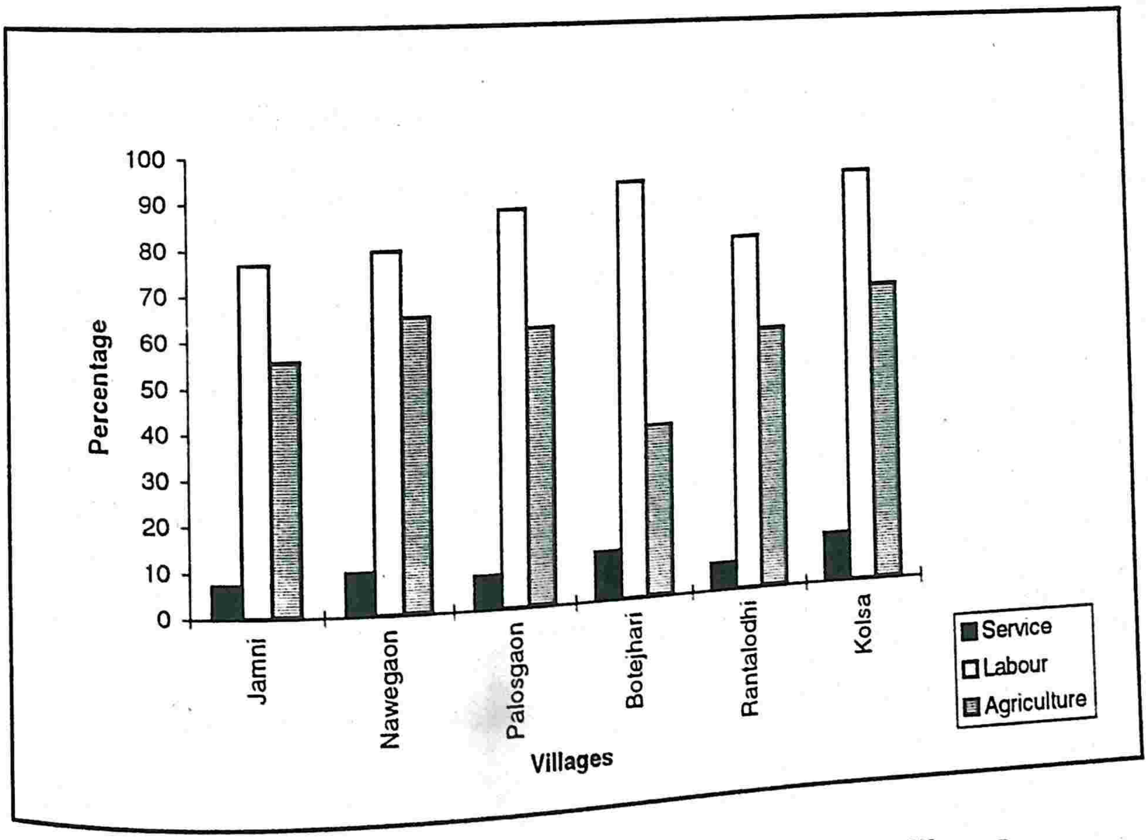


Figure 9.3. Occupational pattern of sample villages

9.4.5. Land holding and land use pattern

Out of the total 494 households in six sample villages only 56.48% families had agricultural land and the rest 43.52% were landless. The results of land holding and land use of each sample village is given below:

1. Jamni

Jamni had a total of 149.2 acres of legal land available for cultivation. Only 56.8% of the families owned land and rest 43.2% were land less. Average size of land holding varied from 1 acre to 6 acre per land owning family. Mean land per family was calculated to 2.76 acre per house hold. Only 1.85 % of total land was irrigated. 2.01% of the total available land was fallow.

2. Nawegaon

Nawegaon had a total of 472.5 acres of land. 67.46% of families had land and rest 32.5% were landless. Average land holding size varied from 1.25 acres to 14 acres per land owning family. 3.91% of the total land available was fallow which left 95.76% of cultivable land. Only 5.35% of the total land was irrigated. Mean land per house hold was calculated to 8.75 acre.

3. Palasgaon

Palasgaon had a total of 85.3 acres of land. 61.53% of the total families were owners of land and 38.46% were land less. Minimum and maximum land holding per family were observed to be 2 and 8 acres respectively. 100% land available was cultivable. 10% of the total land fell under the category of irrigated land and 90% was rain fed. Mean land per house hold was 1.31 acres.

4. Botejhari

Botejhari had a total of 70 acres of land with a mean of 3.3 acres of land per house hold. 45.5% of the total population were land owners and rest 54.5 were landless. 100% land was rain fed. Minimum and maximum land holding per house hold was 2 and 8 acres respectively. 1.42% of total land was fallow.

5. Rantalodhi

Rantalodhi had 138.5 acres of land with a mean of 2.07 acres per family. 61.5% of the total population were land owners and 38.5% were land less. Only 13.56% of the total land was irrigated and rest 86.44% was rain fed. Minimum and maximum land holding per family were observed to be 2 and 8 acres respectively. 16.25% of the total land was encroached and 100% land was cultivable.

6. Kolsa

Kolsa was the largest of all sample villages. It had a total of 168.25 acres of land with a mean of 2.51 acres per house hold. Minimum and maximum land holding per house hold was observed to be 2 and 7 acres respectively. 67% of total household were land owners and 33% were land less. 83.33% of the total land available was irrigated and only 16.67% of land was rain fed. 98.78% of the total land was cultivable and 1.21% was fallow. 1.93% of total land was encroached.

Dung was used as the major source of manure in all villages. Only 11.25% of the total families reported the use inorganic manure as a supplement to dung. The highest proportion of land less was in Botejhari village (54.55%). Mean land holding in terms of acre/house hold was highest in Nawegaon (14 acres) and had the maximum cultivable land also.

9.4.6. Cropping pattern and depredation

By and large the cropping pattern in the entire study area was single crop per year. Paddy formed an important crop in all the villages. Apart from paddy, sorghum, horse gram and wheat was also cultivated depending on irrigation facilities. 27.7% of land owners in Nawegaon village followed by Rantalodhi village (17.7%) took double crops while the lowest was recorded in Kolsa (1% of total land owners). Land owners of Botejhari and Jamni village also took single crop per year.

Mean maximum damage due to crop depredation was reported from Jamni (42.31%) and minimum from Botejhari (21.91%). Analysis of data on crop depredation from Nawegaon, Palasgaon, Rantalodhi and Kolsa villages suggests the crop damage was 34.44%, 41.37%, 31.5% and 24.5% respectively. Crop depredation mainly occurred during night. The most common problem associated with crops as reported by people was too much or too little of rain and crop raiding. Low yield was a major complaint of people of Kolsa village (Table 9.2).

Table. 9.2. Problems related to crop in sample villages in TATR

Problem with the crop	**VILLAGES**											
	Jamni		Nawegaon		Palasgaon		Botejhari		Rantalodhi		Kolsa	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Poor soil	1.8	98.11	25.45	74.5	2.5	97.5	10	90	9.52	90.47	1.49	98.5
Disease	1.8	98.11	3.6	96.36	0	100	15.53	84.47	6.34	93.65	4.47	95.52
Low yield	3.7	96.22	14.5	85.45	25	75	7.36	92.64	23.8	76.19	59.7	40.29
Rain	100	0	96.36	3.63	97.5	2.5	95	5	93.65	6.34	1.49	98.5
Crop raiding	98.1	1.8	85.5	14.5	100	0	93.4	6.6	88.88	11.1	95.5	4.47
Insufficient land	1.8	98.11	1.8	98.18	25	75	25	75	26.98	73.01	19.4	80.5

*** Figures in percent.**

9.4.7. Livestock population and grazing

The total livestock population of the reserve was estimated to 2066 with an average of 4.18 animals per family. Out of this 78.4% were cattle, 1.45% buffaloes and 20.18% were goats. 91.31% of the total livestock population was free ranging and only 8.7% was stall fed.The results of livestock holding pattern in sample villages are given below

1. Jamni

The total livestock population was 324 animals. Cattle formed 81.17% of total livestock population. Buffaloes and goats formed 1.8% and 16.9% of total livestock population respectively. Mean number of live stock per family was 3.41 animals. 79.6% of the livestock population was free ranging and 20.4% was stall fed.

2. Nawegaon

The total live stock population of this village was 558. The mean number of live stock per family was 6.7 animals. Cattle contributed 64.15% of total population whereas buffaloes and goats contributed 1.07% and 34.76% of total population. 90.7% livestock was free ranging and only 9.2% was stall fed.

3. Palasgaon

A total of 223 livestock were counted in this village. The mean number of livestock per house hold was calculated to be 4.8 animals. Cattle, buffalo and goats contributed 84.75%, 0.04% and 14.7% of total live stock population respectively. 97.8% livestock was free ranging and only 2.17% was stall fed.

4. Botejhari

Botejhari was the smallest village in terms of number of house holds. The total livestock population of this village was 194 animals. Mean number of live stock per family was calculated to be 5.24. 67.27% of the total households had livestock. Cattle, buffaloes and goats constituted 90.2%, 6.1% and 3.5% of the total livestock population. 100% livestock population was free ranging .

5. Rantalodhi

Total livestock population was 348 with the mean of 3.62 livestock per family. 23.95% of the total house holds did not have any live stock. Cattle, buffaloes and goats constituted 79.02%, 0% and 20.97% of the total population. In this village also 100% livestock was free ranging.

6. Kolsa

Kolsa was the largest of all sample villages with 100 house holds. The total live stock population of this village was 423 animals with a mean of 5.49 livestock per family. 23% of total households did not have any livestock. Cattle, buffaloes and goats constituted 85.57%, 1.18% and 13.2% of total livestock population respectively. 92.2% of livestock was free ranging and 7.79% was stall fed. Overall data on grazing collected compartment wise was analysed using GIS. The analysis revealed that 73% of the total geographical area of the reserve was free from grazing pressure.

9.4.8. Priority analysis

Villagers opinion about their priorities was collected on nine parameters which were set after initial discussions with the villagers. This gives an idea about what are the things they want. The nine parameters with their abbreviated forms are given below:

PN1 = Employment

PN2 = Fuel wood

PN3 = Fodder for live stock

PN4 = Protection from crop raiding

PN5 = Drinking water

PN6 = Drinking water for livestock

PN7 = Irrigation facilities

PN8 = Medical facilities

PN9 = Roads and transport facilities.

Priority analysis revealed that Employment, Medical facilities and Roads and transportation facilities were the major priorities of villagers residing inside the reserve. There was not much difference in priorities across the sample villages. Fuel wood was the priority for 38% and 67% people of Nawegaon and Palasgaon village. Education was dropped out from the priority list as none of the 494 households opted for it. Fig. 9.4 to Fig. 9.9 show the percent people opting for different priorities in sample villages. Pooled analysis of priorities showed 88% demand for employment, 75% demand for medical facilities, 55% for roads and transportation and 33% for fuel wood (Fig. 9.10).

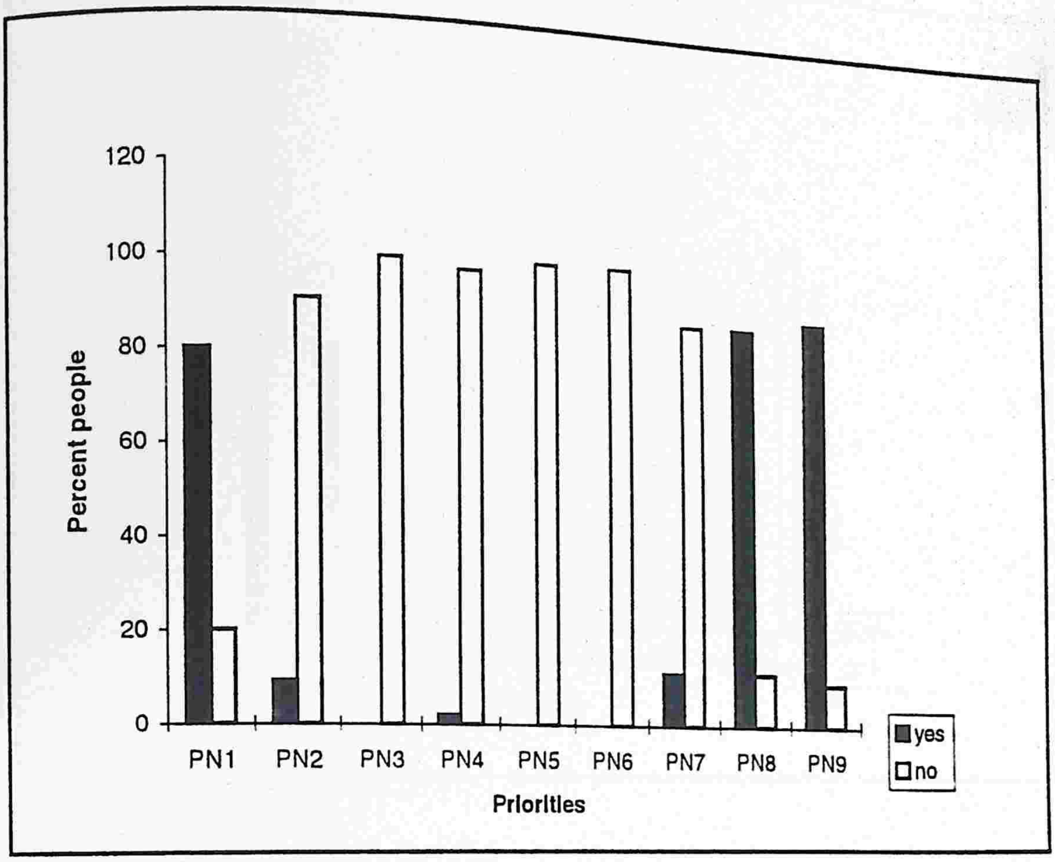


Figure 9.4. Priority of Jamni village

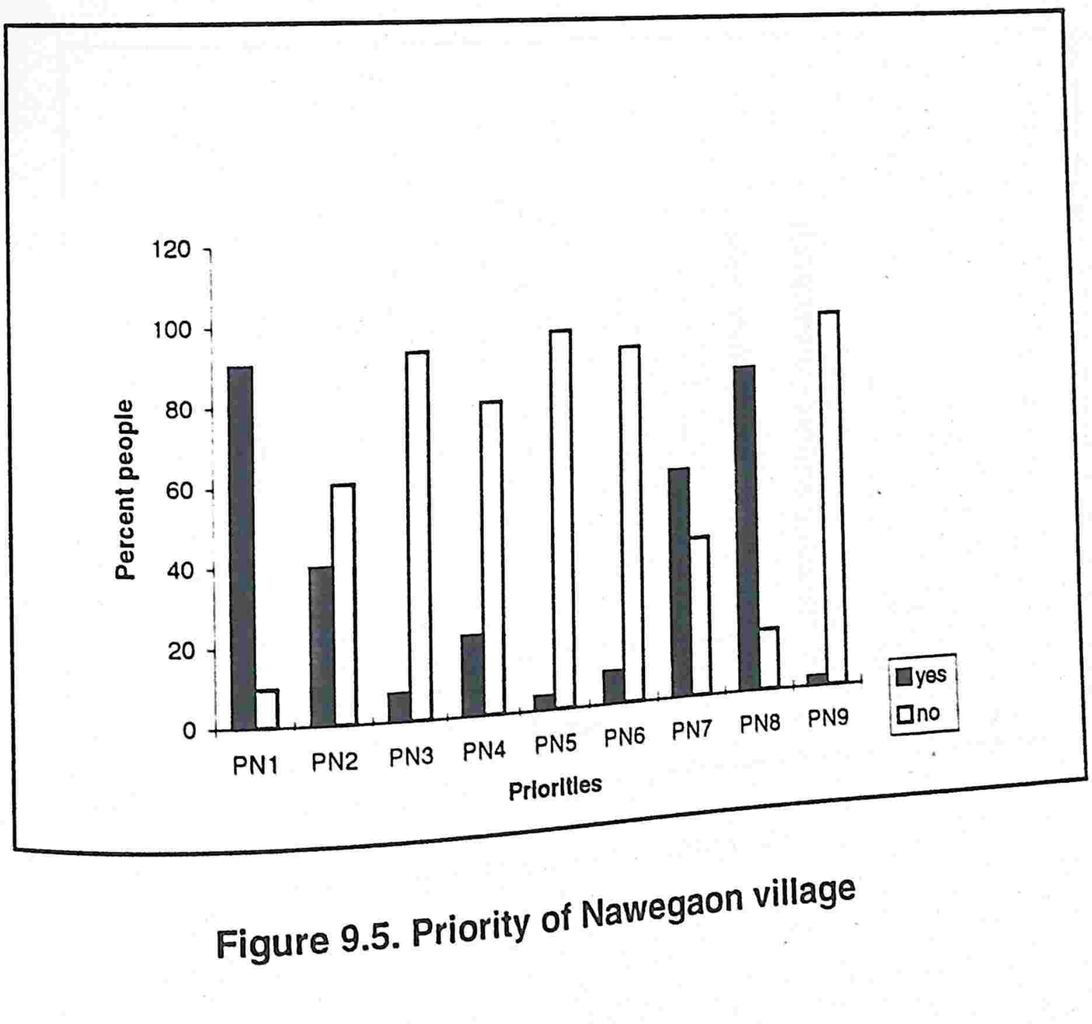


Figure 9.5. Priority of Nawegaon village

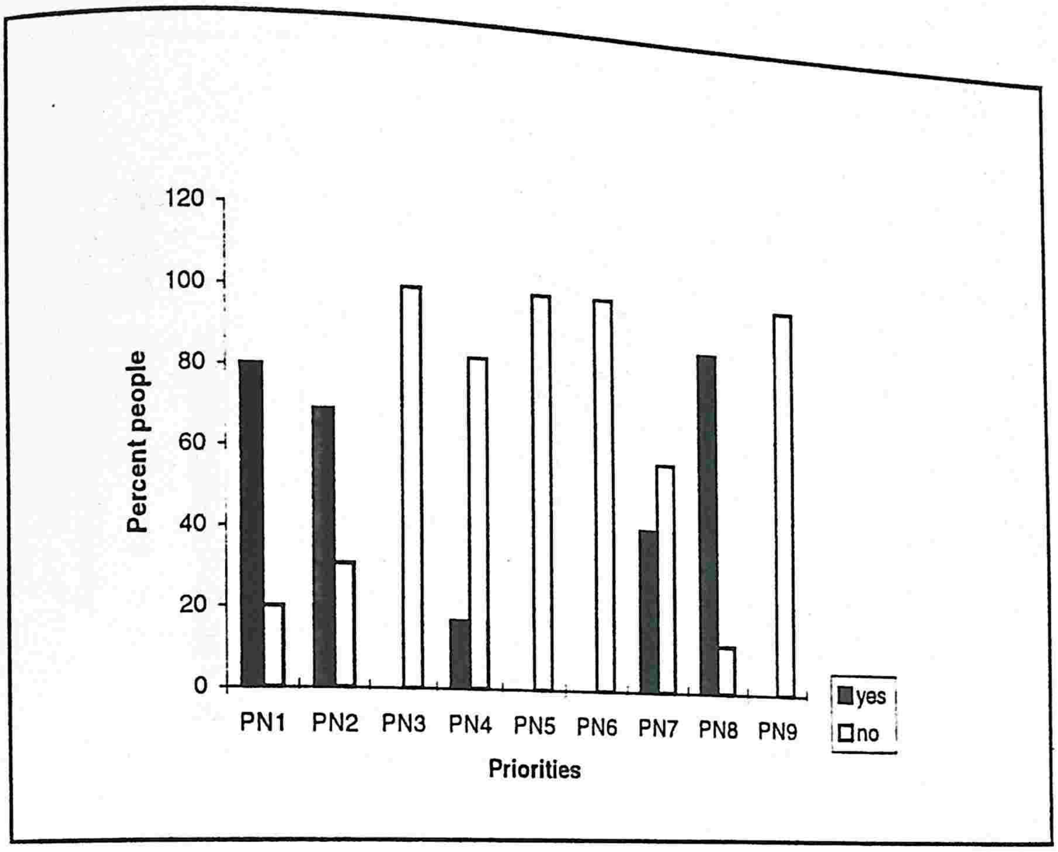


Figure. 9.6. Priority of Palasgaon village

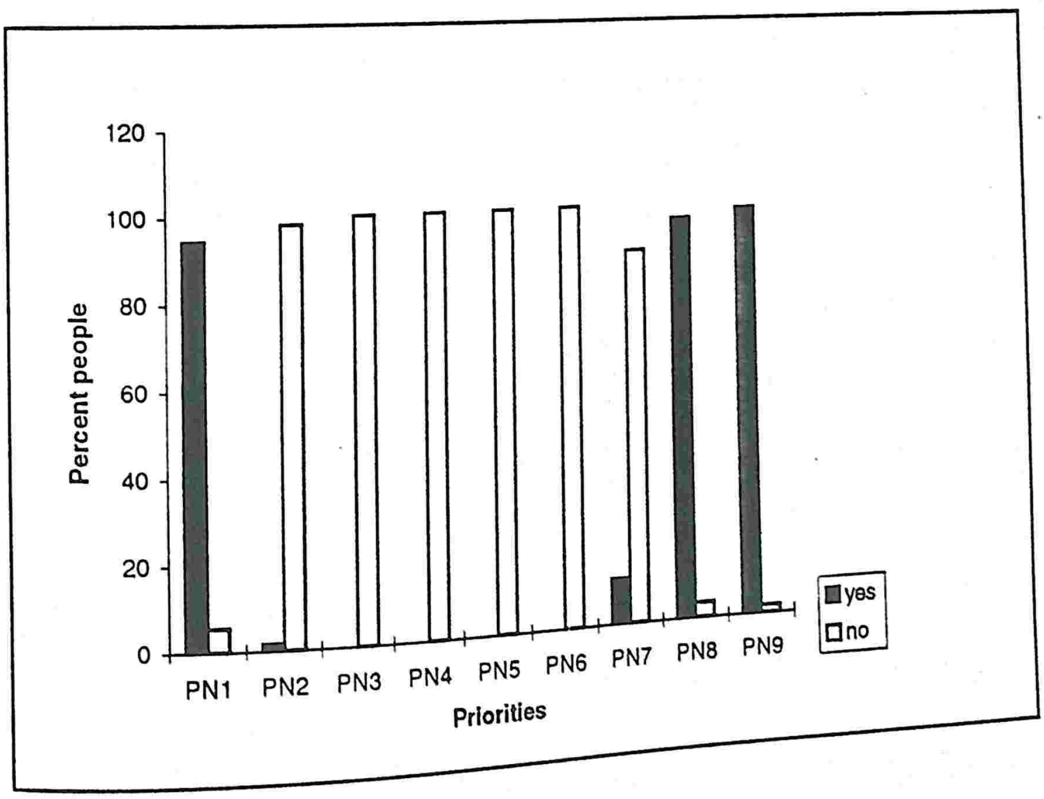


Figure 9.7. Priority of Botejhari

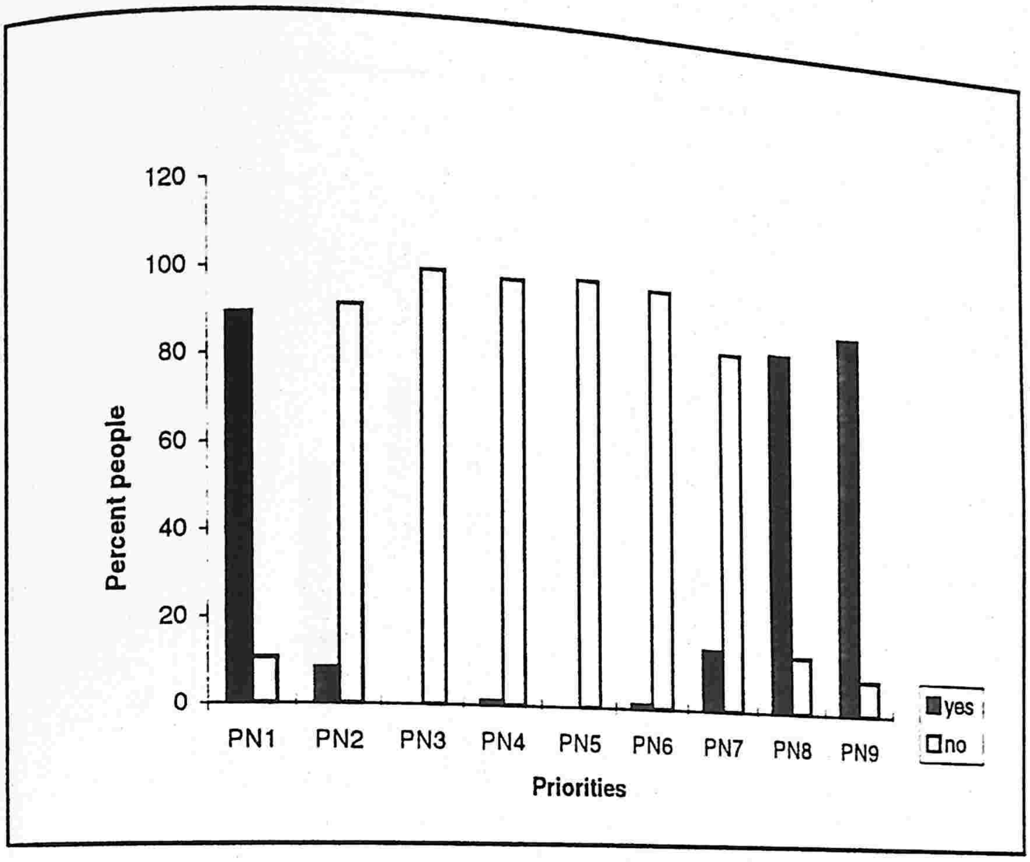


Figure. 9.8. Priority of Rantalodhi village

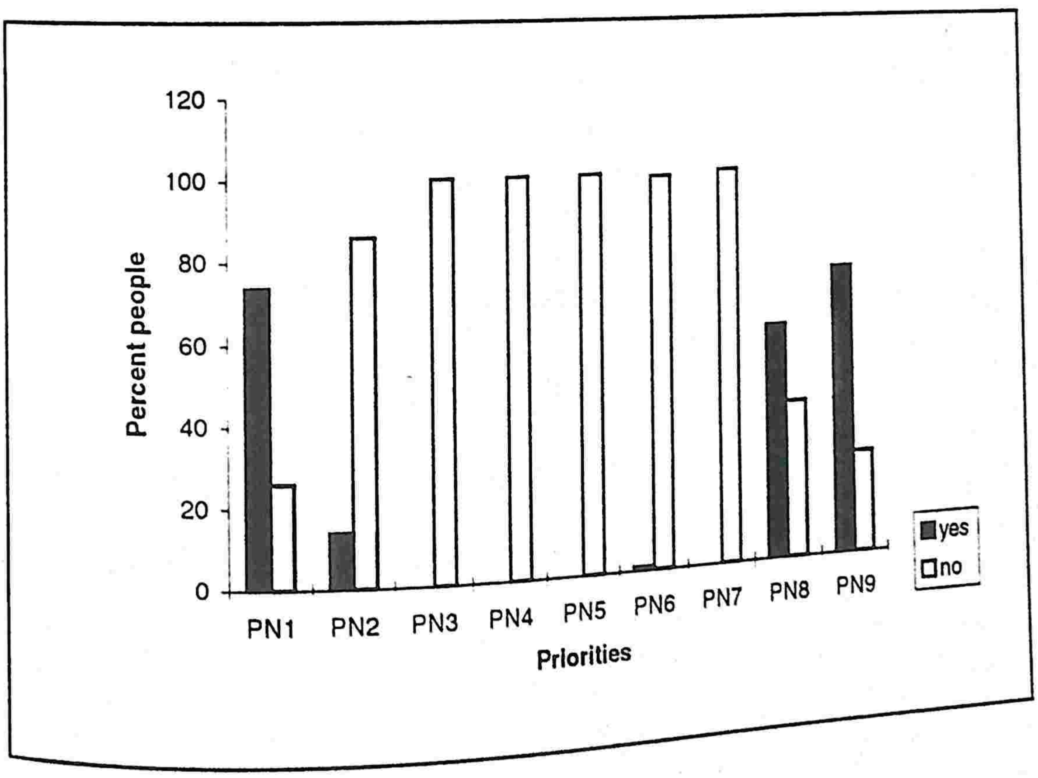


Figure 9.9. Priority of Kolsa village

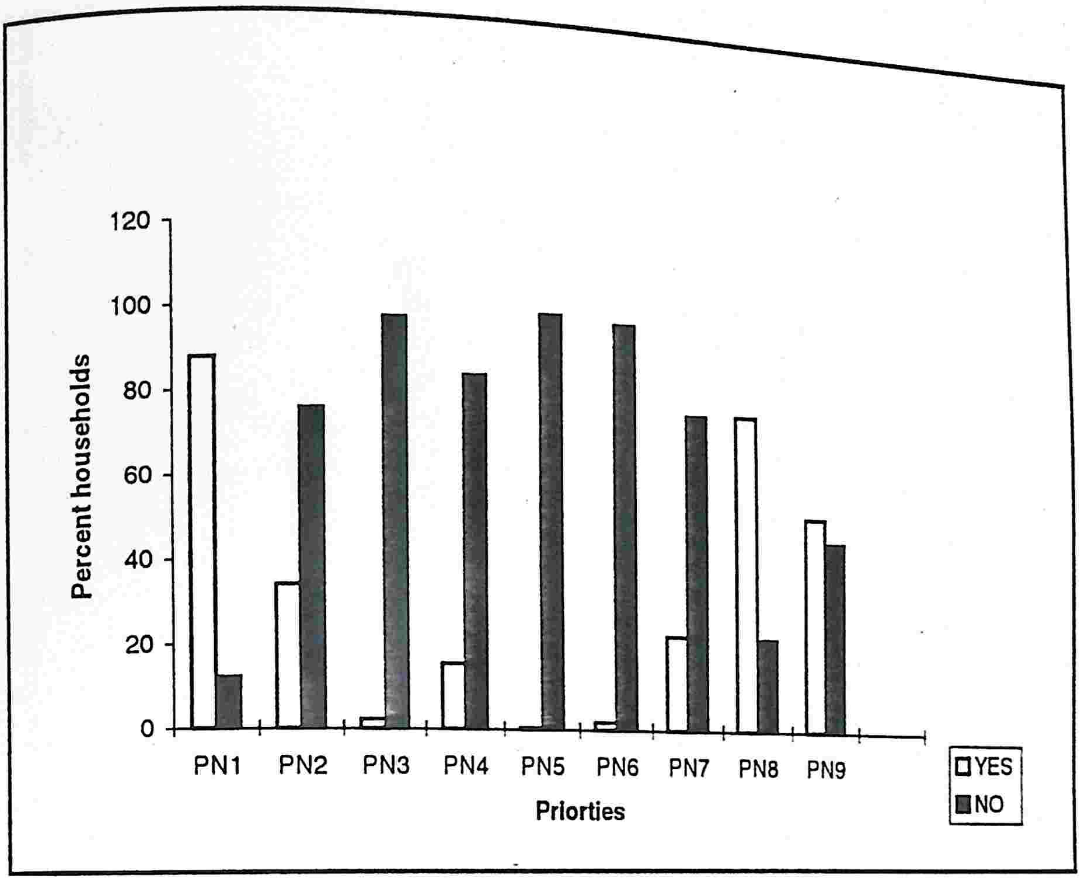


Figure 9.10. Pooled priorities of six sample villages

9.4.9. Minor forest produce Collection

1. Bamboo

Bamboo is extracted by villagers for the construction of fences around their houses and as a foundation material for making roofs of their houses. Sample villages Rantalodhi and Kolsa were highly dependent on bamboo as these villages extracted 20,825 and 18,560 culms per annum from the forest followed by Botejhari 8585 culms per annum. Nawegaon, Palasgaon and Jamni were less dependent of bamboo (Fig. 9.11). Certain amount of bamboo is illegally felled from the reserve for which no data exists.

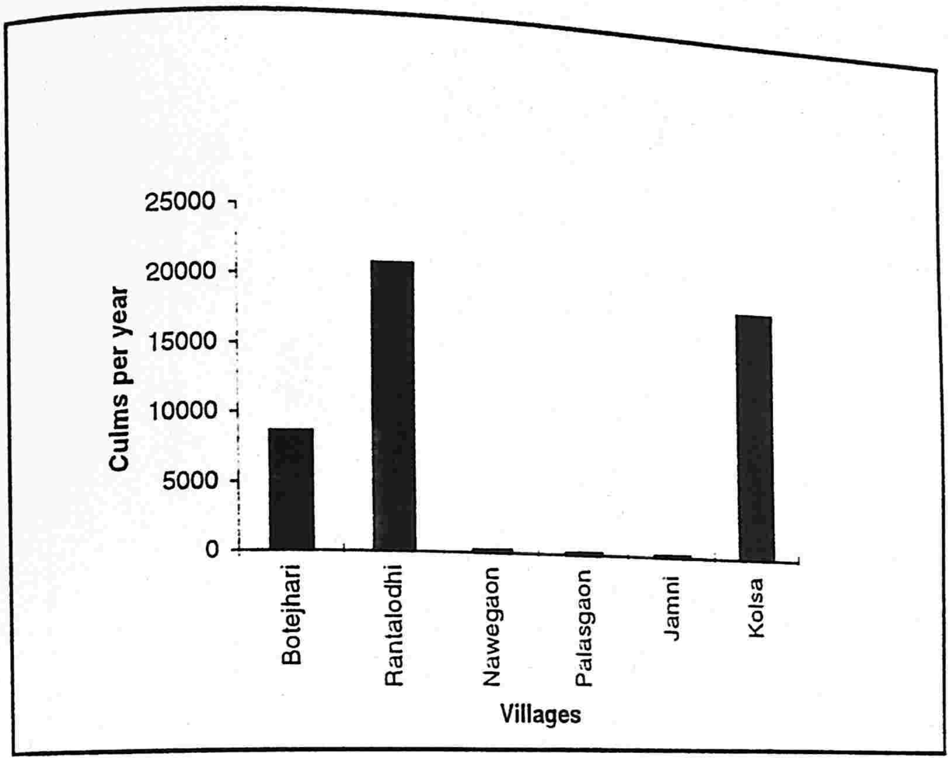


Figure 9.11. Bamboo extraction by sample villages

2. Grass

The most commonly collected grasses are Andropogon, Hetropogon and Vetiveria zizinoides. The grass is collected to make thatches of the roof and as miscellaneous housing material. Only three sample villages went out for organized grass collection viz. Rantalodhi (53 tonnes/year), Kolsa (48 tonnes/year) and Botejhari (32 tonnes/year) (Fig 9.12).

3. Fuel wood collection

Fuel wood was invariably collected by all sample villages. A total of 791 tonnes of fuel wood is extracted from forest annually (Fig. 9.13). Jamni village extracted 22.12% of the total fuel wood extracted followed by Rantalodhi (19.85%), Nawegaon (19.85), Kolsa (18.2%), Botejhari (13.14%) and Palasgaon (10.36%).

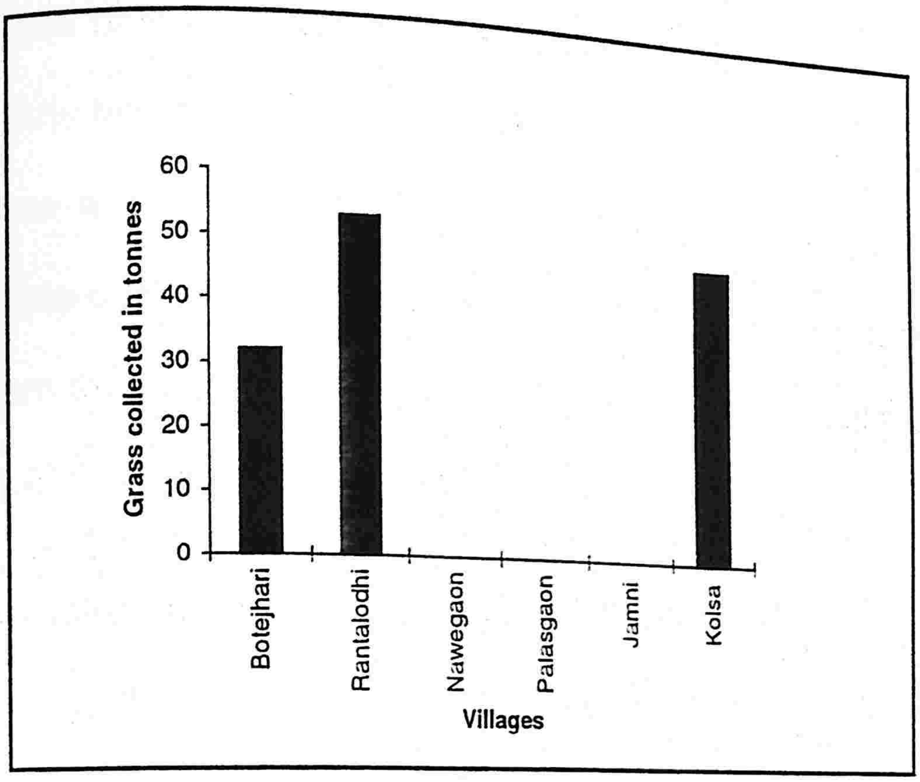


Figure 9.12. Grass harvesting by sample villages

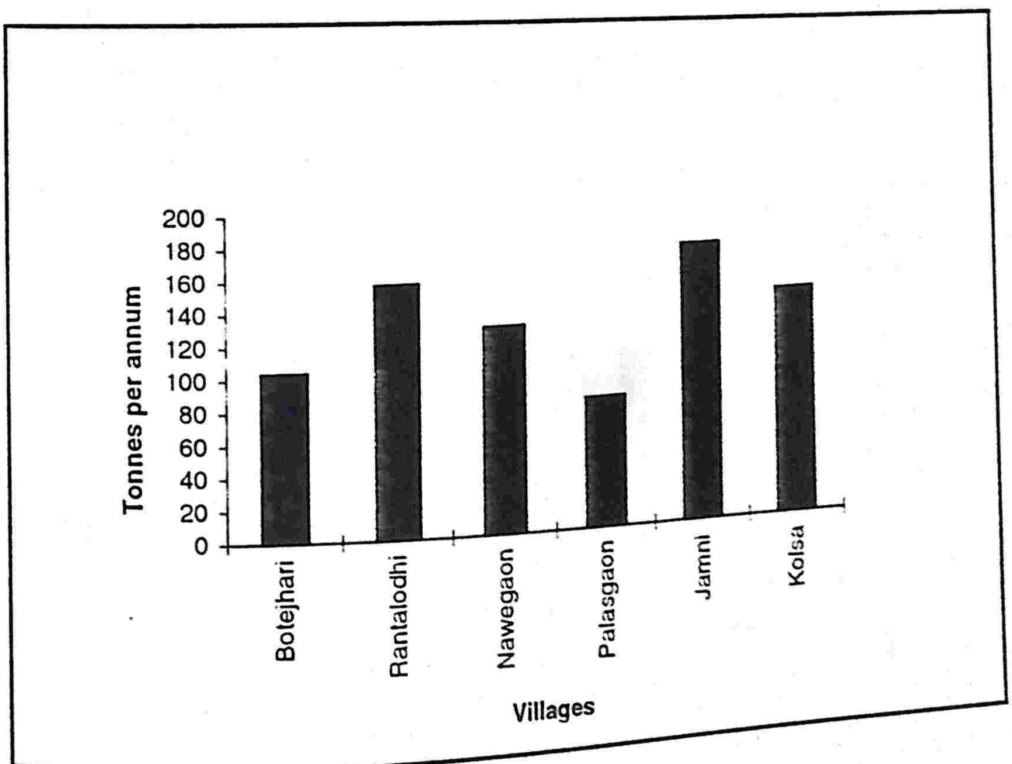


Figure 9.13. Fuel wood extraction pattern

4. **Mahua flowers and seeds:**

Mahua (*Bassia latifolia*) flowers are collected during the months of late Feb and early March. Flowers are collected to act a food source in lean season and to brew a local liquor out of it. Mahua seeds are collected by tribal to extract edible cooking oil out of it. Rantalodhi extracted the highest amount of flowers from the forest 21,400 kg/year, followed by Kolsa (12,030 kg/year) and Jamni (11,205 kg/year) (Figure 9.14).

Mahua seed collection in Rantalodhi village was 11,150 kg/year, followed by palasgaon (6445 kg/year). Seed collection by Nawegaon village was lowest among sample villages (395 kg./year) (Figure 9.14).

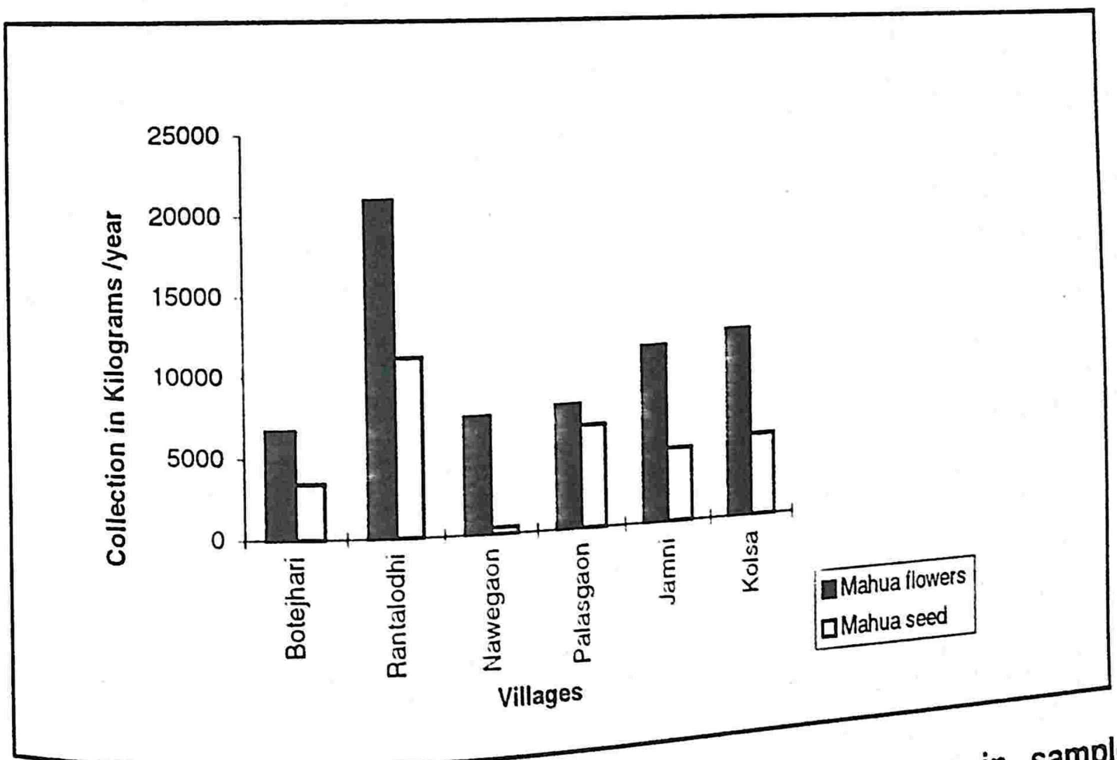


Figure 9.14. Mahua flowers and seed collection pattern in sample villages.

5. **Tendu leaves**

Tendu (*Diospyros melanoxylon*) is a major income generating forest produce. Only three of the six sample villages were involved in Tendu leaf collection. The money generated through tendu leaves is shown in Fig. 9.15.

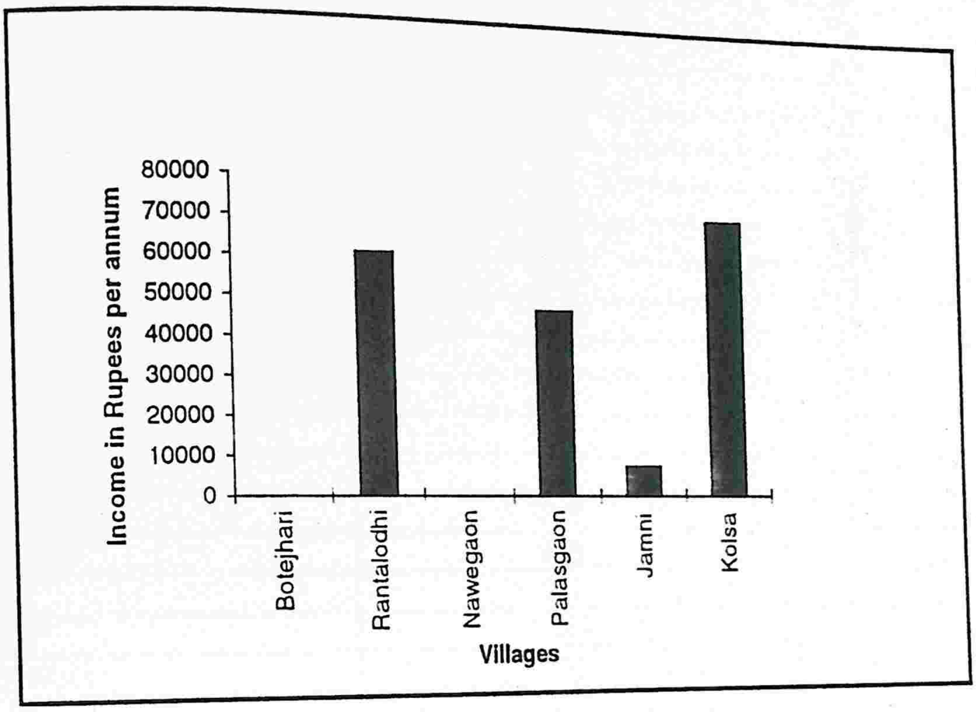


Figure 9.15 Income generated by tendu leaves in sample villages

9.4.10. Villages outside the reserve

There are around 48 villages around the periphery of the reserve. These villages are also partially dependent on reserve. The main pressure from these villages is for fuel wood. Data could not be collected for these villages but nonetheless the resource use pattern of these villages needs to be known, as resource use pattern by these villages does affect the protected area management.The population profiles for human and livestock for these villages in given in Table 9.3.

Table 9.3. Profile of Villages within 5 km radius from the periphery of TATR

VILLAGE	HUMAN POPULATION	COW	BUFF	GOAT
BEMBALA	601	420	35	130
BALAGAON	1113	666	76	127
WAIGAON	767	696	37	322
SHIVANI	145	571	421	145
ARJUNI	134	1151	117	582
KOKEWADA	847	498	60	290
BELAGAON-B	29	309	8	193
NEEMDELA	259	203	6	118
BAMANGAON	298	330	3	56
KOLARA	1303	796	41	319
GONDMOHADI	170	255	34	62
MADNAPORE	669	583	26	137
MASAL	1672	1046	79	414
PALASGAON	1633	1350	130	304
PIPRALA	1047	570	40	134
SATARA	558	511	16	214
NAWEGAON	351	495	27	218
VIHIRGAON	877	848	9	313
SHIVANI	463	1621	157	201
PARANA	226	224	16	8
SHIRKALA	558	361	11	77
KARWA	297	411	4	44
WASERA	2535	1048	159	264
KUKUDHETI	768	6498	51	147
MOHADI	2424	1154	123	228
NALESHWAR	601	406	25	43
PANGDI	118	200	0	13
TAMASALA	1324	736	48	350
PIPERHETI	102	82	0	25
DONI	247	460	0	215
JHARI	73	445	0	9
PAHAMI	51	85	0	0
NIMBALA	616	460	9	110
SONEGAON	331	257	32	156
KINADA	302	309	33	71
ASHTA	1818	1093	111	213
WADALA	799	374	10	145
VILLODA	1397	576	65	241
KATWAL	805	271	29	140
GHOSRI	296	393	3	109
KHUTUNDA DIXIT	416	401	8	62
MUDHOLI	1467	935	95	65
MOHARLI	1149	423	73	257
ADEGAON	223	410	11	60
DEWADA	125	143	0	0
JUNONA	84	135	0	20
KONDEGAON	534	502	21	21
BHAMDELI	1159	316	0	11
KOKEWADAMANKAR	359	296	51	146
SITARAMPETH	584	250	4	38
ADEGAON	367	702	9	145
ADEGAON	876	231	6	277
RAMDEGI	404	515	0	0

9.5. DISCUSSION

9.5.1. Demography

9.5.1.1. Literacy rate

All the sample villages had primary schools. Nawegaon and Palasgaon had a higher literacy rate than other villages owing to better access to towns and good transport facility. The main reason for overall low literacy rate is the lack of awareness among people and poverty. Though there are primary schools in all the sample villages but absence of teachers and remoteness of villages from townships contributes to lower literacy rate. Villages connected to towns with good transportation facility showed a higher literacy rate as compared to villages devoid of transport facility. Literacy is an extremely important factor in spreading conservation awareness among local people. People with higher education from the sample villages work in coal mines and are less dependent on forest as the life style changes once they get used to urban way of living with better salary. Nawegaon with the highest literacy rate was the least forest dependent village.

9.5.1.2. Occupational pattern

Occupation pattern in the area was governed by the cropping pattern. Land less families were forced to work as labourers either with the forest department as and when the work opportunity came up or with the the land holders in their agricultural fields. Most of the land holders took single crop a year as the crops are rain fed and better irrigation facilities do not exist. Land holders also worked as labourers in non-cropping seasons as agriculture alone cannot sustain them economically throughout the year owing to low yield of crops. Proportion of people in service was quite low in all sample villages as the literacy rate was low.

9.5.1.3. Land holding and land use pattern

Results revealed that nearly 50% of the total population was landless. Because of poor irrigation facilities, agriculture was mainly rain fed or dependent on natural sources of irrigation. There were village tanks in three sample villages viz. Kolsa, Jamni and Rantalodhi, but only those families who had their land in the vicinity of the tank benefited from it and the rest were devoid of the irrigation facilities. By and large most of the land was devoid of irrigation and the agriculture was dependent on monsoon.

Among landholders also there was lot of disparity in terms of land holding. Gonds were the major stakeholders of land in all the sample villages except Nawegaon where Mana tribe owned most of the land. Caste does not seems to be determinant of land holding but by and large most of the Scheduled Caste population was land less in all villages.

9.5.1.4. Cropping pattern and depredation

Cropping pattern of the entire area was by and large mono crop type and paddy was the most important crop cultivated. Mixed cultivation of cereals and pulses was also done in a small proportion of land to meet the other needs of the family. Agriculture only constituted as a subsistence and did not contribute to the economy owing to the low yields. Double crop was taken by certain house holds in Nawegaon and Rantalodhi as they had access to better irrigation facility in terms of tube wells and the presence of Village tanks close to their fields.

Crop depredation was a common problem of all the villagers, especially those belonging to Jamni and Palasgaon as the forest surrounding these villages harbours abundant wildlife. Botejhari and Kolsa villages had a lower depredation rate as the forest surrounding these areas had a low population of Chital and Wild pig, which are the major predators on crops. Animals like Gaur, Sambar, Barking deer which are basically forest dwellers never came out of the forest fringes into the crop fields although in lean season these animals have been reported to come to village tanks in search of water. Normally during the cropping season the crops are protected by people by making machans in their crop fields. The most commonly employed method to ward off animals out was to beat canisters and use fire crackers, which are locally made by the people. Sometimes explosives wrapped in some edible material is also placed on the fringes of crop fields and as animal eats it the explosive explodes and in most cases the animal dies. Though it is not the most commonly used deterrent but nonetheless its use was reported in small proportion from the sample villages.

Rain was the limiting factor in the productivity of crops and was also the main complaint of local people. Either too much or too little rain caused most of the problem to farmers as yield of crop is directly dependent on irrigation especially in the case of paddy. Crop depredation was another factor responsible for low yield and was second major concern of the local people. Low yield as an independent problem was reported only from Kolsa village. The use of chemical fertiliser is not a very common practice in the area and most of the people resort to the conventional use of dung manure.

9.5.1.5. Livestock population and grazing

Livestock was owned by most of the house holds. Cattle formed most of the total livestock. Buffaloes were not very common as they formed only 1.45% of the total livestock population. Cows were preferred over any other livestock for the reason that they are cheaper. Goats which formed 20.18% of total livestock population were kept to meet the meat and milk demands. Large number of unproductive livestock meant more manure for agriculture and it was also considered as status symbol among Gonds.

Most of the livestock in the area was free ranging. The most commonly used forage for the livestock was bamboo, grasses and *Wrightia tinctoria* . Agricultural residue was commonly used as stall feed for animals. Animals falling in the category of being stall fed were the young ones, which were not taken out to graze inside the forest owing to the risk of predation by carnivores. Green fodder was never observed being taken from the forest. Low agricultural yield resulting in low availability of agriculture residue and non availability of green fodder around villages leads to livestock venturing in forest. Since the cost of rearing livestock is negligible in terms of fodder the villagers can afford to keep as many as possible. Also to graze the livestock in forest one person of the village is hired and certain amount of money is being paid to him by each livestock owner.

9.5.1.6. Priorities

All the sample villages opted for three priorities namely employment, medical facilities and transportation. Though Nawegaon, Palasgaon and Kolsa are connected to the state transport bus routes, they still wanted improved transportation facilities. Employment was the common problem as that was the root cause of all other related problems like dependency on forest. Employment is directly linked with the transport facility. If transport facilities are improved villagers stand a better chance to move out of their villages and look for better employment opportunities either in coal fields or industrial sector, as the area is surrounded by lots of industrial units.

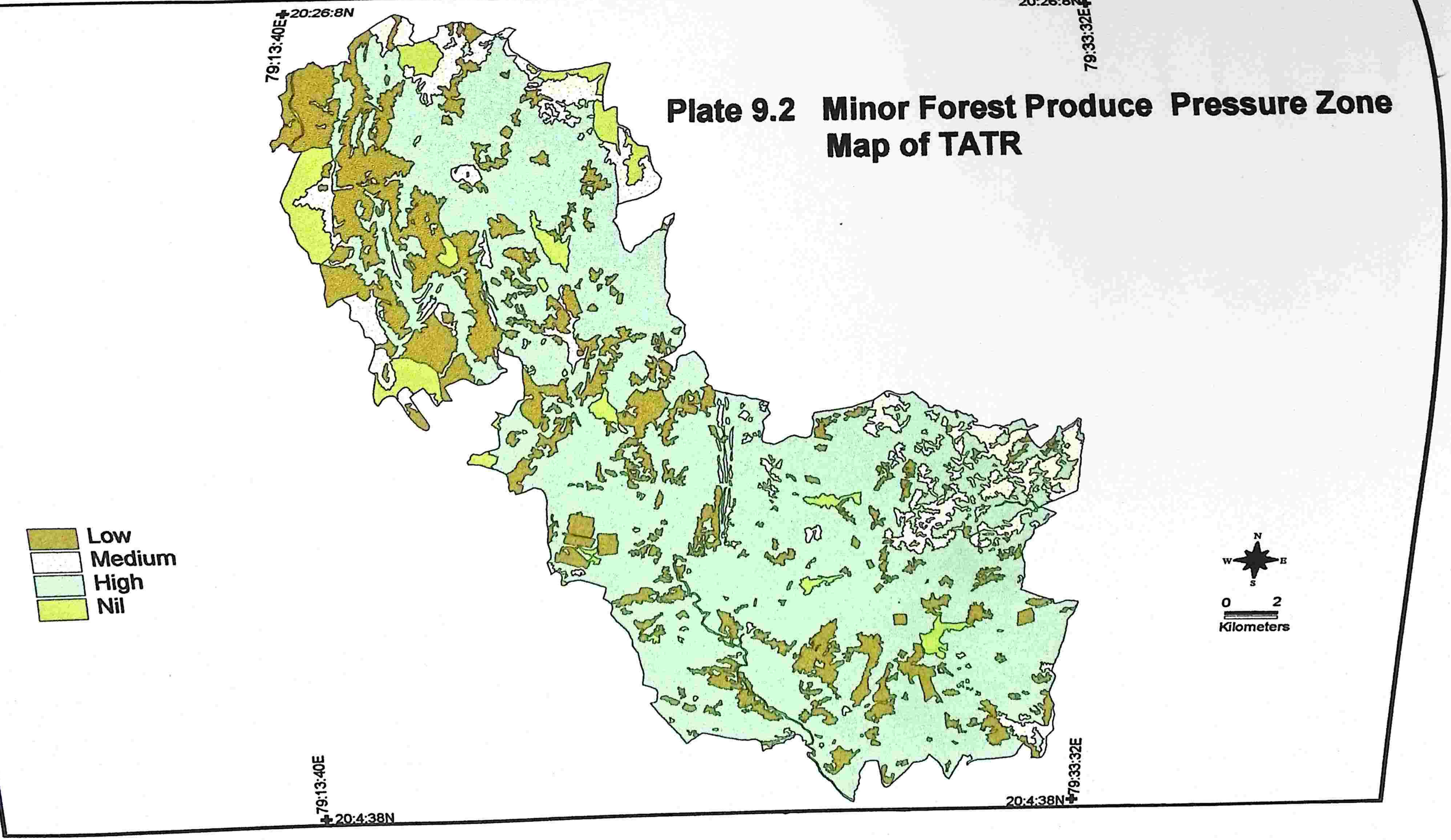
Only one out of six sample villages had a primary health centre but non availability of doctor during most parts of the year especially monsoon when the villages get cut off by transport was the major problem. Botejhari, Rantalodhi and Jamni were in remote locations and did not had access to medical and transport facility. These three priorities emerged as the thrust need of villagers residing in the sample villages.

Protection from crop raiding was indicated by only two out of six sample villages. Protection from crop raiding came up as low priority as villagers know that there is nothing much which can be done about this problem as infiltration of wild animals in crop field cannot be stopped. But still the possibility of providing electric fencing based on cost effectiveness can be considered.

9.5.1.7. Minor forest produce collection

Rantalodhi, Kolsa and Botejhari were highly dependent villages on bamboo. This bamboo was partly used as their housing material and with rest they made baskets and carpets which they sold in the local markets. Nawegaon was the least dependent on bamboo for the reason that bamboo

Plate 9.2 Minor Forest Produce Pressure Zone Map of TATR



was not found in the forest areas in the vicinity of the village. Jamni and Palasgaon were also least dependent on bamboo. The reason for this was the structure of bamboo in the forest adjoining these two villages. Bamboo structure adjoining these villages was thin and highly clumped. This kind of bamboo did not had any utility as housing material.

Dependency for grass was also high in the case of Rantalodhi, Kolsa and Botejhari and the other three villages were not at all dependent on grass. The reason for non dependency on grass of Nawegaon, Palasgaon and Jamni was the subsidised supply of tiles as roofing material for houses under tribal development welfare programme. Subsidised supply of housing material in all the villages can surely help in reduction of pressure on forest if not completely then substantially.

Fuel wood collection is a major activity in the area. Fuel wood is collected by all the households as alternative energy resources does not exist in the area. Gobar gas plant was installed in Palasgaon village but was not successful as there was no maintenance after the installation. It is not only important but also imperative to develop better alternative of energy in the area as fuel wood need and demands would keep on increasing numerically as the number of members per household would increase. Fuel wood in the area is not collected through head loads. People take their bullock carts and collect fuel wood twice a year once before monsoon and once after winter and store it for the entire year.

Madhuca latifolia flowers and seed are the most important MFP collected in the area. All the sample villages were dependent on the Bassia flowers and seeds. Rantalodhi was the most dependent village in terms of Mahua flowers and seeds. The flowers were stored as food source in lean season by people. The flowers are also used to extract locally brewed liquor which is part and parcel of the socio-cultural set up of Gond life style. The seeds are crushed locally to extract edible oil which is used for cooking in most of the Gond families, though people have started using other vegetable oils also. Plate 9.2 shows areas under different MFP collection pressure zones.

Diospyros melanoxylon leaves commonly known as bidi leaves are major source of economy as they provide cash money on the basis of amount of leaves supplied to the contractor. The tendu season starts in the early April and lasts till third week of April. People collect tendu leaves and tie them in bundles of hundred leaves. These bundles are then deposited at the contractors site. Tendu season is a major earning season and mostly all the members of working age group of household are involved in tendu leaf collection with the basic philosophy - more leaf bundles, more money. People of Botejhari village were not involved in the collection as Botejhari is remotely situated. The reserve forest around Nawegaon village did not had Diospyros distribution. People of other sample villages went to the adjacent patches of reserve forest mainly Chandrapur division and Mul division for leaf collection.

Chapter 10

CONCLUSIONS

The overarching aim of the management of Tadoba - Andhari Tiger Reserve is the long term conservation of its floral and faunal diversity. This chapter discusses the overall results of the present study alongwith their implications on management. In this study an attempt has been made to demonstrate the utility of development of a spatial database, in Geographic Information System (GIS) domain for enhancing management decision making capabilities.

A total of 48 themes depicting the availability, distribution and extent/abundance of physical and ecological attributes of the study area were derived using GIS technology. The various thematic data layers generated through this study will provide valuable assistance in the assessment, management and monitoring of PA resources.

Geocoded satellite imageries (IRS-LISS II) on 1:50,000 scale were visually interpreted to prepare the vegetation map of the study area. A total of 11 vegetation categories were delineated. Miscellaneous Bamboo I (MB I), Teak Miscellaneous Bamboo (TMB) and Miscellaneous Bamboo II (MB II) emerged as the most dominant vegetation types covering 25.27%, 21.65% and 21.01% respectively of the total area. Teak Miscellaneous Bamboo vegetation type had the highest crown cover (> 60%) as derived from the satellite image. Data on count and measurement of trees, seedling, sapling, canopy cover, shrub was collected from 239 plots of 20m X 20m each. The overall tree density was calculated to be 357trees/ha. Tree density was 344 trees/ha in the National Park and 369 trees/ha in the Sanctuary. Teak was the most dominant species followed by *Chloroxylon sweitenia, Lagerstromia parviflora* and *Diospyros melanoxylon*. Eleven vegetation types were classified based on similarity in vegetation association using TWINSPAN analysis. Tree density (456 trees/ha) was highest in *Tectona grandis - Chloroxylon sweitenia - Diospyros melanoxylon* (TCD) association . Tree diversity and shrub volume was maximum in *Chloroxylon sweitenia - Tectona grandis - Cassia fistula - Emblica officinalis* (CTEO) association. 30% of the total species showed highly clumped distribution, 18% showed a tendency towards clumped distribution while 52% species showed uniform distribution.

Data on density of ungulates was gathered using vehicle based transects covering three winter and three summer seasons. Density estimates reveal an increasing trend in population in case of Sambar, Wild pig and Gaur during the study period. The total ungulate biomass in the study area was estimated to be 3858.4 kg/km^2. Chital, Sambar and Gaur contributed 86% to the total ungulate biomass of which Gaur alone contributed 40%. Sex ratios were heavily skewed towards females in all the species. Grouping tendencies differed in different cover types. Open habitats supported larger group sizes.

Data on habitat utilization was collected through direct and indirect methods. Chital habitat use was 42.35% in meadows, 28.29% in Teak and 17.6% in Misc-Bamboo (N=650) . Sambar habitat use was 24.83% in Teak II, 17.9% in

Teak Misc-Bamboo, 14.7% in Misc-Bamboo I (N=463), whereas Gaur habitat use was 39.6% in Misc-bamboo I, 9.42% in Grassland on plateau, 9.3% Teak Bamboo and 8.84% in Misc. forest (N=218). Chital used 94.3% of plain areas whereas Sambar showed 39% use of medium slopes, 7% of steep slopes and 54% of plain areas. Gaur used 86.5% of plain areas and 13.5% of medium slopes. Most of the ungulates used flat slopes.

Predation ecology of tiger was investigated in this study. Tiger scats were analysed to establish food habits of the species. Based on the analysis of 140 scats Chital, Sambar and Wildpig formed 38%, 32% and 16% respectively of the tigers diet. Kill data suggests a heavily biased predation pattern on males as compared to their proportion in population. 46.7% kills were made in prey weight class 51-100 kg whereas only 9% kills were made in prey weight class < 25 kg. Ambush cover played an important role in predation success as 62.33% kills were made at sites with high ambush cover. The prey selection in the study area is governed not only by body weight of the prey but also prey detectibility and predator evasion strategies employed by the prey species. Tiger and Leopard distribution was mapped based on data collected using direct and indirect evidences, which provides a valuable insight into their distribution in the study area.

Unique habitats comprising of caves, cliffs, talus and culverts were monitored for their use by different animal species. All these features were mapped using Global Positioning System (GPS) technology. Results suggest that these habitat features are used by a wide range of animals. Bats and sloth bear were the most frequent user of caves. Tiger used caves only in summers, which could be because of the fact that inside the caves the temperatures was lower by 20 - 25° C compared to outside. Culvert were used mainly by tiger and sloth bear. Tiger used culverts throughout the year with an increased use in summer. Culverts were used by a wide groups of animals and in all 734 animal tracks were recorded in culverts. These habitat features form an excellent resting and breeding site for different group of species. It is quite evident that the unique habitats perform important functions for a wide range of animals and animal groups. Results indicate that they provide diversity to the environment which is otherwise dominated by vegetation communities. Though small in extent these features constitute important microhabitats. This is perhaps for the first time that systematic observations have been made on the unique habitats. It is expected that the information generated on the role of unique habitats would initiate their mapping and management in other PAs.

Data was collected on fire incidence and related fire hazard values. Remotely sensed data was used to develop the fuel map for the study area. Leaf litter in different habitat types was quantified using 1x1 m quadrats in fire prone season i.e. Feb to May. Mean litter weight was high in Grassland on Plateau fuel type. Mean Rate of Spread (ROS) of fire was high in Grassland on Plateau, Meadow, Miscellaneous Bamboo II and Miscellaneous Bamboo I. Probability of Ignition (PI) was high in Grassland on plateau, Meadow, Miscellaneous bamboo I, Miscellaneous bamboo II and Teak miscellaneous Bamboo. Most of the fires occurred during the months of April and May. Fuel types Miscellaneous bamboo I, Miscellaneous bamboo II and Teak miscellaneous Bamboo were most prone to fire risk. Miscellaneous bamboo I, Miscellaneous bamboo II were damaged most in terms of cover and forage loss. Local practice of Minor Forest Produce collection played a major role in fire occurrence in the study area.

Socio economic data was collected from six villages inside the Tiger Reserve. Villages having better access to towns and good transport facility had higher literacy rate compared to other villages. Occupational characteristics of local communities are governed by cropping pattern, land holding and land use pattern. 50% of the total population was land less. Agriculture was mainly rainfed. Gonds were the major land owners while the Schedule Caste were by and large landless. Cropping pattern of the entire area was monocrop type with paddy being the most important crop cultivated. Crop depredation was a common problem in all the villages.

Most of the livestock in the study area is free ranging. Cows are preferred over other livestock. Most of the livestock is unproductive in terms of milk yield. Livestock is kept only for manure value. Employment, medical facilities and transportation are the three most important priorities for most of the households.

Villages having better access to transport and towns were less dependent on Minor Forest Produce collection whereas villages in the interior parts of the tiger reserve heavily subsist on MFP collection. Mahua flowers and Tendu leaves are two major MFP's which are of immense economic importance to tribals. Bamboo and grass is being harvested for its use as thatch material. There is a high dependency of villages on forest for fuel wood.

This study has provided extensive datasets on ungulate population structure, distribution, abundance and habitat utilization patterns which will provide a scientific basis for management of these species and their habitats. The very comprehensive spatial database in GIS domain created by this study would assist the management in informed decision making and monitoring of various resources.

The study has successfully demonstrated the utility of remote sensing used in conjunction with the GIS technology for mapping and management of natural resources. As the planning process will become more participative and transparent GIS technology will play a very significant role in the planning and management of resources in the protected areas.

REFERENCES

Abhijeet et al, (1996). *Current Science*, Vol. **70**, No. 10.

Ables, E. D. (1977). (ed.) *The Axis deer in Texas*. Kleberg studies in natural resources. Texas Agricultural Experiment Station, College Station.

Acharya, B. B. (1997). Habitat occupancy by wild ungulates in Pench Tiger Reserve, Madhya Pradesh, M.Sc dissertation, Submitted to Saurashtra University, pp-50.

Ackerman, B. B., Lindzey, F. G. and Hemker, T. P. (1984). Cougar food habits in southern Utah. *J. Wildl. Manage.* **48**: 147-155.

Agee, J.K. and Pickford, S.G. (1985). Vegetation and fuel mapping of North Cascades National Park, Final Report, College of Forest Resources, Seattle.

Agee, J.K.; Stitt, S; Nyguist, M and Root, P. (1989). A Geographic Analysis of Historical Grizzly Bear Sightings in the North Casscades. *Photgram. Eng. of Remote Sensing*, Vol. **55**, pp 1637 - 1642.

Altmann, S. A. 1974. Baboons, space, time and energy. *Am.Zool.* **14**: 221-248.

Anderson, D. R. and pospahala, R. S. (1970). Correction of Bias in Belt Transect Studies of Immotile Objects. J. Wildl. Manage. **34** (1) : 141-146

Anderson, D. R., Laake, J. L., Crain, B. R., and Burnham, K. P. (1979). Guidelines for Transect Sampling of Biological populations. J. Wildl. Manage. **43** (1) : 71-79

Anon (1961). Mounting death toll follows severe draught. *Wildlife* **3**, pp22.

Artsybasher, E.S. (1983). Forest Fires and Their Control, Oxanian, New Delhi (1st ed. In Russian, 1974).

Ayeni, J.S.O (1975). Utilization of Water Holes in Tsavo National Park (East). *E. Africa Wildlife Journal*, Vol. **13**, Pp 305 - 323.

Ballon, P. (1986). Bilan Technique des amenagements realises en France pour reduire les impacts des grandes infrastructure lineaires sur les ongoles giblers (1) *Bull. Mens. Off. Natn. Chasse*, **104**, 33-39.

Barnes, R. F. W. and K. L. Jensen. (1987). How to count Elephants in Forests. IUCN Afican Elephant & Rhino Specialist Group Technical Belletin **1**: 1-6.

Barrette, C. (1991). The size of Axis deer fluid groups in Wilpattu national park, Sri Lanka. *Mammalia*. **55**(2): 207-220.

Basu, N.G. (1987). Forests and Tribal. Manisha, Calcutta. pp15.

Bell, R.H.V. (1982). The Effect of Soil Nutrient Availability on Community Structure in African Ecosystem. In Ecology of Tropical Savannas. B.J. Huntley and B.H. Walker (eds). Springerverlag, New York. pp193-216.

Ben-Shahar (1990). Resource availability and habitat preferences of three African ungulates, *Biol. Conserv* 54:357-365.

Ben-Shahar, R. (1990). Resource availability and habitat preferences of three African Ungulates. *Biological Conservation*, 54:357-365

Berger, J. 1978. Group size, foraging and anti predator ploys: an analysis of big horn sheep decisions. *Behav. Ecol. Sociobiol.* 4: 91-99.

Bertram, B. C. R. 1978. Living in groups: predators and prey. In: Behavioural ecology, an evolutionary approach.(Eds.J.R. Krebs and N. B. Davies), 64-96. Sinauer. Sunderland, Mass.

Berwick, S.H. & Jordan, P.A. (1971). First report of the Yale-Bombay Natural History Society studies of wild ungulates at the Gir forest, Gujrat, India. *J.Bombay nat. Hist. Soc.* 68:412-423

Berwick, S.H. (1974). The Community of Wild Ruminants in the Gir Forest Ecosystem, India. Ph.D. Thesis, Yale University, USA. pp226.

Bhatnagar, Y. (1997). Ranging and habitat utilization by Himalayan Ibex (*Capra ibex sibirica*) in Pin valley Wildlife Sanctuary, *Ph.D thesis*, submitted to Saurashtra University.pp. 114

Bhujanga Rao, D.D (1991). Habitat Utilization and Distribution pattern of Indian Wild Pig (*Sus scrofa cristatus*) in Sariska Tiger Reserve, Rajasthan. M.Sc. Dissertation, Saurashtra university, Rajkot. 51p.

Bishop, I.D. and Cutler, M. (1986). Information system for local fire hazard management. School of Environment and Planning, University of Melbourne.

Bourlier, F. (1963). Specific Feeding Habitats of African Carnivores. *African Wildlife*, Vol. 17, pp 21-27.

Bourliere, F. (1963). Conservation and Management of Game Stock, In: UNESCO, 1963. A Review of the Natural Resources of the African Continent, UNESCO, Paris. 437pp.

Brass, J.A.; Likens, W.C. and Thornhill, R.R. (1983). Wildland inventory for Douglas and Carson City Counties, Nevada, using Landsat and digital terrain data, NASA. Technical Paper 2137, Washington D.C.

Brown, A.A. and Davis, K.P. (1973). Forest fire control and use. McGraw-Hill, New York.

Brown, J.H. (1984). On the Relationship between Abundance and Distribution of Species. *American Naturalist*, 124: 255-279.

Buckland, S.T., Anderson, D.R., Burnham, K.p and Laake, J.L. (1993). Distance Sampling; Estimating abundance of Biological Populations. Chapman and Hall, London.

Burgan, R.E. and Shasby, M.B. (1984). Mapping of broad-area fire potential from digital fuel, terrain and weather data. *Journal of Forestry* 82:228-231.

Burnham, K.P., Anderson, D.R. and laake, J.L. (1980). Estimation of Density From Line Transect Sampling of biological populations. Wildlife Monograph, 72 : 1-202.

Burrogh, P.A. (1990). Principles of Geographical Information System for land Resources Assessment, Claredon Press, Oxford.

Camby, A. and Maizeret, C. (1985). Permeabilite des routes et dutoroutes vis-a-vis des mammiferes Carnivores: Exemple des etudes menees dans les landes de Gascogne. In Routes et faune Sauvage. Actes du Colloque. Ministere de 1' Equipment, du Logement, du, 1' Amenagement du Territoire et des Transports, Bagneux Cedex. pp183-201.

Causton, D.R. (1988). An Introduction to Vegetation Analysis: Principles, Practice in Interpretation. Unwin Hyman. 342p.

Chakrabarty, B. (1991). Habitat use by Radio Instrumented Chital, Sambar and Nilgai in Sariska Tiger Reserve. M.Sc Dissertation, Saurashtra University, Rajkot. 44p.

Champion and Seth (1968). A Revised Survey of the Forest Types of India. Manager of Publication, New Delhi.

Champion, H.G. (1936). A preliminary survey of the forest types of India and Burma, *Indian For. Rec.* 1:1-286.

Chaterjee, D. (1939). Studies on the endemic flora of India and Burma. *J. Roy. Asiat. Bengal Sci.* 5:1-69.

Chellam, R. (1993). Ecology of the Asiatic Lion (*panthera leo persica*). Ph.D. Thesis submitted to the Saurashtra University, Rajkot. 170p

Choudhary, R. (1986). Fire in bamboo areas: Lessons from Tadoba Naitonal Park, *The Indian Forester*, vol. **112** (10) pp 900-907.

Chuvieco, E. and Javier Salas (1996). *Int. Journal of Geographic Information System*, Vol. 10, No. 3, 333-345.

Chuvieco, E. and R.G. Congalton (1986). Remote Sensing of Environ, 29: 147-159.

Cody, M. L. (1974). Bird communities. Princeton, New Jersey. 318 pp.

Coe, M.J.; Cumming, D.H. and Phillipson, J. (1976). Biomass and Production of Large Aftican Herbivores Relation to Rainfall and Primary Production. *Oecologia*, 22:341-354.

Consentino, M.J.; C.E. Woodcock and J. Franklin (1981). Scenic Analysis for Wildlife fire-fuel characteristics in a Mediterranean climate, in Proceedings, 15th International Symposium on Remote Sensing of Environment, ERIM, Ann Arbor, MI, Pp 635-646.

Curio, E. (1976). *Ethology of predation*. Springer-Verlag, Berlin.

Curran, P.J. (1985). Principles of Remote Sensing (London: Longman).

Dabral, S.L. (1992). Use of Remote Sensing in Preparing Stock Maps. Proceedings of the Silver Jubilee Seminar on Training and Education in Remote Sensing for Resource Management, Indian Institute of Remote Sensing, Dehradun. pp168-176.

Dasman, R. F., and A. S. Mossman. (1962): Road strip counts for estimating numbers of African ungulates. J. Wildl. Manage. **26** (1): 101-104.

De Ruiter, J. R. 1986. The influence of group size on predator scanning and foraging behaviour of wedge capped capuchin monkeys. *Behaviour*. **98**: 240-258.

De, R.C & Spillett (1966). A study of the Chital or spotted deer in Corbett national park, Uttar Pradesh. *Journal of Bombay natural History Society*, **63**(3):576-598.

Deeming et al. (1978). The National Fire Danger Rating System, U.S. Department of Agriculture, Forest Service, Ogden, UT.

Delabraze, P. (1982). Les criteries devaluation des risques dincendies de forets, In Forest Fire Prevention and Control, Martinus Nijhoff/Junk Publications, The Hauge. 62-76pp.

Desmet. P.J.J. and Govers, G. (1996). Comparison of Routing Alogrithms for Digital Elevation Models and Their Implications for Predicting Ephemeral Gullies. *International Journal of Geographical Information System*. Vol. **10**, No. 3, pp311.

Dewis, J. and F. Frietas (1984). Physical and Chemical Methods of Soil and Water Analysis. *F.A.O. Soils Bulletin* 10. Rome. 275pp.

Dhaundiyal, R. (1997). Economic Assessment of Human-Forest Interrelationship in the Forest Corridor Linking the Rajaji and Corbett National Parks. Ph.D. Thesis, Jiwaji University. Pp 220.

Dinerstien, E. (1980). An Ecological Survey of Royal Kamali - Bardia Wildlife Reserve, Nepal. *Biological Conservation.* 18:5-38.

Dwivedi, A.P. (1993). Forests - The Ecological Ramifications. Natraj Publishers. pp38 & 47.

East, R. (1984). Rainfall, Soil Nutrient Status and Biomass of Large African Savanna Mammals. *African Journal of Ecology,* Vol. **22**: 245-270.

Eberhardt, L. L. (1968). A Preliminary Appraisal of Line Transect. J. Wildl. Manage. **82** (1) : 82-88.

Eberhardt, L. L. (1978). Transect Methods for Population Studies. J. Wildl. Manage. **42** (1) : 1-31

Edroma, E.L. (1981). Effect of Grazing on the Productivity of Grassland in Rwenzori National Park, Uganda. *African Journal of Ecology,* **19**: 313-316.

√**Édward, A.J. (1992).** Fire and Vegetation Dynamics, Studies from the North American Boreal Forests, Cambridge University Press. 6-7pp.

Eisenberg, J. F. and Lockhart, M. C. (1972). An ecological reconnaissance of Wilpattu national park, Ceylon. *Smithsonian Contributions to Zoology,* **101**: 1-118.

Eisenberg, J.F. (1980). The Density and Biomass of Tropical Mammals. In M.E. Soule and B.A. Wilcox (eds). pp34-35.

Eisenberg, J.F. and Seidensticker, J. (1976). Ungulates in Southern Asia: A consideration of Biomass Estimates for Selected Habitats. *Biological Conservation.* 10:293-307.

Elliot, J.P.; Cowan, I.M. and Holling, C.S. (1977). Prey Capture by the African Lion. *Canadian Journal of Zoology.* 55, pp1811-1828.

Esser, J. D. 1980. Grouping pattern of ungulates in Bonoue national park and adjacent areas, northern Cameroon. *Spixiana.* **3**: 179-191.

Estes, R. and Goddard, J. (1967). Prey selection and hunting behaviour of the African wild dog. *J. Wildl. Mgmt.,* **31**: 52-70.

FAO/ESCAP (1983). Wood Energy Development. Report of the Regional Workshop. pp5.

Findely, J.S. (1993). Bats: a community perspective, Cambridge university press, Pp 167.

Fitzgibbon, C. D. (1990). Why do hunting cheetahs prefer male gazelles. *Animal Behaviour*, **40**: 837-845.

Flasse, S.P. and P. Ceccato (1996). *International Journal of Remote Sensing.* Vol. 17, No. **2**, 419-424pp.

Forest Survey of India (1987). The State of Forest Report. GOI, Ministry of Environment and Forests, Dehradun. pp7.

Foster, J.B. and Coe, M.J. (1968). The biomass of game animals in Nairobi National park. *J.Zool.Lond.* **155**:413-425.

Fryxell, J.M. and Sinclair, A.R.E. (1988). Seasonal Migration by White Eared Kob in Relation to Resources. *African Journal of Ecology.* **26**:17-26.

Gadgil, M. & Meher-Homji, V.M. (1982). Conserving India's biological diversity. *In* Indo U.S. binational workshop on conservation and management of diversity. Dept. of Environment, New Delhi and India Inst. Of Sci., Banglore.

Giles, R.H. Jr. (1971). Population Manipulation. In R.H. Giles, Wildlife Management Techniques. 3rd Ed. revised. Wildlife Society, Washington, DC. Pp 521-526.

Giles, R.H. Jr. (1978). Wildlife Management. W.H. Freeman Co., San Francisco, CA. pp416.

Giles. R.H. Jr. and M.S. Fujita (1989). Proceedings of the International Conference on National Parks and Protected Areas, Kualalumpur, Malaysia. pp11-17.

Green, J.B. and Michael (1985). Aspects of the Ecology of Himalayan Musk Deer, Cambridge, St. John's College.

Greig-Smith, P. (1983). Quantitative Plant Ecology. In Studies in Ecology, Vol. 9. Blackwell Scientific Publications. 359p.

Haque, N. (1990). Study on the ecology of wild ungulates of Keoladeo National park, Bharatpur, Rajasthan, Ph.D Thesis, Centre of Wildlife & Ornithology, Aligarh Muslim University, Aligarh, pp-308.

Hayne, D. W. (1949). An Estimation of the Strip Census Method for Estimating Animal Populations. J. Wildl. Manage. 13 (2) : 145-157

Hill, M.O. (1979). TWINSPAN: A FORTRAN programe for Arranging Multivariate Data in an Ordered Two-way Table by Classification of the Individuals and Attributes. Ecology and Systematics, Cornell University, Ithaca, New York. 90pp.

Hirst, S. M. (1969). Ungulate Road-Strip Census In Africa. J. Wildl. Manage. **33** (1) : 41-49

Hodgson, M.; Jensen, J.; Mackey, H. and Coulter, M. (1988). Monitoring of Wood Stork Foraging Habitat Using Remote Sensing and Geographic Information Systems. *Photogram. Eng. Remote Sensing.* **54**:1601-1607.

Hoogerwerf, A. (1970). Udjung Kulon: Land of the last Javan Rhinoceros. E. J. Brill, Leiden.

Hopkins, B. (1965). Observations on Savanna burning in the Olokemji Forest reserve, Nigeria. *Journal of Applied Ecology*, **2**: 367-381.

Horn, H. S. 1968. The adaptive significance of colonial nesting in the Brewers Blackbird. *Ecology.* 49. 682-692.

Hornocker, M. G. (1970). An analysis of mountain lion predation upon mule deer and elk in Idabo primitive area. *Wildl. Monogr.*, **21**: 1-39.

Hubbell, Stephen P. (1979). Tree Dispersion, abundance and diversity in a tropical dry forest. *Science*, 30 march, **203**:1299-1309.

Hunt, A.; H.J. Dickens, and R.J. Whelan (1987). Movement of Mammals through Tunnels Under Railway Lines. *Australian Zool.*, **24**:89-93.

Jarman, M.V. and P.J.Jarman, (1973). Daily Activity of Impala. *E. African Wildlife Journal*, Vol. **11**, pp75-92.

Jarman, P. J. 1974. The social organization of antelope in relation to their ecology. *Behaviour.* **48**: 215-267.

Jarman, P.J. (1972). The Use of Drinking Sites, Wallows and Saltlicks by Herbivores in the Flooded Middle Zambesi Valley. *E. African Wildlife Journal*, Vol. **10**, pp193-209.

Johnsingh, A. J. T. (1983). Large mammalian Prey-predators in bandipur. *J. Bombay nat. Hist. Soc.* **80**:1-57.

Johnsingh, A. J. T. (1992). Prey selection in three large sympatric carnivores in Bandipur. *Mammalia.* **56**:4

Johnsingh, A.J.T. & K. Sankar (1991). Food plants of Chital, Sambar and cattle on Mundanthurai Plateau, Tamil nadu, South India. *Mammalia*, **55**(1):57-66.

Johnson, D.H. (1980). The comparison of usage availability measurements for evaluating resource preference. *Ecology* **61**: 65-71

Joslin, P. (1973). Asiatic Lion: A study of ecology and behaviour. Ph.D. thesis, University of Edinburgh: 1-249.

Karale, R.L. (1992). Natural Resource Management - A New Prespective, Natural Resource Management System, Department of Space, Govt. of India, Banglore.

Karanth, K. U. & Sunquist, M. E. (1992). Population structure, density and biomass of large herbivores in the tropical forest of nagarhole, India. *Journal of tropical Ecology* **8**:21-35.

Karanth, U. (1993). Predator-prey relationship amoung the larger mammals of nagarhole national Park. *Ph.D thesis*, submitted to Manglore University, India pp-180.

Karanth, U. K. (1988). Population structure, density and biomass of large herbivores in a South Indian tropical forest. *M.Sc. thesis*, University of Florida. 90pp.

Karanth, U. K. and Sunquist, M. E. (1995). Prey selection by tiger, leopard and dhole in tropical forests. *Journal of applied ecology.* **64**: 439-450.

Kent, M. & P. Coker. (1992). Vegetation Description and Analysis: A Practical Approach. CRC press & Belhaven press. 363p.

Keogh, H. J. (1983). A photographic reference system of the microstructure of the hair of southern African bovids. *S. Afr.J. Wildl. Res.* **13**:90-131.

Kesley, C. (1985). Master Plan Process for Parks and Recreation. Reston: Am. Alliiance for Health, Physical Education, Rec and Dance, 1985.

Kessell. S.R. and R.B. Good (1985). Technological Advances in Bush Fire Management and Planning in Symposium - Natural Disasters in Australia, Sydney.

Khan, J. A. and Vohra, U. 1992. Group size and group composition of Chital (Axis axis) in Gir, India. *Mammalia.* 56(4)

Khan, J.A. (1994). Habitat Ungulate Relationship in Gir Lion Sanctuary. Ph.D. Thesis submitted to Aligarh Muslim University.

Khan, Jamal. A. (1990). Gir Lion Project, Ungulate habitat Ecology In Gir. Project Report. Wildlife institute of india, Dehra Dun, India.

Khan, Jamal. A. (1994). Estimation of Ungulate Densities in Dry Tropical Forests of Gir: A Comparison of Three Analysis Procedures. *Tropical Ecol.* Vol. **35** (2): 275-283.

Khan, Jamal. A., Ravi Chellam and A.J.T. Johnsingh. (1995). Group Size and Age-Sex Composition Of Three major Ungulate Species In Gir Lion Sanctuary, Gujrat, India. *J. of B.N.H.S.* Vol. **92** (3) : 295-302

Khan, Jamal. A., Ravi Chellam., W.A. Rodgers and A.J.T. Johnsingh.(1996). Ungulate Densities and Biomass in the Tropical Dry Deciduous Forests of Gir, Gujrat, India. *J. of Tropical Ecol.* Vol. **12** (1) : 149-162

Koppikar, B. R. and Sabnis, J. H. (1976). Identification of hairs of some Indian mammals. *J. Bombay Nat. Hist. Soc.* **73**: 5-20.

Koster, S. H. and Hart, J. A. (1988). Methods of estimating ungulate population in tropical forests; *Afr. J. Ecol.* **26**: 117-126.

Kotwal, P.C. (1987). Ecological studies on evaluation of certain wildlife habitats and their utilization by major mammals in kanha National park. *D.Sc. thesis*, Sagar University, India.

Kruuk, H. (1972). *The spotted hyena.* Chicago: Univ. Chicago press.

Lakshmi, V. U. and Dutt, C. B. S. (1998). Micro-level planning and sustainable forestry through GIS, *Current Science*, Vol. **75** (3). Pp 245-255.

Lakshmi, V. U., Murthy, M. S. R. and Dutt, C. B. S. (1998). Efficient forest resources management through GIS and remote sensing, Current Science, Vol. **75** (3). Pp 272-282.

Lal, J.B. (1989). India's Forest Myths and Realities. Natraj Publishers, Dehradun. pp304.

Lal, J.B.; A.K. Gulati and M.S. Bist (1991). *International Journal of Remote Sensing.* Vol. **12**, No. 3, 435-443pp.

Lamprey, H.F. (1964). Estimation of Large Mammal Densities, Biomass and Energy Exchange in the Tarangive Game Reserve and the Masai Steppe in Tanganyika. *E. African Wildlife Journal*, **2**:1-46.

Lancia, R.A., Miller, S.D., Adams, D.A. and hazel, D.W. (1982). Validating habitat quality assessment : An example. *Trans. N. Am. Wildl. Conf.*, **47**:96-110

Lea, N.J. (1992). An Aspect-Driven Kinematic Routing Alogrithum, In Overland Flow, Hydraulics and Erosion Mechanics. A.J. Parsons and A.D. Abrahams (eds). London: UCL Press. pp393-407.

Legg, C. (1995). A Geographic Information System for Planning and Managing the Conservation of Tropical Forests in the Knucles Range. Special Issue of the Sri Lanka Forester. *Journal of Sri Lanka Forest Development.* pp37-62.

Legg, C. and N. Jewell (1995). A 1:50,000 Scale Forest Map of Sri Lanka: The Basis for a National Forest Geographic Information System. Special Issue of the Sri Lanka Forester. *Journal of Sri Lanka Forest Department.* pp3-21.

Leopold, Aldo. (1933). Game management. The Univ. of Wisconsin Press.

Lilisand, T.M. and R.W. Kiefer (1979). Remote Sensing and Image Interpretation. (New York: John Wiley).

Lynch, O.J. (1992). Securing Community based Tenurial Rights in the Tropical Forests of Asia - An Overview of Current and Prospective Strategies. Issues in Development, WRI. pp2.

MacArthur, R. H. and Pianka, E. R. (1976). On the optimal use of patchy environment . *American naturalist.*, **100**: 133-140.

Macleod, S.B.; G.I.H. Kerley and A. Gaylard. (1996). Habitat and diet of bushbuck *Trageleaphus scriptus* in the woody cape Nature Reserve: observations from fecal analysis, *S.Afr.J.Wildl.Res.* **26**(1): 19-25.

Manjrekar, N. (1997). Feeding ecology of Ibex (*Capra ibex sibirica*) in Pin valley Wildlife Sanctuary, *Ph.D thesis*, submitted to Saurashtra University.

Mark, D.M (1984). Automated Detection of Drainage Networks from Digital Elevation Models. *Cartographica.* **21**:168-178.

Maselli, F.; A. Rodolf; L. Bottai and C. Conese (1996). *International Journal of Remote Sensing.* Vol. **17**, No. 7, 1417-1423pp.

Maser, C.; J.E. Rodick and J. Thomas (1979). Wildlife Habitats in Managed Forests, The Blue Mountain of Oregon and Washington. Agriculture Handbook No. 553, Washington DC. pp96-103.

Mathur, V.B. (1991). The Ecological Interaction Between Habitat Composition, Habitat Quality and Abundance of Some Wild Ungulates in India. Ph.D Thesis submitted in University of Oxford, U.K.

Mathur, V.B. (1992). Habitat Monitoring in Protected Areas in India. Proceedings of the IV World Parks Congress on National Parks and Protected Areas at Caracas, Venezuela.

✓**Matson, M and B. Holben (1987).** *International Journal of Remote Sensing.* Vol. **8**, 509-516.

✓**Matson, M., Schneider, S.R., Aldridge, B. and Satchnell, B (1984).** NOAA Technical Reports, NESDIS, Washington, DC.

McArthur, R. H. and Wilson, E. O. (1967). The theory of island biogeography. Princeton, New Jersey. 203 pp.

McDougal, C. (1977). *The face of the tiger.* London: Rivington books.

Mckay, G. and Eisenberg, J. F. (1974). Movement patterns and habitat utilization of ungulates in Ceylon. In: The behaviour of ungulates and its relation to management. Pp:708-721. V. Geist and F. Walther (eds.). IUCN Publication, new Ser. No.41.

Mcnab,, B. k. (1963). Bioenergetics and the determination of home range size. *American Naturalist*, **97**: 133-140.

Mentis, M. T. (1970). Estimates of natural biomasses of large herbivores in the Umfolozi Game Reseve. *Mammalia* **34**:363-393.

Miller, W. and Johnston, D. (1985). Pecora X symposium, pp. 305-314.

Miquelle, D. G. et al. 1992. Sexual segregation in Alaskan Moose. Wildl. Monog. 122. J. *Wildl. Manage.* 20-35.

Mishra, C. (1993). Habitat use by Goral (*Nemorhaedus goral bedfordi*) in Majhatal Harsang Wildlife Sanctuary, Himachal Pradesh, India, M.Sc dissertation, Submitted to Saurashtra University, pp-55.

Muckenhirn, N. A. and Eisenberg, J. F. (1973). Home ranges and predation of the Ceylon leopard. In R. L. Eaton, ed. *The world's cats*, Vol **1**. World Wildlife Safari, Winston, Oregon.

Muirhhead, K. and Cracknell, A.P. (1985). Int. J. Remote Sens., Vol-**6**., pp. 827-833.

Mukherjee, S. Goyal, S. P. and Chellam, R. (1994). Standardisation of scat analysis techniques for leopard (panthera pardus) in Gir National park, Western India. *Mammalia*. **58**: 139-143.

Muller Dombois and Ellenberg (1974). Aims and Methods in Vegetation Ecology. John Wiley and Sons. 359pp.

Muller, C. (1993). Wildfire Threat Analysis - An Effective Decision Support System for Fire Protection Planning. In The Burning Question Fire in NSW Conference 5-7 August, 1993. Colls Harbour.

Musto, I.P. and T.J. Stubbs (1985). Adelaide Hills Bushfire Hazard Mapping Project. S.A. Department of Environment and Planning.

Natrajan, C. (1992). Geographic Information System in Resource Management. Proceeding of the Silver Jubilee Seminar on Training and Education in Remote Sensing for Resource Management. Indian Institute of Remote Sensing, Dehradun. pp128-130.

Norton, P. M., Lawson A. B., henley S. R. and Avery G. (1986). Prey of leopards in four mountain areas of the south-western Cape province. *S. Afr. J. Wildl. Res.* **16**: 47-52.

Norusis, M.J. (1948). SPSS + Advance Statistics. SPSS Inc., 444 N, Michigan Avenue, Chicago. Illinois, USA.

O'Callghan, J.F. and D.M. Mark (1984). The Extraction of Drainage Networks from Digital Elevation Data. *Computer Vision Graphics and Image Processing.* **28**:323-344.

Odum, E.P. (1971). Fundamentals of Ecology. W.B. Saunders Co., Philadelphia. 547pp

Owaga, M.L. (1975). The Feeding Ecology of Wildebeest and Zebra in Anthi-Kaputei Plains. *E. Afr. Wildlife Journal*, **13**:375-383.

Pabla. H.S. (1998). Development of a user-friendly wildlife monitoring methodology for protected areas in India, Ph.D thesis submitted to Forest Research institute (Deemed Univ) Pp.196.

Palenik, S. (1983). Light microscopy of medullary micro-structure in hair identification. *Microscope* **31**:129-137.

Palihawanda, N. (1995). The Application of Remote Sensing and GIS Techniques for the Detection of Change in Forest Cover. Special Issue of the Sri Lanka Forester. *Journal of the Sri Lanka Forest Department.* pp73-77.

Palmer, R. and Fairall, N. (1989). Caracal and African wild cat diet in the karoo National Park and the implications thereof for hyrax. *S. Afr. J. Wildl. Res.* **18**: 30-34.

Panwar, H.S. and V.B. Mathur (1992). Protected Area Network in India: A Review. Paper presented in the IV World Parks Congress, Venezuela.

Patel, A. H. (1992). Are cheetal stags more vulnerable to dhole predation than does?. *J. Bombay nat. Hist. Soc.* **89**: 153-155.

Peek, J.M. (1980). Natural regulation of ungulates (What constitutes a real wilderness?). *Wildl. Soc. Bull.* **8**:217-227.

Perrin, M. R. and Campbell, B. S. (1979). Key to mammals of the Andries Vosloo Kudu Reserve (Eastern Cape), based on their hair morphology, for use in predator scat analysis *S. Afr. J. Wildl. Res.* **10**: 3014.

Petrides, G.A. (1956). Big Game Densities and Range Capacity in East Africa. *Trans. N. Am. Wildlife Conf.* **21**:525-537.

Philips, J. (1965). Fire as Master and Servant: Its Influence in the Bioclimatic Regions of Trans-Saharan Africa. In Proceedings of 4th Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, Florida, 7-109pp.

Pianka, E. R. (1974). Evolutionary ecology. Harper and Row, New York. 356 pp.

Pielou, E.C. (1975). Ecological Diversity. John Wiley & Sons. 165pp.

Pielou, E.C. (1977). Mathematical Ecology. John Wiley & Sons. 348pp.

Prasad, N. (1998). Conservation planning for the Western Ghats of Kerela: II. Assessment of habitat loss and degradation, Current Science, Vol. **75** (3). Pp 228-235.

Prasad, S. N., Vijyan, L., Balachandran, S., Ramachandran, V. S. and Verghese, C. P. A. (1998). Conservation planning for the Western Ghats of Kerela: I. A GIS approach for location of biodiversity hot spots, Current Science, Vol. **75** (3). Pp 211-219.

Pratt, R.M., Putman, R.J., Ekins, J.R. and Edwards, P.J. (1986). Use of habitat by free ranging cattle and ponies in the New Forest, Southern England. *Journal of Applied Ecology*, **23**:539-557.

Pulliam, H. R. and T. Caraco. 1984. Living in Groups: Is there an optimal group size. In Behavioral ecology: an evolutionary approach. 122-147. Sinaur. Sunderland, Mass.

Putman, R.J. (1984). Facts from feaces. *Mammal. Rev.* **14**: 79-97

Rabinowitz, A. (1989). The density and behaviour of large cats in adry tropical forest mosaic in Huai Khaeng Wildlife Sanctuary, Thailand. *Nat. Hist. Bull. Siam. Soc.* **37**(2): 235-251.

Rajaram, A and Menon, R. K. (1986). A scanning electron microscope study of the hair keratins of some animals of the Indian subcontinent - a preliminary report. *J. Bombay Nat. Hist. Soc.* **83**: 427-429.

Raman, T.R.S. (1997). Factors influencing seasonal and monthly changes in the group size of Chital or axis deer in southern India, *Journal of Bio Sciences*, **22**(2): 203-218.

Rautenstrauch, K.R. and P.R. Krausman (1989). Influence of Water Availability and Rainfall on Movements of Desert Mule Deer. *J. Mamm.* **70**:197-201.

Raymond, S. (1991). College of Forestry. Stephen F. Austin State University, Texas.

Rice, C. (1984). The Behaviour and Ecology of Nilgiri Tahr, Texas. Texas A.M. University.

Roche, L. (1989). Forestry and Famine: Arrangements Against Growth Without Development. *The Ecologist.* 19(1) pp18.

Rodgers, W.A. (1979). The Implications of Woodland Burning for Wildlife Management: In Wildlife Management in Savannah Woodland, (Eds.) S.S. Ajayi and L.B. Halstesd. Taylor and Francis, London. 151-165pp.

Root, R.R.; S.C.F. Stitt; M.O. Nyquist; G.S. Waggoner and J.K. Agee (1986). Vegetation and Fire Fuel Models Mapping of North Cascades National Park. ACSM-ASPRS. *Annu. Convetion Tech.* 3:78-85.

Sale, J. B., A.J.T. Johnsingh and S. Dawson. (1990). Priliminary trials with an indirect method of estimating Asian elephant numbers. A report prepared for the IUCN/SSC Elephant Specialist Group.

Salwasser, H.H., Black, H. and Hanely,T. (1980). The Forest Service fish and wildlife habitat relationship system. USDA For. Serv., Pac. Southwest Reg., San Fransisco Typescript. 22pp.

Sankar, K. (1994). The Ecology of Three Large Sympatric Herbivores (Chital, Sambar, Nilgai) with Special Reference for Reserve Management in Sariska Tiger Reserve, Rajasthan, Pd.D. Thesis, Univ. of Rajasthan, Jaipur.

Sathyakumar, S. (1994). Habitat Ecology of Major Ungulates in Kedarnath Musk Deer Sanctuary, Western Himalayas. Ph.D Thesis submitted in Saurashtra University, Rajkot, Gujarat.

Sawarkar, V. B. (1986). Animal damage:predation on domestic livestock by large carnivores. *Indian Forester.*, **112**: 858-866.

Sawarkar, V. B. (1986). Fire fighting in Indian wildlife areas today, *The Indian Forester,* vol. **112** (10) pp 926-932.

Schaller, G.B. (1967). *The deer and the tiger.* The University of Chicago Press, Chicago.

Schaller, G.B. (1972). *The Serengeti Lion.* The University of Chicago Press, Chicago

Schoener, T. W. (1971). Theory of feeding strategies, *Ann. Rev. Ecol. Syst.*, **2**: 369-404.

Seidensticker, J. (1976a). Ungulate populations in Chitwan valley, Nepal. Biol. Conserv. **10:** 183-210.

Sharkey, M.J. (1970). The Carrying Capacity of Natural and Improved Land in Different Climatic Zones. *Mammalia.* 34:564-572.

Sharma, D. (1995). Ecology and Management of Lion and Ungulate Habitat in Gir Lion Sanctuary. Ph.D Thesis submitted to Saurashtra University, Rajkot, Gujarat.

Sinclair, A.R.E.; P.D. Olsen and T.D. Redhead (1990). Can Predators Regulate Small Mammal Populations? Evidence from House Mouse Outbreaks in Australia. *Oikos.* **59**:382-392.

Singh, R. V. (1995). Some studies on the ecology and behaviour of Nilgai (*Boselephus tragocamelus*) with an assessment of damage to agricultural crops and development of strategy for damage control in south western Haryana. Ph.D Thesis, Submittted to Aligarh Muslim University, India, pp-120.

Skidmore, A.K.; A.Gaul and P. Walker (1996). Classification of Kangaroo Habitat Distribution Using Three GIS Models. *International Journal of Geographical Information System.* Vol. **10**, 441-454.

Skovlin, J.M (1971). The Influence of Fire on Important Range Grasses of East Africa. In Proceedings of 11th Annual Tall Timbers Fire Ecology Confrence, Tall Timber Research Station, Tallahassee, Florida, 201-217.

Sokal, R.R. & F.J. Rolph (1981). *Biometry. The principles and practices of statistics in Biological Research.* Second edition. W.H. Freeman and Co., New York. 859 pp.

Stoen, G. O. (1994). The status and food habits of the tiger (*Panthera tigris*)population in the Karnali flodd plains of Royal Bardia National park, Nepal. *A thesis submitted in partial fulfilment of the requirement of M.sc. degree*, NLH, Agricultural University of Norway, pp 1-41.

Sunquist, M. E. (1981). The social organization of tigers (Panthera tigris) in Royal Chitwan National Park, Nepal. *Smithson. Contrib. Zool.*, **336**: 1-98.

Tangren, C.D. (1976). The Trouble with Fire Intensity. *Fire Technology.* **12**: 261-265.

Taylor, R. J. (1976). Value of clumping to prey and the evolutionary response of ambush predators. *American naturalist*, **110**: 13-29.

Taylor, R. J. 1982. Group size in the eastern grey kangaroo and the wallaroo. *Aust. wildl.* Res. 9: 229-237.

Thomas, J.W. (1979). Wildlife habitats in managed forests: the blue mountains of Oregon and Washington (ed. By Jackward Thomas) Washington DC: Wildlife Management Institute, Pp 512.

Tomlin, S.D.; S.H. Berwick and S.M. Tomlin (1987). The Use of Computer Graphics in Deer Habitat Evalution. In Geographic Information Systems for Resource Management: A Compendium. W. Ripple (ed.) American Society for

Photogrammetry and Remote Sensing and American Congress on Surveying and Mapping, Falls Church, VA. pp145-146.

Treisman, M. 1975. Predation and the evolution of gregariousness. I Models for concealment and evasion. *Anim. Behav.* 23:779-800.

Ulbirch, P. (1984). Untersuchung der Wirksamkeit von Wild warnreflektoren und der Eignung von Wilddurchschlassen. *Z. Jagdwiss.* 30:101-116.

Underwood, R. 1982. Seasonal changes in African ungulates groups. *J. Zool.* Lond. 196: 191-205.

Van Wagner, C.E. (1965). Describing Forest Fires - Old Ways and New. *Forestry Chronicle.* **41**: 301-305.

Van Wagner, C.E. (1977). In Fire and Vegetation Dynamics, Studies from North American Boreal Forest. Cambridge Studies in Ecology. Cambridge University Press. 43-44pp.

Varman, K. S. (1988). *A study on census of large mammals and their habitat utilization during dry season in Mudumalai Wildlife Sanctuary*, M.Sc. dissertation, Bharathidasan University, Tiruchirapalli.

Varman, K. S., Ramakrishnan, U and Sukumar, R. (1995). Direct and indirect methods of counting elephants: a comparison of results from Mudumalai Santuary; in *Proc. International Workshop on Conservation of Asian Elephants* (ed.) J. C. Daniel, B.N.H.S.

Varman, S.K. and R. Sukumar (1995). The Line Transect Method for Estimating Densities of Large Mammals in a Tropical Deciduous Forest: An Evaluation of Models and Field Experiment. *J. Biosci.* Vol. 20, 273-287pp.

Vesey-Fitzgerald, D. (1971). Fire and Animal Impact on Vegetation in Tanzania National Parks. In Proceedings of 11th Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, Florida. 297-317pp.

Vijayakumaran, P. and Menon, A. R. R. (1998). Estimation of bmaboo resources in Kerela by remote sensing techniques, *Current Science*, Vol. **75** (3). Pp 209-210.

Walther, F. 1972. Social grouping in Grants Gazelle in the Serengeti national park. *Z. Tierpsychol.* **31**: 348-403.

Webb, W. L. (1942). Notes on a Method of Censusing Snowshoe Hare Populations. *J. Wildl. Manage.* **6**: 67-69.

West, O. (1965). Fire in Vegetation and its Use in Pasture Management with Special Reference to Tropical and Sub-Tropical Africa. Mimeo Publication NO. 1/1965 Commonwealth Bureau of Pastures and Field Crops, Hurley.

West, O. (1971). Fire, Man and Wildlife as Interacting Factors Limiting the Development of Climax Vegetation in Rhodesia. In Proceedings of 11th *Annual Tall Timbers Fire Ecology Conference.* Tall Timbers Research Station, Tallahassee, Florida. 121-145pp.

Western, D. (1975). Water Availability and its Influence on the Structure and Dynamics of a Savannah Large Mammal Community. *E. Afr. Wildlife Journal.* Vol. **13**, 265-286pp.

Williamson, D.T and B. Mbano (1988). Wildebeest Mortality During 1983 at Lake Xau, Botswana. *Afr. J. Ecol.* **26**:341-344.

Williamson, D.T.; J. Williamson and K.T. Kgwamotsoki (1988). Wildebeest Migration in the Kalahari. *Afr. Journal of Ecology.* pp269-280.

Windberg, L. A and Mitchell, C. D. (1990). Winter diets of coyotes in relation to prey abundance in southern Texas. *J. Mammal.* **71**: 439-447.

Yanes, M; J.M. Velasco and F. Suarez (1995). Permeability of Road and Railways to Vertebrates: The Importance of Culverts. *Biological Conservation.* **71**: 217-222.

Yapp, W. B.(1956). The Theory of line Transects. *Bird Study* 3(2) : 93-104.

Yonzon et al. (1991). *Ambio.* Vol. **20**, No. 7, 285-288pp.

Yool, S.R., O.W. Eckhardt, J.E. Estes and M.J. Cosentino (1985). Describing the Bush Fire Hazard in Southern California. *Annual Association Am. Geography.* 75: 417-430.

Young, T.N.; J.R. Elby; H.L. Allen; M.J. Hewitt and K.R. Dixon (1987). Wildlife Habitat Analysis Using Landsat and Radiotelemetry in GIS with Application to Spotted Owl Preference for Old Growth. In Proceeding of GIS'87 San Francisco. American Society for Photogrammetry and Remote Sensing and American Congress on Surveying and Mapping. University of California, Berkley. 595-600pp.

Appendix I

PLANT LIST

Common name	Scientific name
1. ACHAR	(*Buchnania lanzan*)
2. AIN	(*Terminalia tomentosa*)
3. AMALTAS	(*Cassia fistula*)
4. APTA	(*Bauhinia recemosa*)
5. AMTA	(*Bauhinia malabarica*)
6. ANJAN	(*Hardwickia binnata*)
7. ARJUN	(*Terminalia arjuna*)
8. AONLA	(*Emblica officinalis*)
9. BAHERA	(*Terminalia belerica*)
10. BEL	(*Aegel marmelos*)
11. BER	(*Zizyphus jujuba*)
12. BHARATHI	(*Gymnosporia montana*)
13. BHIRRA	(*Chloroxylon swietenia*)
14. BHUL BHULI	(*Indigofera pulchella*)
15. BIBA	(*Semecaepus anacardium*)
16. BIJA	(*Pterocarpus marsupium*)
17. CHICHWA	(*Albizzia odoratissima*)
18. CHILATI	(*Caesalpinia sepiaria*)
19. DHAMAN	(*Grewia abutifolia*)
20. DHAURA	(*Annogeissus latifolia*)
21. DHOBEN	(*Dalbergia paniculata*)
22. DIKAMALI	(*Gardenia lucida*)
23. GADHAPALAS	(*Erythrina suberosa*)
24. GARADI	(*Cleistanthus collinus*)
25. GHATBOR	(*Zizyphus xylopyra*)
26. GHOGAR	(*Gardenia latifolia*)
27. GHOTI	(*Zizyphus rotundifolia*)

28. GUNJ (*Abrus precatorius*)
29. HALDU (*Adina cordifolia*)
30. HARDULI (*Olax scandens*)
31. HINGAN (*Balanites roxburghii*)
32. HIRDA (*Terminalia chebula*)
33. HIWAR (*Acacia leucppholea*)
34. IMLI (*Tamarindus indica*)
35. IRUNI (*Zizyphus cenoplia*)
36. JAMUN (*Sizhizium cuminii*)
37. KAWIT (*Feronia elephantum*)
38. KAKAI (*Flacourtia ramontchi*)
39. KARAM (*Mitragyna parviflora*)
40. KALA SIRIS (*Albizzia procera*)
41. KARAI (*Miliusa velutina*)
42. KARANJ (*Pongamia pinnata*)
43. KATUMBER (*Ficus hispida*)
44. KHAIR (*Acacia catechu*)
45. KATSAWAR (*Bombax malabaricum*)
46. KHIRNI (*Mimusops hexandra*)
47. KINHI (*Albizzia lebbek*)
48. KALA KUDA (*Wrightia tinctoria*)
50. KUKADRANJ (*Calycopteris floribunda*)
51. KARU (*Sterculia urens*)
52. KUMBHI (*Carea arborea*)
53. KUSUM (*Schleichera* oleionoidea)
54. KATAIN (*Bridelia retusa*)
55. LAHAN LOKHANDI (*Dodonoea viscosa*)
56. LOKHANDI (*Ixora parviflora*)
57. MAHUA (*Bassia latifolia*)
58. MEDSINGH (*Dolicandrone falcata*)
59. MOKA (*Schrebera swietenioides*)
60. MOWAI (*Odina wodier*)
61. MAROR (*helixtris isora*)