Development of Spatial Database in Geographical Information System Domain for Bandhavgarh Tiger Reserve and Assessment of Landuse/Landcover changes

THESIS
SUBMITTED TO THE

FOREST RESEARCH INSTITUTE
DEEMED UNIVERSITY
DEHRADUN, UTTARAKHAND
FOR
THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
FORESTRY
(Forest Ecology and Environment)

By

PANNA LAL
Wildlife Institute of India,
Chandrabani, Dehradun
Uttarakhand

2007

Dedicated to my teachers who introduced me to the intricacies of research and to my family members for their love and support.

DECLARATION

I hereby declare that the thesis entitled **"Development of Spatial Database in Geographical Information System Domain for Bandhavgarh Tiger Reserve and Assessment of Landuse/Landcover Changes"** submitted to Forest Research Institute (Deemed University), Dehradun, for the award of the degree of Doctor of Philosophy in Forestry, embodies the result of my own work and observations and in that respect investigation appears to advance the knowledge in the subject.

(Panna Lal)

V. B. Mathur, D.Phil. (Oxon.)
: & Dean,
ulty of Wildlife Sciences

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that the thesis entitled **"Development of Spatial Database in Geographical Information System Domain for Bandhavgarh Tiger Reserve and Assessment of Landuse/Landcover Changes"** submitted to the Forest Research Institute (Deemed University), for the award of the degree of Doctor of Philosophy in Forestry, embodies bonafide research work carried out by Shri Panna Lal under my supervision and guidance. No part of this thesis has been submitted for any other degree. To the best of my knowledge and belief, the thesis embodies the original work of the candidate. It fulfills all the requirements laid down in the Ordinance of Forest Institute (Deemed University) for this purpose.

Place : Dehradun
Date : 27th February, 2007

(Dr. V.B. Mathur)
Supervisor

1. Qamar Qureshi
enior Reader

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that the thesis entitled **"Development of Spatial Database in Geographical Information System Domain for Bandhavgarh Tiger Reserve and Assessment of Landuse/Landcover Changes"** submitted to the Forest Research Institute (Deemed University), for the award of the degree of Doctor of Philosophy in Forestry, embodies bonafide research work carried out by Shri Panna Lal under my supervision and guidance. No part of this thesis has been submitted for any other degree. To the best of my knowledge and belief, the thesis embodies the original work of the candidate. It fulfills all the requirements laid down in the Ordinance of Forest Institute (Deemed University) for this purpose

Place : Dehradun
Date : 27th February, 2007

(Sh. Qamar Qureshi)
Co-Supervisor

FOREST RESEARCH INSTITUTE
DEEMED UNIVERSITY
DEHRADUN

This is to certify that Mr.**Panna Lal** enrolment no **0109/WII/E-1120/R-626/7-759** carried out work under Dr.V.B. Mathur and Shri Qamar Qureshi at the Wildlife Institute of India Centre of Forest Research Institute (Deemed University). The topic of the research registered with FRI Deemed University was **"DEVELOPMENT OF SPATIAL DATABASE IN GEOGRAPHICAL INFORMATION SYSTEM DOMAIN FOR BANDHAVGARH TIGER RESERVE AND ASSESSMENT OF LANDUSE/LANDCOVER CHANGES"**. The scholar presented his work in the pre-thesis submission seminar held on date 20th February, 2007 and the RAC found the work to be satisfactory and recommends the work to be presented in the form of the thesis for evaluation by examiners for "Award of Ph.D. Degree" by FRI Deemed University.

(Supervisor)

Head of Division

(Co-Supervisor)

P. K. Mathur 27/2/07

Expert Member

Expert Member

Expert Member

Chairman RAC

No. F/ /7-759/2001-DUC
Forest Research Institute
(Deemed University)
P.O.: I.P.E., Kaulagarh Road
Dehra Dun – 248 195

Dated ________________ 2001

☎: 0135 – 751826
EPBX: 757021-28 – 4439, 4495 (Ext.)
E-Mail: arorasd@icfre.up.nic.in

To,

Sh. Panna Lal
Wildlife Institute of India
P.O. Box.18, Chandrabani,
Dehra Dun – 248 001.

Sub: -Registration for **Doctor of Philosophy Degree in Forestry.**

Dear Sir/Madam,

In response to your application dated 14-8-2001 for enrolment as Research Scholar for the Degree of Doctor of Philosophy in this Institute, it is to inform you that the following decisions have been taken: -

i. You have been registered for Doctor of Philosophy w.e.f. 01-09-2001 as an **External** Research Scholar.

ii. Your registration number is: - 0109/WII/E-1120/R-626/7-759.

iii. The Topic for research approved by the F.R.I (Deemed University) **"Development of Spatial database in geographical information system Domain for Bandhavgarh Tiger reserve and assessment of Landuse/Landcover changes."**

iv. Name of Supervisor: -Dr. V.B. Mathur.

You are advised to deposit immediately the following fees in the office of Deemed University by Bank Draft in favour of Registrar, F.R.I., Deemed University.

i.	Registration Fee	Rs. 1000/-
ii.	Magazine Fee	Rs. 300/-

and start your research work after showing the payment slip to the Head of the Division/Supervisor.

The requisite fee should be deposited within one month from the date of issue of this letter in the FRI(Deemed University) failing which his/her registration number given above stand cancelled.

... record of the progress of every Ph. D. Scholar shall be kept by his/her Supervisor. Six monthly progress reports of the candidate shall be forwarded by the Supervisor in March and September.

Registration of a Ph. D. Scholar is liable to be cancelled by the Director at any time if:

Two consecutive six monthly progress reports are not submitted at all or are not satisfactory.

A Ph. D. Scholar shall not be permitted to take any other degree course, but may be permitted by the RAC to take part-time Diploma or Certificate course(s) not affecting the scholars research work adversely.

A Research Scholar shall be permitted to submit his thesis not earlier than twenty four months from the date of his/her registration.

The Research Scholar may not later than eight months from the date of Registration, modify the scheme of the research work or nature or scope of the subject, on the recommendation of the Supervisor and RAC with the approval of Director.

In case a Research Scholar does not submit his thesis within six calendar years from the date of permission granted to him unless the term is extended by the Research Degree Committee on the recommendation of the Advisory Committee for a further period of 1 year as a special case, his/her registration shall lapse and the name of the candidate will be removed from the list of those registered for Ph. D. Degree without any intimation.

Further the performance of the Research Scholar shall be evaluated at the end by the R.A.C. concerned and evaluation report may be sent to the Registrar, F.R.I., (DEEMED UNIVERSITY).

Please note that your Registration as Research Scholar is to be governed as per rules, regulation and ordinances of F.R.I., Deemed University, which will be applicable from time to time. For all further correspondence please quote your registration number.

Yours faithfully,

(S.D. Arora)
Registrar
F.R.I., Deemed University

Copy to :-

1. Dr. V.B. Mathur, Professor & Head, Department of Protected Area Network, Wildlife Institute of India, Dehra Dun 248 001.
2. The Nodal Officer, Wild Life Institute of India, P.B. No. 18, Chandrabani, Dehra Dun – 248 001.
3. The Guard File.

(S.D. Arora)
Registrar
F.R.I., Deemed University

ACKNOWLEDGEMENTS

I express my sincere thanks and gratitude to Sh. S.K. Mukherjee, Sh. V.B. Sawarkar, Sh. S.Singsit, all former Directors of the Wildlife Institute of India (WII) and Sh. P.R. Sinha, Director, WII, Dr. A.J.T. Johnsingh, former Dean WII for providing encouragement and logistic support during the course of this study.

I would like to express special gratitude to my supervisor Dr.V.B. Mathur, Dean for introducing me to research and for his guidance, suggestions, encouragement, inspiration and patience throughout the study, which has helped me to complete the thesis.

I wish to express my gratitude to my Co-supervisor Sh. Qamar Qureshi, Senior Reader for his guidance, suggestions, encouragement, analysis and for carefully going through the final draft of the thesis.

I thank the Madhya Pradesh State Forest Department and Bandhavgarh Tiger Reserve authorities for supporting this study. I am grateful to Shri P.K. Mishra, former PCCF (Wildlife) Govt. M.P., Shri P.K. Sen, former Director, Project Tiger, MoEF for their valuable support for this study. I am also grateful to Shri Asit Gopal, Shri L.K. Chowdhary, Dr. U. Prakasam all former Field Directors of BTR, Shri Ashish Verma, former Dy.Director BTR, for their cooperation and logistic support for the fieldwork. I am thankful to Shri Banerjee former ACF, Shri O.P. Tiwari, ACF, Shri Kumbare, ACF, Shri Korche, ACF, Field Staff and Office staff of BTR, Shri A.K. Dewedi, Cartographer, Shri

Mishra, Shri Shukla, Shri B.D.Tripathi, Shri Khan, Shri B. Patel, Shri Ashish, Shri Jiyalal, Shri Sanjay Pandey for the help and co-operation extended by them during the field work.

At the Institute I am grateful to Dr. P.K. Mathur, Dr. G.S. Rawat, Dr. Y.V. Jhala, Dr. Asha Rajvanshi, Dr. S.P. Goyal, Dr. K.Sankar, Sh. A.K. Bhardwaj, Dr. B.S. Adhikari, Dr. V.P. Uniyal, Dr. S. Sathyakumar, Dr. K. Vasudevan, Dr. Bivas Pandav, Dr. K.Sivakumar, Dr. S. Chowdhary, Shri B.C. Choudhary, Dr. NPS Chauhan, Dr. S.A. Husssain, Smt. Bitapi Sinha, Dr. Ruchi Badola, Sh. D. Chakraborty, Dr. P.K. Malik, Dr. Parag Nigam, Dr. B.K. Mishra for their guidance and support at various stages of work.

I also extend my thanks to Dr. K. Ramesh, Dr. Ashish David, Dr. Hiten, Dr. Ashok Verma, Sh. Shrish, Dr. Daraksha Baquer, Ms. Babita, Sh. Jayapal, Sh. Rashid, Sh. Bhaskar, Sh. Santanu, Dr. Bargali, Dr. Naim, Sh. Sandeep, Dr. Ashish, Dr. Harish for helping me in various ways.

I thank Shri S.S. Oberoi, former Finance Officer, Shri S.S. Lamba Finance Officer, Shri Dubey, Shri Gopalacharyalu, Shri Naveen Singhal, Smt. Baljeet Kaur, Shri Khrak Singh, Shri Rajeev Gupta, Sh. Pathak, Shri Rawat, Sh. Malhotra, Sh. P.K. Aggrawal, Ms. Ahuja, Sh. Rajeev Mehta, Sh. Ramkumar, Sh. M.D. Gupta, Sh. Negi, Sh. Narendra Aswal, for their support in management of project accounts and administration. Dr. M.S. Rana, Dr. P. Pal, Sh. Y.S. Verma, Sh. Madan Uniyal, Sh. Kishen, Sh. Mahesh, Sh. Wilson, Sh. Ajay, Sh. Vinod, Sh. R.Sundriyal, Sh. C.P.Sharma and Sh.M.M Babu, Sh. P.L. Saklani, Sh. Ravindra, Smt M. Bishnoi, Sh. Gyanesh, Sh. N.P. Sai are thanked for providing assistance in the study.

I express my special thanks to Shri R. Thapa, Shri V.Sukumar, Dr. M.K. Agarwal, Shri L.N. Sharma, Shri D.S. Pundir, Shri M. Veerappan, Dr. J.S. Kathayat, Shri V. Sharma, Shri Harendra, Shri N.S. Bist, Shri M. Arora, Smt. Alka Aggarwal, for their vital support in carrying out Computer & GIS work.

I would like to express my sincere and gratitude to Late Dr. A.K. Tiwari, Director U-SAC, for valuable suggestions and guidance. I thank Dr. R. Dobhal, Direct U-SAC, Sh. Sunil Chandra, Sh. Anurag, Sh. Saurav, Sh. Abhishek, Ms. Monika, Ms. Chandrika, Sh. Jaswant, Sh. Jaisingh and Sh. Bharti for their assistance. I would like to thank Dr. S.P.S. Kushwaha, Scientist IIRS, Dr. Sarnam Singh, Scientist IIRS, Sh. A.K. Sardar Scientist for their valuable suggestions and library support.

I express my deepest gratitude to my parents and my wife Sunita, daughter Ashlesha, son Piyush, for their care, love, and affection.

Last but not least I thank Shri G.C. Patial and Shri Rajeev Thapa for their assistance in word processing. I express my warm appreciation collectively to all the people who have helped me directly or indirectly during the study and in finalization of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

MODEL

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

SUMMARY

The study on "Development of spatial database in Geographical Information System Domain for Bandhavgarh Tiger Reserve and Assessment of Landuse/Landcover Changes" was carried out between 2001 and 2006. The major objectives of the study were (a) Mapping of major vegetation communities using remotely sensed data, (b) Assessment of changes in landuse/landcover using time series analyses with a focus on areas from which villages have been relocated as part of the ecodevelopment initiative (c) Development of a resource database on ecological and management attributes for management of Bandhavgarh Tiger Reserve.

The study has covered the physical, floral and faunal aspects of Tiger Reserve. The Tiger Reserve comprises two management units *viz.* Bandhavgarh National Park (448.84 km^2) and Panpatha Wildlife Sanctuary (245.84 km^2). The Bandhavgarh Tiger Reserve is located in Umaria district of Madhya Pradesh (between 23^0 30' 00" N to 23^0 57' 00" N latitude and 80^0 47' 15" E to 81^0 11' 45" E longitude).

Landuse/Landcover mapping plays a very important role in natural resource management. In this study, a detailed landuse/landcover analyses has been carried out using remotely sensed data and ground truthing. Mapping of major landuse/landcover categories was done using satellite data (FCC of digital IRS 1A, 1B and 1C, Nov/Dec 1988, 1994 and 2000). A total of 12 classes, 7 in forest area and 5 in non-forest were mapped. Area under different landuse/landcover categories has been determined. The major forest types are Sal forest, Mixed forest, Open Mixed forest, Bamboo, Grassland, Riparian, Scrubland and the major non-forest types are Rocky outcrops, Plantation, Habitation, Agriculture and Water bodies. In year 1988, forest area was 92.68% and non-forest area was 7.32%. In year 1994, forest area was 92.03% and non-forest area was 7.97%. In year 2000, forest area was 91.54% and non-forest area was 8.46%. The satellite data has been digitally interpreted in this study.

The vegetation structure and composition were studied by laying 200 sample plots and species associations were determined using "Nearest Neighbor' method. There are 5 major vegetation associations *viz* Sal, Teak, Bamboo, Khair and a mixed association of 17 species. Species Richness and Diversity Index were also calculated. Tala and Magdhi Ranges have higher Species Richness and Diversity Index compared to Khitauli and Panpatha Ranges, mainly because of good forest cover and availability of water sources. The overall Species Richness is 15.49$\pm$ 2.35; Evenness Index is 0.93 $\pm$ 0.02 and Diversity Index is 1.10 $\pm$ 0.08.

Change detection analysis was done for two time periods *viz.* 1988 - 1994 and 1994 - 2000. For change detection ERDAS, Arcinfo and Arcview softwares were used. The techniques used were Image differencing, NDVI Differencing and Image Regression. Changes were studied to understand the landscape pattern and function both at the spatial as well as temporal scale. Change detection analysis provided information on changes in forest types and spatial statistics. Increasing human and cattle populations and road construction are the major drivers of forest change in and around Bandhavgarh Tiger Reserve. The total change in landuse/landcover categories from 1988 to 1994 was 11.75% and from 1994 to 2000 it was 11.83%. The total geographical area

remained unchanged. The decrease in area of forest types was observed in Sal forest, Mixed Forest, Open Mixed forest and Bamboo forest. The increase in area of forest type was observed in Grassland, Scrubland, Habitation and Agriculture areas. Bamboo forest have decreased in the buffer zone but have increased in core zone.

Between 1988 – 1994, decline in area was observed in Sal forest (1.08%), Mixed forest (0.59%), Open Mixed forest (2.48%) and Bamboo forest (1.07%) while during the same period increase in area was observed in Grassland (0.32%), Scrubland (2.76%), Agriculture (10.98%) and Habitation 15.58%. Between 1994 – 2000, a decline in area was observed in Sal forest (1.35%), Mixed forest (0.68%), Open Mixed forest (2.05%) and Bamboo forest 0.63% while during the same period an increase in area was observed in Grassland (2.22%), Scrubland (2.35%), Agriculture (7.50%) and Habitation 10.27%. The buffer zone has been subjected to more changes as compared to the core zone mainly due to pressures from habitations. The considerable changes observed in agriculture and habitation areas between 1994 to 2000, have increased the pressure on the forest of Bandhavgarh Tiger Reserve due to increase in livestock numbers.

The assessment of the landuse/landcover changes from 1988 to 1994 and 1994 to 2000 in different categories in Bandhavgarh Tiger Reserve shows interesting trends. There has been a general reduction in Sal forest, Mixed forest and Open Mixed forest but in core area Bamboo forest has increased during the 12 year period. There is also an increase in the overall grassland area in core area, which has been very beneficial for many ungulates species.

During the mid 1980s gregarious flowering of bamboo occurred in Umaria district of Madhya Pradesh. As part of this study, an effort was mode to detect the change in Bamboo forest cover from 1988 to 2000. Tala Range which is the most protected Range in BTR was selected for this study. The results indicate that in Tala Range, Bamboo forest cover increased by 96.79 ha between 1988 and 1994 and by 102.15 ha between 1994 and 2000. This increase in bamboo has proved to be very useful for the ungulate species as the young bamboo provides good forage values.

Using BioMapper statistical software, an Ecological Niche Factor Analysis (ENFA) was carried out. The ENFA was conducted for one herbivore species (Chital) and one carnivore species (Tiger). Global correlation matrix, global mean vector, species covariance matrix, species mean vector eigenvalues and score matrix were calculated for these species. Based on the above values, Habitat Suitability Index was calculated and mapped.

In this study a very comprehensive spatial database in GIS domain has been developed. The spatial database has 23 thematic layers out of which 17 are primary layers and 6 are derived. This database has been transferred to Bandhavagrh Tiger Reserve and is being used in the preparation of the management plan and monitoring of natural resources. The study has successfully demonstrated the use of Remote Sensing and GIS in enhancing protected area management capability.

CHAPTER 1

General Introduction

1.1 INTRODUCTION

The Bandhavgarh Tiger Reserve (BTR) is very rich in flora and fauna and forms a part of 6A Biogeographic Zone (Rodgers and Panwar, 2002).

Forest is a major natural resource and plays a prominent role in maintaining environmental balance. To ensure planned development of this critical resource through scientific management, knowledge of its interaction with other landuse, density, composition, regeneration status is required.

In many areas forest maps have been found lacking in accuracy, appropriate details and timeliness to be used effectively for forest management requirements (Houghton and Woodnell, 1981).

Recent developments in remote sensing technology have indicated that if it is judiciously combined with ground based studies, it is possible to carry out detailed forest inventories and monitoring of natural vegetation cover at various scales (Botkin *et al,* 1984). Application of GIS in assessing habitat, resource availability and its management have been done in several studies (Dubey, 1999).

Satellite remote sensing has played a key role in providing information about forest cover, vegetation type, and their changes on a regional scale. Forest vegetation types have been described on the basis of physiognomy, structure, function and composition (Forsberg, 1967).

Based on specific needs of wild animals, a grid based criteria indexing method has also been adopted to derive a habitat suitability index in Kanha National Park for wild animals such as the gaur, sambar and tiger. Satellite data has also been successfully used to delineate different cover boundaries (Tiwari *et al.* 1990). Naithani (2000) has done habital charcterization in the Great Himalayan National Park (GHNP) using Remote Sensing and GIS. A GIS approach to landuse change dynamic detection has been carried out by Lo and Shipman (1990).

Vegetation activity can be monitored and related to different phenological status of vegetation. Singh (1989) reviewed available digital change detection and ground truth methods. Bhan *et al*. (1989) used digital change detection techniques in an area around Shimla.

Landuse planning is a continuous, dynamic and cyclic process in which monitoring of cover changes play a vital role.

1.2 THE OBJECTIVES OF THIS STUDY ARE

i) Mapping of major vegetation communities using remotely sensed data.

ii) Assessment of changes in landuse/landcover using time series analyses with a focus on areas from which villages have been relocated as part of the ecodevelopment initiative.

iii) Development of a resource database in (ecological and management attributes) for management of Bandavgarh Tiger Reserve.

1.3 JUSTIFICATION

The present study provides valuable and significant inputs for management of a protected area. For better management, spatial database in Geographical Information System (GIS) domain has become a very effective tool to aid and facilitate informed decision-making.

The potential of Geographical Information System (GIS) and Remote Sensing capabilities to develop and analyse multi-layered thematic database and changes over a time period has been successfully demonstrated in this study.

1.4 ORAGNIZATION OF THE THESIS

The thesis is organized in six chapters; Chapter I deals with general introduction and objectives of the study. Chapter II deals with the study area. Chapter III provides brief review of literature with detailed landuse/landocver classification for the years 1988, 1994 and 2000 and mapping of vegetation in and around Bandhavagrh Tiger Reserve. Chapter IV deals with change detection of landuse/landcover from 1988 to 1994 and 1994 to 2000 using remotely sensed data. Chapter V provides information about multi-thematic layer spatial and aspatial information for development of a resource database in GIS domain. Chapter VI provides conclusions from the study area.

CHAPTER 2

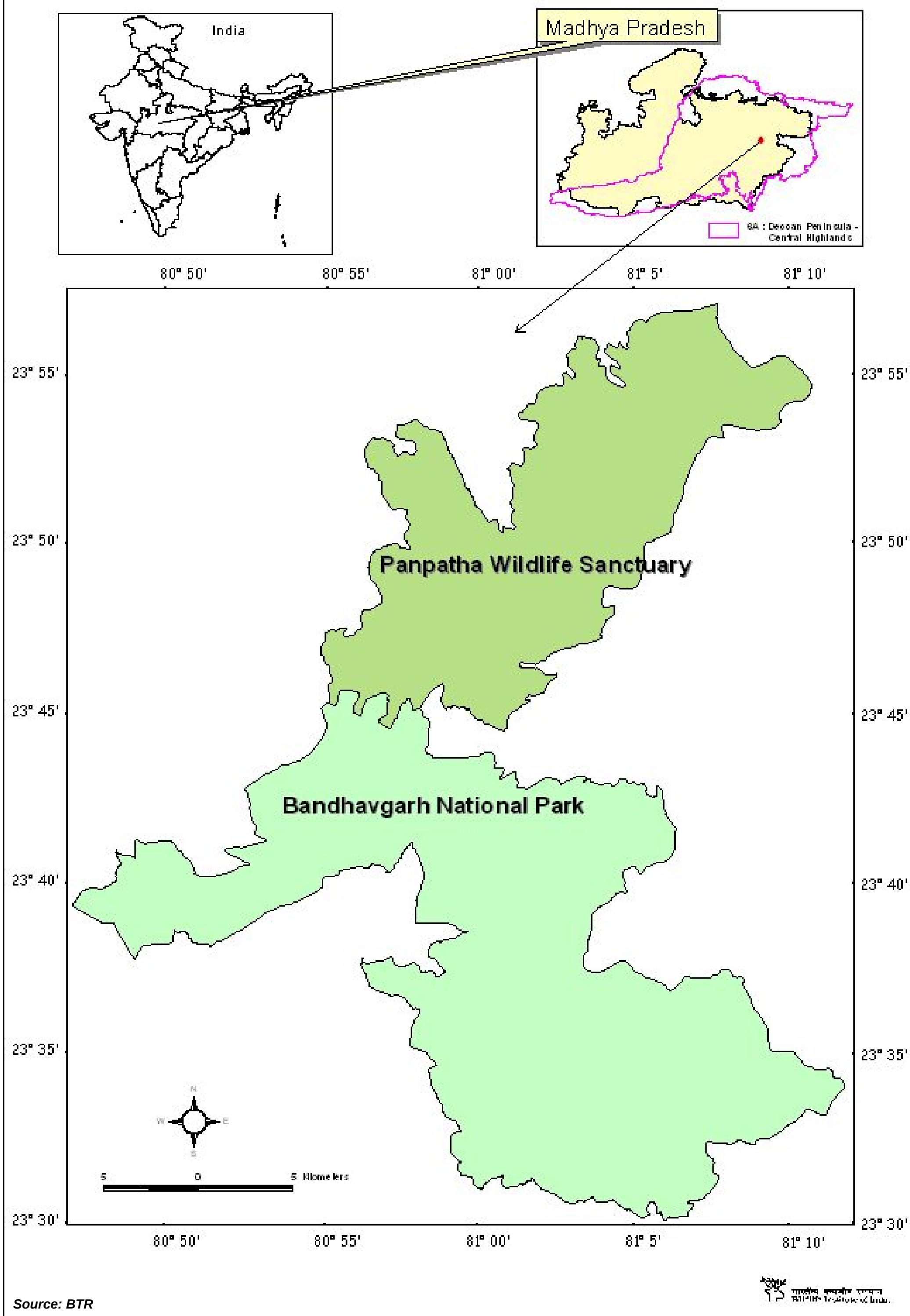
Study area

2.1 INTRODUCTION

The study was carried out in Bandhavgarh Tiger Reserve (BTR) in Madhya Pradesh (Fig 2.1). The area of BTR is 694.68 sq. km and lies between 23^0 30’ 00” N to 23^0 57’ 00” N latitude and 80^0 47’ 15” E to 81^0 11’ 45” E longitude and altitude varies from 440m to 810m. The area is surrounded on all sides by Umaria Forest Division and Johila River forms the boundary of North Shadol Forest Division. Bandhavgarh Tiger Reserve is a prominent tiger reserve in India. The rich flora supports an equally diverse fauna (Gopal, 1991). Bandhavgarh Tiger Reseve is a classic example of a habitat island (Sawarkar, 1986). High density of tigers reaching almost saturation level for the area, tends to show ‘spacing phenomenon’ in the individuals and spreading towards buffer zone (Dwivedi, 1987). The park provides very good sighting Opportunities of Tiger (Tyabji, 1991). The Bandhavgarh Tiger Reserve is an important tiger conservation area of the country (Panwar, 1986). The Bandhavgarh National Park has great future, not only for Vindhyan region but also for the State and country as well and its planning and management should be done in a scientific way (Gruber *et al*, 1982). The Tiger Reserve comprises Bandhavgarh National Park (448.84 sq.km) and Panpatha Wildlife Sanctuary (245.84 sq.km).

Fig. 2.1

Bandhavgarh Tiger Reserve



Source: BTR

BTR has perennial nalas and rivers such as Charanganga, Janad, Damar, Bhadar, Umarar, Nanagar and Dudharia. It is approachable by road from both Umaria and Katni by motorable road, by rail Umaria is the nearest station and air service is available at Jabalpur (191 km) and Khajuraho (275 km) from tiger reserve.

2.2 TOPOGRAPHY AND GEOLOGY

Topographically, Bandhavgarh TR is extremely rugged with small hillocks. It is part of a larger plateau having a minimum altitude of 400m and maximum altitude is 810m above m.s.l. The topography is rugged, interspersed with grassy swamps (Gopal, 1991). The hill formations are bounded by Charanganga and Damna river. The Sanctuary areas is generally plain and some parts have undulating hillocks, highest point of the Sanctuary is 500m above m.s.l. The sandstone covers almost entire Bandhavgarh Tiger Reserve. Topography, several faults occurs NE – SW and SW – SE, and it has a rugged topography (Sonakia, 1993).

Geology

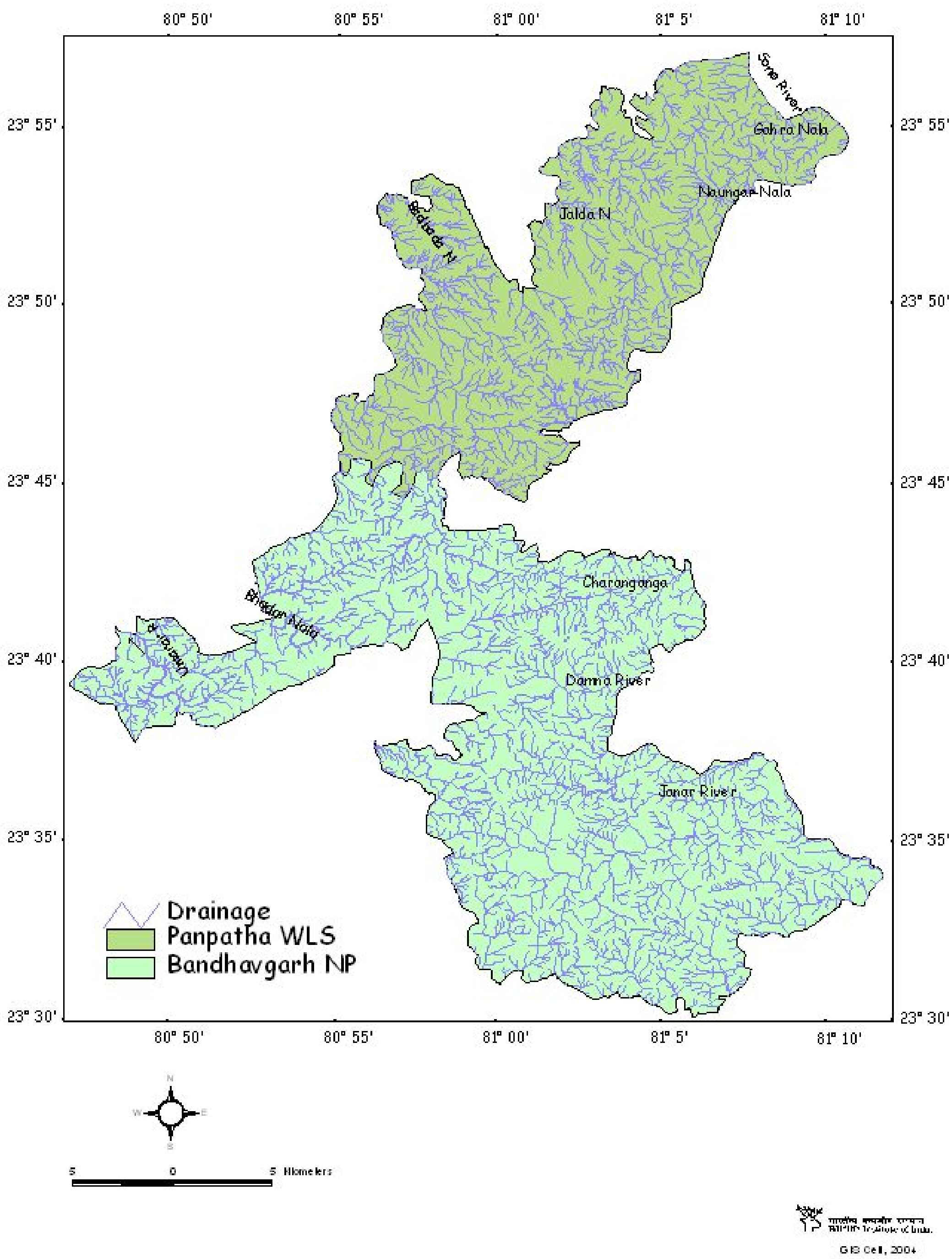
The Bandhavgarh Tiger Reserve contains one of the oldest rocks in the world – the Gondwana (Tiwari, 1979), Gondwana rocks spread over Umaria (Singh, 1986). The soft felspathic sandstone of medium to coarse texture of Supra Bharakar is the main geological formation of the park. In this rock, rounded quartzite pebbles are embedded in soft sandy matrix. The beds of rivers and nalas are sandy. The soil is brownish red or grey in colour (Sinha, 1977).

The main geological formation 'Supra Bharakar' is represented by soft felspathic sandstone at place embedded with quartzite pebbles. The sandstone has resulted in sandy soil, which is deep of the foot hills (Gopal, 1991).

2.3 DRAINAGE PATTERN

The area forms the catchments of numerous seasonal and perennial streams (Lad and Gopal, 1992). The major perennial rivers, are Umarar, Damar, Janad, Johila, Charanganga and seasonal nalas are Bhadar, Chachahi and Chamkuli. Sone river flows is north eastern direction along the boundary of Panpatha WLS. One of the new reservoir is Bamera in Panpatha WLS. A large number of perennial springs originate on the slope of Bandhavgarh Hill (Pabla, 1998). Charanganga nala rises from the north-eastern slope of the Bandhavgarh hill, Sheshashaiya is fed by the seepage water of some of these tanks. The type of drainage and its pattern is shown in Fig. 2.2. Tala range has a very high density of waterholes in comparison to other areas. In Sanctuary area the main rivers are Halphal, Jaruwahi Nala and Bagaiha Nala.

Fig. 2.2 **Bandhavgarh Tiger Reserve : Drainage**



2.4 SOIL

The various rock formations and local topography has played an important role in the formation of soil. Soils derived from Gondwana sandstone and conglomerates are sandy loams. At few places where trap occurs, the percentage of sand is less and rich black soil or alluvial loam are found. Sandstone is formed due to deposition of secondary rocks. Major underlying rock formation of the area is sandstone and loams. Basic rocks give rise to black cotton soil on weathering, which are best suited for agriculture. Such soils are available though restricted in extent in Badrehal, Pathari etc around (Sonakia, 1993). The sub soil is usually unbroken and impervious. Sedimentary rocks are mainly responsible for the tropical dry deciduous type of forest. The pH of the soil is 20 and the composition of the chloride is 13 (Roy *et al,* 1992). The soils are usually poor in nitrogen and organic matter and fairly rich in potash.

2.5 CLIMATE

The Bandhavgarh Tiger Reserve typically exhibits tropical climate. Broadly, three main season of BTR are winter (October to February) summer (March to June), rainy (June to October). About 70 percent of the precipitation is received from the South –Westernly monsoon during the rainy season and about 20 percent comes from the north-eastern monsoon during the winter season.

Average annual rainfall for the area varies from 1,329 mm to 1,448 mm (Roy, *et al* 1992). May and June are the hottest months and December – January are the coldest month of the year. In the month of August, humidity is highest and April, May are the driest month. There are many marshy areas with seepages from ground available in the park especially low-lying meadows. The mean annual rainfall is 1173 mm (Sinha and Singh 1982). The temperature of area varies from 0^0C to 44^0C. The mean maximum annual temperature 31.8^0 C and mean minimum annual temperature 18.7 ^{0}C, the hottest month May to mid June (Tyagi, 1996).

Figure 2.3: Yearly Precipitation (Rainfall) from 1988 -2004 at BTR (Source : Umaria Observatory)

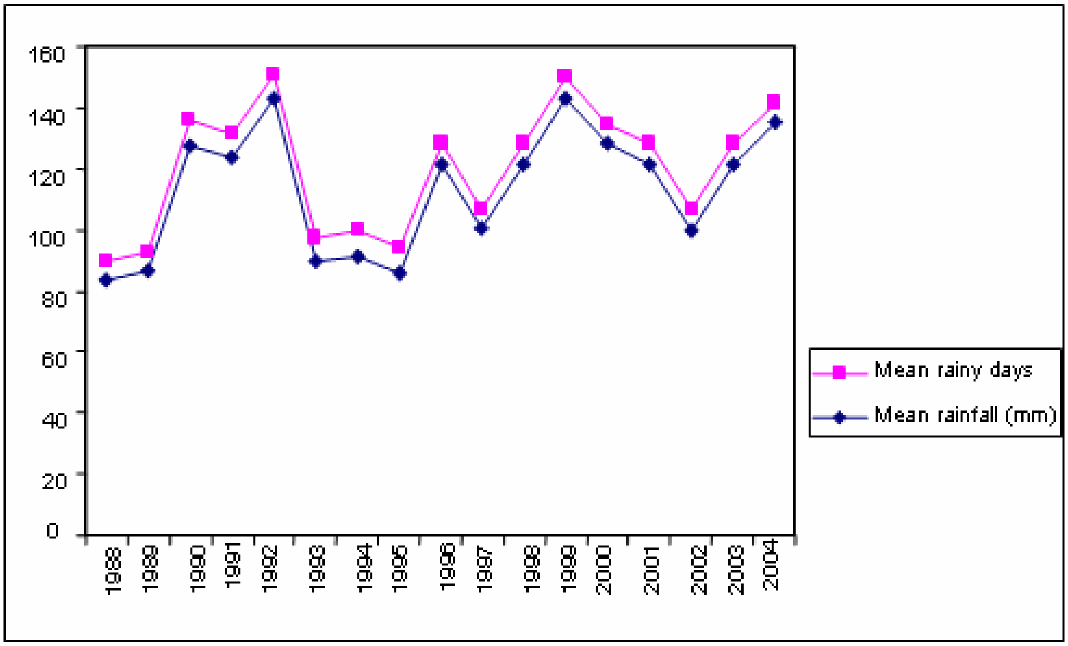
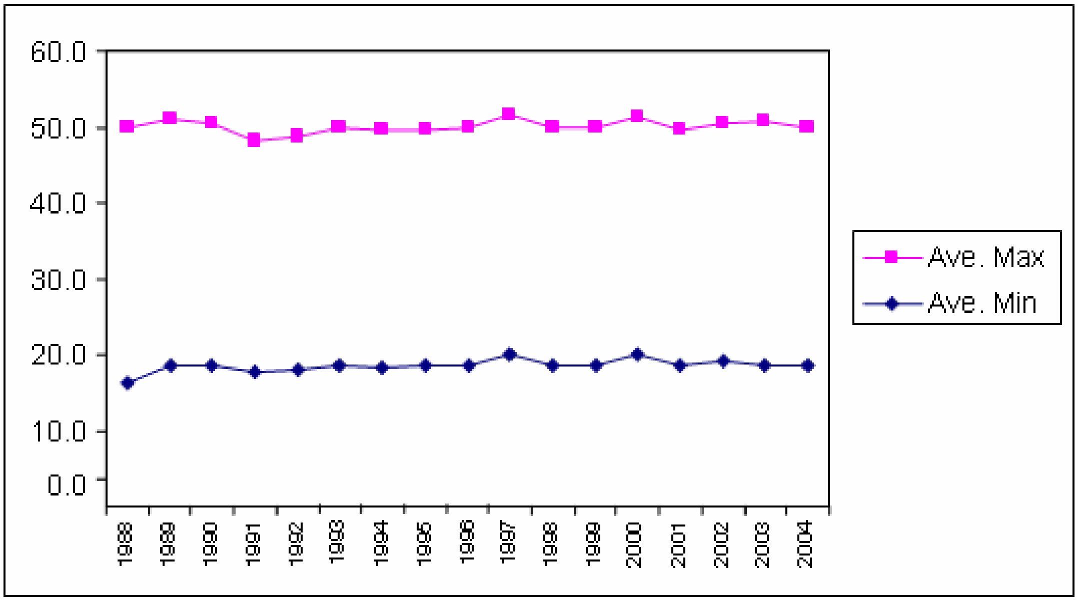


Figure 2.4 Average Mean Maximum and Minimum Temperature (1988 – 2004) at BTR (Source : Umaria Observatory)



2.6 VEGETATION

The forest occurring in Bandhavgarh TR can be broadly grouped on the basis of physiognomy and dominance of species as follows:

i) Sal Forest
ii) Mixed Forest
iii) Grassland and
iv) Bamboo

Sal Forest: In Bandhavgarh Tiger Reserve Sal forests cover low undulating, plain tracts with degenerative growth. In most of the area, Sal is aggressive compared to other associates. Sal forests are climax vegetation giving way to the deciduous forests on account of localized edaphic conditions (Gopal, 1994).

Mixed Forest: In BTR, mixed forest domainate due to hotter aspect of southern and western part. Mixed forest occur mainly hill slopes and hill tops due to shallow and rocky outcrops. Few patches of mixed forest occurs in nala banks, where alluvial black clayey soils are available.

Grasslands: In Bandhavgarh TR, occur very good patches of grass lands along the Charanganga, Damar, Chachahi, Sukhi, Bandehi in National Park and number of small grasslands in Sanctuary, where insectivorous plant "Drosera" is found. The local people call Grass patches as 'Vahs'. Some of the grasses found in BTR, are *Bothriochoa odorata, Chrysopongen fulous, Cynodon dactylon, Dichanthium ammmmulation, Digitaria Granularies* and *Heteropogen contortus.*

Bamboo: The dense bamboo distribution occurs mainly in Panpatha WLS. Some of the area occurs with mixed forest in National Park. Dense bamboo found mainly in Sanctuary area and there are a few patches in National Park. Due to strict protection measures and elimination of all kinds of forestry operations inside the park area, natural regeneration of bamboo occurs in all areas (Gopal, 1989).

Moist peninsular low level Sal: The Sal forest have faces of their own which is due to the undisputed pre-dominance of one of the gregarious species. Sal is very generally more aggressive than any of its associates and competitors and has a natural gregarious habit. Sal typically forms high forest in which it constitutes 60 to 90 percent of the top canopy, which is 25 – 40 m. high and less disturbed forest. A feature of Sal, which is important, is its semi-evergreen habit with a deciduous period of about 5 - 15 days at beginning of the hot weather.

The species occurring in this formation are *Shorea robusta, Terminala tomentosa, Pterocarpus marsupium, Anogeisus latifolia, Madhuca indica, Emblica officinalis, Buchanania lanzan, Diospyros melanoxylan, Terminalia Chebula, Kydia calcina, Ougeinia oojenensis, Bridelia retusa, Bauhinia retusa.* The above occurs on crystalline rocks with yellow loam soils. Almost 60 % of the Tiger Reserve area comprises by Sal forests and its associates.

West Gangetic moist mixed deciduous forest: It occurs in the hilly tracks in the Tiger Reserve with various associates. I – *Terminalia tomentosa, Pterocarpus marsupium, Lagerstroemia parviflora, Anogeissus latifolia, Salmalia malabarica, Adina cordifolia, Terminalia chebula, Diospyros tomentosa, Terminalia bellerica Schleecheraoleosa, Soymida febrifuga, Stereospermum personatum, Bauhinia retusa, Lannea coromandelica, Mitrayyna parvifolia, Terminalia arjuna* (along streams)*;* II – *Ougeinia*

oojeinensis, Cassia fistula, Kydia calycina, Bauhinia, racemosa, Emblica officinalis, Bauhinia variegata, Aegle marmelos, Grewia tiliaefolia, Erioloena hookeriana, Bridelia retusa, Casearia spp. Cleistanthus collinus, Gardenia turgida, G.latifollia, Holarrhena antidysenterica, Garuga pinnata, Morinda exserta, Buchanania lanzan, Wendlandia exserta, Butea monosperma;
II a - *Dendrocalamus strictus* is a dominant species (Lall, 1988); and III – *Helicteres isora, Colebrookia oppositifolia, Petalidium barlerioides, Pogostemon plcetranthoides, Moghania, Embelia, Strobilanthes spp.*

Most of the moderately moist mixed deciduous forest in which sal is scarce or absent appears to be only seral in status and the indications are that once the progression has reached a point at which Sal can obtain a rooting, it relatively quickly establishes its dominance and characteristics of the climax formation (Champion & Seth, 1968). The degraded forest conditions at Tala forest are attributed to serve biotic pressure as the forest area is open to human interference from nearby villages (Lall, 1990).

Northern dry mixed deciduous forest: The species are *Anogeissus pendula, Acacia catechu, Butea monosperma, Bauhinia, Acacia leucophloea, Soymida febrifuga, Carissa, Flacourtia indica, Zizyphus xylopyrus, Capparis decidua, Holarrhena antidysenterica,* *Aristida depressa, Cymbopogon martini, Heteropogon centortus, Aristida depressa, Themeda quadrivalvis* etc.

The total list of plants found in this locality is 553 belonging to 362 genera and 94 families. List of plant species in Bandhavgarh Tiger Reserve shown *appendix I* (Sonika, 1993). Bandhavgarh is a rich locality for exploration of flora and it should prove an important landmark to Botanists (Tiwari, 1968).

2.7 FAUNA

The Bandhavgarh TR is well known for its rich diverse fauna. In Bandhavgarh, tiger occurred in the highest known density in India in 1981. Tigers are widespread and may be seen throughout the park (Anon, 1997). The BTR has typical Central India fauna. The fauna of the BTR comprises 22 species of mammals (Gopal, 1991, 1992; Sonakia 1993; Singh 1994; Pabla, 1998 and Nath, 2000) and more than 242 species of bird (Gopal, 1991, 1992; Sonakia, 1993 and Pabla, 1998). This park lies in the heart of Vindhyas and besides its richness in wildlife it is unique. The large herbivores were found in Bandhavgarh Tiger Reserve – Chital (*Axis axis*), Sambar (*Cervus unicolor*), Barking deer (*Muntiacus muntjac*), Nilgai (*Boselaphus tragocamelus*), Chinkara (*Gazella gazella*), Chausingha (*Tetraceros quadricornis*) and Wildpig (*Sus scrofa*). Gaur presence was reported during 1989 (Tyabji, 1990). There are 242 species of birds to belonging 77 families. The diverse habitat of Sal mixed forest and grasslands of Peninsular and Eastern Gangetic region along with undulating terrain accounts for high bird species diversity (Singh, 1997). Due to degradation of the forest tract between the Kalwah and Magdhi ranges in the core areas of Bandhavgarh NP (Kalique, 1997), the Wild buffalo, Barasingha and Gaur are no longer seen in the area. Some of the reptiles Cobra, Krait, Viper, Rat snake, Python, Turtles and Lizard are common and a wide range of insects are found.

In addition to Tiger, the other carnivore species existing in the area are Leopard (*Panthera pardus*), Wild dog (*Cuon alpinus*), Jackal (*Canis aureus*), Jungle Cat (*Felis chaus*) and Wolf (*Canis lupus*).

2.8 PAST HISTORY OF MANAGEMENT

Based on flora and fauna Bandhavgarh NP was notified on 23/3/1968 under M.P. Park Act 1955 (No. VII of 1955), covering 105 sq. km of the Reserve Forest. Subsequently, Tala Reserved Forest was included in National Park on 23/3/1968 (Notification No. 2977/x/68), Sonakia, 1993). The Govt. of M.P. notified its intention to enlarge the park to an area of 448.842 sq. km in 1982. Panpatha Wildlife Sanctuary (Notified vide No. 2411/x-12/10-83 Dated 4/6/1983, area 245 sq. km was included in Bandhavgarh Tiger Reserve in the year 1993. The total area of BTR is 694.68 sq. km including National Park area (448.842 sq.km) and Panpatha Wildlife Sanctuary (245.842 sq.km). The entire area was declared as Bandhavgarh Tiger Reserve in the year 1993 under Project Tiger.

Bandhavgarh Tiger Reserve has a very old history, ruins of the bygone era are scattered all over the tiger reserve. No records however remain to show when Bandhavgarh Fort was constructed. It is believed to be some 2000 year old and there are references on it in the ancient texts, the Narad Panch Ratra and the Shiva Purana. Bandhavgarh is named after Shri Lakshmana, the younger brother of Lord Rama, hero of the Hindu epic Valmiki Ramayana. It is said that while returning from Ayodhya after the coronation of Lord Rama, two monkey engineers Nala and Nil thought of presenting a tribute to lord hence they built Bandhavgarh fort. Later, Lord Rama handed over these forts to his brother Lakshamana, who became known as 'Bandhavdhish', the Lord of the fort (Tiwari, 1998). Various dynasties have ruled the fort (Sharma, 1994). During 300 A.D. several caves were developed in the area and in Bandhavgarh fort. Bhimsen was prominent ruler during 300 A.D. In 1494 the King Baghel ruled Bandhavgarh. In 1535 Virbhanu Singh ruled in Bandhavgarh. A famous Saint poet Kabir Gupta was there. Vikramaditya ruled from 1597 to 1624 A.D. Bandhavgarh fort habitation started after 1617 A.D.

The old park area was declared reserved forest under 'Kanun Jungle' Riyasat Rewa 1927 and restriction on felling of certain species were also imposed. The new ruled formed under 'The nistar grazing' related to reserved forest and Am Jungle in 1930. In 1959 the M.P. Govt. Act came and hunting ended in 1968 when it was declared as National Park.

CHAPTER 3

Vegetation Mapping

3.1 INTRODUCTION

The vegetation of Central India is tropical dry deciduous type. The major plant communities in the area are Sal, Teak and Bamboo. Good soil and drainage have played a major role in the development of forests in the area.

One important function of remote sensing is in generation of maps, which exhibit the spatial interaction of various land surface features and make it possible to quantify the spatial spread of various features. One important use of remote sensing is in the characterization and classification of spectral measurements taken from satellite into various features of the land surface. Remote Sensing has become a powerful tool for the mapping of natural resources and geological formations. This technology is also being widely used for monitoring vegetation mapping.

The remote sensing technology captures the synoptic view of resources and GIS technology has made it easier to integrate multi-theme information on spatial scales and to derive requisite information for planning and management.

The utility of the Indian Remote Sensing satellite data has been amply demonstrated for various resource applications through a number of recent studies(Tiwari and Kudarat 1988; Bhan *et al* 1989a; Jha 1990; Tiwari *et al,* 1990; 1991; Raghubanshi *et al,* 1991).

The vegetation maps provide locational information along with distribution and abundance and of plant species. The most important use of vegetation map is in various ecological application such as long term monitoring, change detection, biomass estimation, habitat mapping and biodiversity characterization.

Vegetation mapping of habitats has been done to help the park management, especially in context of biotic pressure assessment from adjacent settlement, for MFP collection, cattle grazing inside the BTR.

For this project objective, digital data of IRS 1A, 1C, LISS II of November 1988, 1994 and LISS III 2000 have been used. Vegetation type mapping has been done through digital interpretation of satellite data of IRS 1A, 1C that having a resolution 36.5m and 23.5m respectively.

3.2 RELEVANCE OF REMOTE SENSING AND GIS IN VEGETATION MAPPING

The Landsats 1, 2 and 3 NASA satellites of first generation, which were launched in 1972, 1975 and 1978 all have ceased operation, but they have produced hundreds of thousands of valuable images (Sabins, 1996). The science of remote sensing is based on interaction of earth surface feature with electromagnetic radiation. Earth surface features have three types of interactions with light *viz.* absorption, reflection and transmission. The behavior of interaction by different objects assist in identification of various features. The remote sensing sensors record mainly reflected energy. The reflectance of an object when plotted against wavelength of light forms a curve, which is called spectral signature of the object (Tiwari *et al,* 1996). GIS provides the ability to produce output at all stage of planning (Dubey, 1999). A GIS system allows the results of data processing for an intensive test area to be transferred over the entire study area. In this way, the characteristics of the entire study area can be mapped in one form in a database, which can be easily manipulated for later computer modeling (Haber & Schaller, 1988).

The satellite with its sensors on board has the immense potential to provide information on forest resources for their surveillance and monitoring (Roy *et al,* 1996). Advantage of the satellite remote sensing and sensor related technological advancements has made it possible to undertake precise vegetation classification and mapping (Roy *et al* 1986; William & Nelson 1986; Domoghue and Shenan 1987; Hall *et al* 1991; Prasad *et al* 1994;). Remotely sensed imagery is often too complex for direct scientific analysis and image processing is required at an initial stage (Bosworth *et al,* 2003). Monitoring is an important requisite for managing living resources. Monitoring helps in understanding the ecological interrelationships between various components of ecosystems (Mathur, 1991). Remote sensing is the primary tool for the synoptic analysis of habitats at landscape scale (B.O. Oindo *et al*, 2003). Multi spectral images and panchromatic images give more spectral information (Mohanty and Mjumdar, 2003). In recent times, remote sensing supplemented by ground surveys play a vital role in mapping the existing forest resources (NRSA, 1983).

Remote sensing techniques can be utilized as a tool for mapping of forest and other landuse/landcover patterns.

3.3 LITERATURE REVIEW

The first record of plants from Central India under Latin nomenclature was produced by W.Griffith in 1842. It was followed by a list of such plants in 1870 in the Gazetteer of the Central Provinces by Grant and Capt. Forsyth in his book 'The Highlands of Central India' in 1872. The monumental work by Sir J.D. Hooker, namely "The Flora of British India" appeared in 1879 (Tiwari, 1979).

The most significant work on forest types in central India has been done by Champion & Seth, 1968. Floristically, Madhya Pradesh has been explored thoroughly since 18th centaury 'Flora of British India'. Recent studies on the vegetation/flora of Madhya Pradesh area by Roy *et al,* 1992; Tripathi *et al,* 1994. Numbers of studies have been conducted with respect to the mapping of wet, moist and semi moist conditions of forest vegetation in different parts of India using Landsat data (Roy *et al* 1985; Unni 1983; Pant & Roy 1990). A number of studies on the status of various species in Bandhavgarh National Park with respect of forest types have been carried out by Gopal, (1991;1992). Visual interpretation of IRS data for prepration of a vegetation map has been done for Bandhavgarh National Park (Pabla, 1998).

Mixed forests of good quality occur in a belt of varying width between the Sal and the Teak areas in Madhya Pradesh (Dutta and Panwar, 1979). Remote sensing provides a means for obtaining a synoptic view of forest and their condition on real time basis (Madhavanunni *et al,* 1991). The capabilities of remote sensing to map and extract information about earth resources for various applications are well documented among those prominently used in landcover mapping (Campbell, 1987) Satellite remote sensing is being utilized extensively for mapping landuse/landcover in India (NRSA, 1988). Standard landuse and landcover classification has been adopted for mapping landuse categories using remote sensing data (Anderson *et al,* 1976; NRSA, 1989; Pathan, 1992) Landuse and vegetation assessment is one of the most important parameters, which can be done very efficiently using remote sensing (Tiwari *et al,* 1996). Mapping of landuse vegetation through satellite images can be done using visual interpretation of images or through computer aided digital classification (Hoffer, 1986). A number of image enhancement procedures are now available (Saha & Kudrat, 1992).

3.4 VEGETATION TYPES IN THE STUDY AREA

The forests of Bandhavgarh Tiger Reserve have been broadly classified by Champion and Seth (1968) into following categories:

Sub-group 3C – Northern Indian Tropical Moist Deciduous Forest:

- Moist peninsular low level Sal Forest (3C/C_{2e})
- Northern Dry Mixed Deciduous Forest (5B/C_2)
- Dry deciduous Scrub (DS_1)
- Dry Grassland (5/DS_4)
- West Gangetic Moist Mixed Deciduous Forest (3C/C_{3a})

Moist peninsular low level Sal

The top canopy Sal (*Shorea robusta*) is very abundant in entire tiger reserve. It forms climax vegetation and has adequate natural regeneration. Saja (*Terminalia tomentosa*), *Petrocarpus marsupium*, Dhaora (*Anogeissus latifolia*) occur as its associates in the top canopy. The middle canopy trees are mainly Tendu (*Diospyros melanoxylon*), Tinsa (*Ougeinia oojeinensis*), *Terminalia chebula, Bridelia retusa, and Bauhinia retusa.* Bamboo (*Dendrocalamus strictus*) is well distributed in Panpatha Wildlife Sanctuary. Shrubs *viz Indigofera pulchella, Moghania semialata,* *Phoenix acaulis, Embelia arborea,* and *Woodfordia fruticosa* are found more or less in the entire area. Grasses found are mainly *Aristida setacea, Arundodonax, Apluda aristata, Banbusa arundinacea, Imperata Cylindrica, Veliveria Zizanioides*. Climbers are Bauhinia *vahlii, Butea superba and Smilax zeylanica*.

Northern Dry Mixed Deciduous Forest

The northern dry mixed deciduous forests occur in the entire tiger reserve. The top canopy tree species are *Anogeissus pendula*, *Anogeissus latifolia, Accaia catechu, Feronia limonia, Albizzia spp, Acacia leucophloea, Miliusa tomentosa* and *Bauhinia spp.* Shrubs species are *Carissa sp., Flacourtia indica, Zizyphus xylopyrus, Zizyphus nummularia, Holarrhena antidysenterica, Gymnosoria spinosa, Capparis* and *Calotropis procera.* Grasses found are mainly *Aristida setacea, Arundodonax, Apluda aristata, Banbusa arundinacea, Imperata Cylindrica and Veliveria Zizanioides*.

Dry deciduous Scrub

Dry deciduous scrub occurs in small parts in BNP and Panpatha WLS. Lower storey is formed by *Heteropogen contortus, Aristida depressa, Themeda quadrivalvis, Saccharum spontaeum* and *Cymbopogen martini*.

Dry Grassland

Dry grasslands species are *Dichanthium annulatum, Bothriochloa pertusa* and *Eremopogen foveolatus Aristida setacea* (Gharonch), *Arundodonax spp* (Baruhi barru), *Apluda aristata* (Phuli phulera), *Bambusa arundinacea* (Kantabans banskatang), *Cymbopogon martini* (Rusa), *Cyanodon dactylon* (Doob), *Eragrosrns interrupta* (Bhusbusi), *Heteropogen centortus* (Kusul/lampa), *Phragmites karka* (Nal), *Saccharum spontaneum* (Kans) and *Veliveria zizanioides* (Khus) etc.

West Gangetic Moist Mixed Deciduous Forest

West gangetic moist mixed deciduous forests are found in areas where moisture conditions are high. The top storey species found are *Terminalia tomentosa, Pterocarpus marsupium, Anogeissus latifolia, Salmalia malabarica, Adina cordifolia, Terminalia chebula, Diospyros tomentosa, Stereospermum personatum, Bauhinia retusa, Madhuca indica* and *Terminalia arjuna*. The middle storey species found are *Ougeinia oojeinensis*, *Cassia fistula, Bauhinia racemosa, Emblica officinals*, *Aegle marmelos, Grewia tiliaefolia, Casearia spp. G.latifolia, Butea monosperma* etc. Shrub are *Helicteres isora, Colebrookia oppositifolia, Petalidium barlerioides, Moghania, Strobilanthes* spp.

3.5 VEGETATION MAPPING

In BTR, three time IRS satellite data year 1988, 1994 & 2000 were used. Raw data were geometrically corrected with SOI toposheets. NDVI was generated for all three periods. Unsupervised classification generated 25 classes. The Unsupervised map printout at scale 1:50,000 were used for ground verification. Twenty line transect were laid in the study area and along each transect plots 10 m for tree, 5m for shrub and $1m^2$ for plot ground. In field area selected ground verification based on spetral signature and GPS location were also recorded for various vegetation communities. For better refinement Supervised classification and Hybrid classification methods were used. Accuracy assessments were done using ground points and random points. Landuse/landcover map of all three periods was generated for BTR.

3.6 MATERIAL

Vegetation mapping has been done using satellite data from IRS 1A LISS II, and 1C LISS III.

3.6.1 Satellite Data

IRS 1A and 1C False Colour Composite (FCC) of bands 4,3,2,1 (path and row 25/51, 25/51 and 101/55) of November 1988, 1994 and 2000, were used to identify the vegetation types. Area represented by each pixel is 36.50*36.50m and 23.5*23.5m. Digital data was preferred as it is less prone to human error and the analysis is less time consuming (Jensen, 1996).

3.6.2 Ancillary Data

- Survey of India toposheet No. 64E/1, 64E/2, 64E/3, 64A/13 and 64A/14; scale 1:50,000.
- Management Plan of Bandhavgarh National Park
- GPS locations
- Other equipment used in field work was Compass, Altimeter, Tapes, Camera.
- Literature related with vegetation types and distribution in the study area was extensively reviewed.

3.7 METHODOLOGY

3.7.1 Hardware and Software

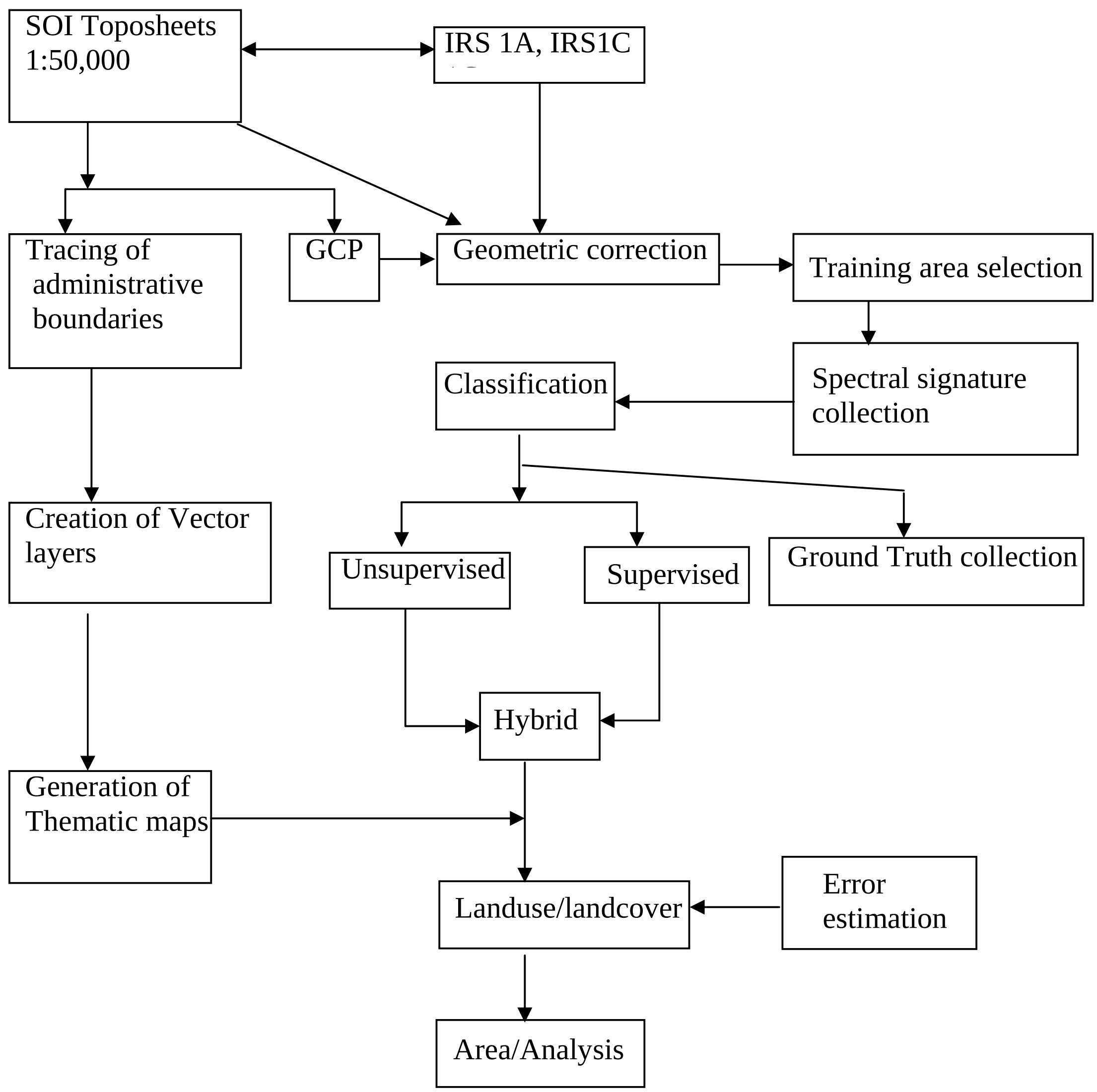
For analysis of remote sensing and thematic data hardware used was Sun Microsystems Workstation on Windows NT platform. Digital image processing of the data carried out using ERDAS IMAGINE ver 8.5 software. For various thematic layers contour, drainage, road etc were extracted from SOI topsheets and digitized in Unix based Arc/INFO ver 8.2 software. Area statistics was calculated using Arc/INFO and Arc View. Some of the vector layers were converted to raster. Several empirical studies have observed that rasterized map maintain better map accuracy (Nicols 1975; Hord and Brooner 1976, Van Ggendern and Lock 1977).

3.7.2 Digital Image Processing (DIP)

The work was carried out in step wise manner (Fig. 3.1) – Pre fieldwork, reconnaissance survey, ground truth and field data collection and post fieldwork. After loading the digital data on the system, a FCC was generated and different processes such as rectification, extraction of study area, enhancement and classification were carried out.

Globally landcover classification from satellite data have largely been used to derive annual time series of the NDVI, as a measure of pheonlogical variability throughout the year (Tucker *et al,* 1985; Townshend *et al,* 1987; Loveland *et al,* 1991; Defries and Townshed 1995). NDVI Maximum Likelihood Techniques was used to produce a global landcover data set of $1^0 * 1^0$ resolution (Defries and Townshend, 1994a). Normalized Difference Vegetation Index (NDVI) is generally recognized as a good indicator of terrestrial vegetation productivity for understanding climate influences in particular prediction of productivity changes under different climatic scenarios (J. Wang *et al,* 2003). Digital data was loaded in the DIP system and the FCC was generated.

Figure 3.1 Steps in Landuse/Land cover mapping using digital interpretation technique



3.7.3 Rectification

Rectification is the process of conversion of raw data onto a plane, and it defines the map real coordinate system. For geo-referencing, 35 ground control points (GCPs) were selected from SOI toposheet, through out the study area, in order to reduce the root mean square (RMS) error to 0.02. After geo-referencing the image was resampled using Nearest Neighborhood algorithm.

3.7.4 Enhancement

The procedure was applied to image data in order to effectively display the data for subsequent visual analysis. After the extraction of Area of Interest (AOI), edge enhancement with a kernel size of 3x3 was used to sharpen the edges for better image classification.

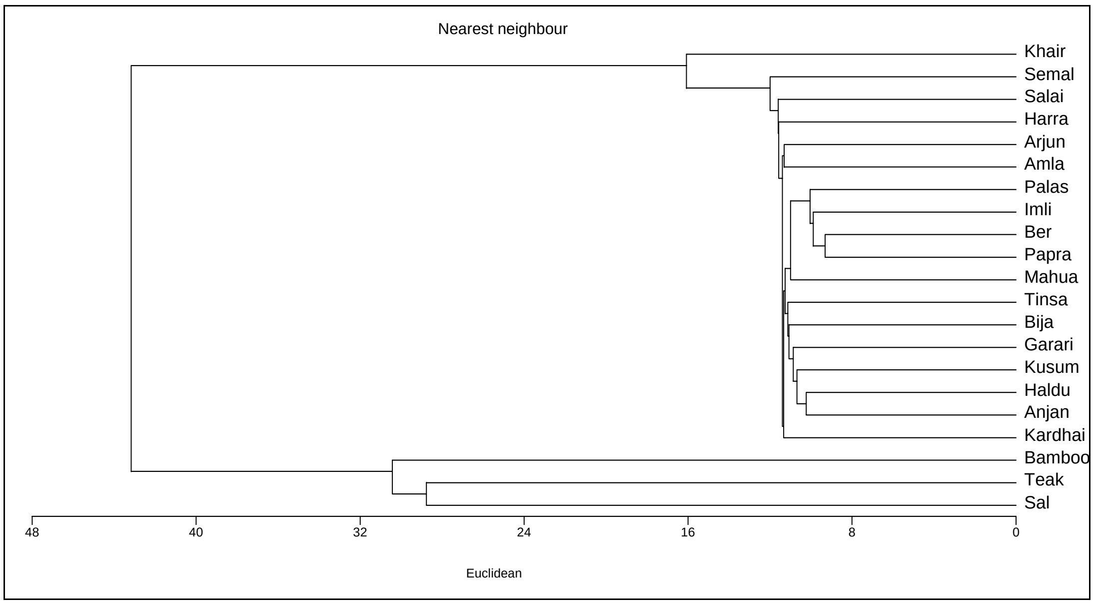
3.7.5 Classification

Image classification refers to conversion of all pixels in an image into landcover classes. After image enhancement it was subjected to classification stage. Two approaches for image classification used were Unsupervised and Supervised.

3.7.6 Vegetation Structure and Composition

A total of 200 plots were laid down in the study area. Associations between the vegetation structure and composition were investigated through species presence in these plots. The dendrogram produced for the Nearest Neighbour for Euclidian distances among the species present therein indicate five major associations Fig. 3.2.

Fig. 3.2 Dendrogram indicating species associations based on plots (n=200)



The five major associations are: Sal, Teak, Bamboo, Khair and a mixed association of 17 species. There was notable presence of Amla, Arjun, Mahua and Bija in the mixed forests as also closer to the villages. Bamboo was widespread in Panpatha WLS, Sal and Teak occurred more in the NP area. Khair presence was observed within mixed communities and along the riparian patches.

Diversity indices

Table 3.1 : Diversity indices based on ground plots

Sample	Diversity Inde	Evenness Index	Species Richness
1	1.14	0.927	17
2	1.182	0.942	18
3	1.133	0.941	16
4	1.155	0.939	17
5	1.149	0.915	18
6	1.156	0.96	16
7	1.125	0.934	16
8	1.165	0.928	18
9	1.178	0.922	19
10	1.105	0.898	17
11	1.082	0.899	16
12	1.177	0.938	18
13	1.097	0.933	15
14	1.11	0.969	14
15	1.093	0.929	15
16	0.861	0.903	9
17	1.129	0.96	15
18	1.06	0.952	13
19	1.12	0.977	14
20	1.068	0.932	14
21	1.093	0.953	14
22	1.054	0.92	14
23	0.974	0.903	12
24	1.053	0.945	13
25	1.001	0.961	11
26	1.195	0.971	17
27	0.893	0.893	10
28	1.133	0.941	16
29	0.944	0.907	11
30	1.019	0.944	12
31	1.059	0.924	14
32	0.993	0.892	13
33	1.114	0.925	16
34	1.085	0.947	14
35	1.007	0.933	12
36	1.071	0.935	14
37	1.074	0.913	15
38	1.075	0.965	13
39	1.005	0.931	12
40	1.042	0.966	12
41	1.025	0.92	13
42	1.079	0.941	14
43	0.984	0.912	12
44	1.045	0.938	13
45	1.11	0.944	15
46	1.158	0.941	17
47	1.187	0.946	18
48	1.123	0.955	15
49	1.156	0.939	17

Sample	Diversity Inde	Evenness Index	Species Richness
50	1.095	0.955	14
51	1.179	0.939	18
52	1.16	0.924	18
53	1.176	0.92	19
54	0.985	0.884	13
55	1.104	0.898	17
56	1.133	0.921	17
57	1.024	0.92	13
58	1.146	0.975	15
59	1.189	0.947	18
60	1.155	0.92	18
61	1.202	0.957	18
62	1.095	0.931	15
63	1.175	0.936	18
64	1.223	0.925	21
65	1.137	0.906	18
66	1.046	0.889	15
67	1.078	0.917	15
68	1.063	0.928	14
69	1.161	0.943	17
70	1.118	0.929	16
71	1.177	0.938	18
72	1.128	0.959	15
73	1.156	0.94	17
74	1.189	0.93	19
75	1.123	0.912	17
76	1.018	0.888	14
77	1.11	0.902	17
78	1.133	0.921	17
79	1.187	0.945	18
80	1.168	0.949	17
81	1.189	0.947	18
82	1.155	0.92	18
83	1.183	0.943	18
84	1.095	0.931	15
85	1.16	0.924	18
86	1.169	0.914	19
87	1.153	0.919	18
88	1.046	0.889	15
89	1.05	0.916	14
90	1.168	0.93	18
91	1.139	0.946	16
92	1.184	0.944	18
93	1.16	0.943	17
94	1.202	0.957	18
95	1.084	0.922	15
96	1.198	0.937	19
97	1.223	0.925	21
98	1.048	0.891	15
99	1.014	0.885	14
100	1.125	0.934	16
101	1.05	0.916	14
102	1.158	0.962	16

Sample	Diversity Inde	Evenness Index	Species Richness
103	1.065	0.93	14
104	1.201	0.939	19
105	1.091	0.952	14
106	1.159	0.942	17
107	1.165	0.928	18
108	1.102	0.915	16
109	0.995	0.893	13
110	0.981	0.909	12
111	1.026	0.895	14
112	1.187	0.945	18
113	1.168	0.949	17
114	0.905	0.905	10
115	1.155	0.92	18
116	1.202	0.957	18
117	1.095	0.931	15
118	1.093	0.929	15
119	1.125	0.914	17
120	0.951	0.881	12
121	1.046	0.889	15
122	1.093	0.929	15
123	1.095	0.955	14
124	1.187	0.946	18
125	1.096	0.956	14
126	1.21	0.93	20
127	1.1	0.96	14
128	1.182	0.942	18
129	1.165	0.928	18
130	0.996	0.894	13
131	0.985	0.884	13
132	1.136	0.943	16
133	1.058	0.899	15
134	1.187	0.945	18
135	1.139	0.946	16
136	1.16	0.943	17
137	1.155	0.92	18
138	1.202	0.957	18
139	1.095	0.931	15
140	1.17	0.932	18
141	1.223	0.925	21
142	0.985	0.884	13
143	0.98	0.88	13
144	1.065	0.905	15
145	0.944	0.907	11
146	1.187	0.946	18
147	1.095	0.931	15
148	0.945	0.875	12
149	1.12	0.952	15
150	1.125	0.934	16
151	1.189	0.93	19
152	1.156	0.921	18
153	1.065	0.906	15
154	0.97	0.899	12
155	1.034	0.902	14

Sample	Diversity Inde	Evenness Index	Species Richness
156	1.056	0.922	14
157	1.139	0.946	16
158	1.079	0.941	14
159	1.129	0.937	16
160	1.202	0.957	18
161	1.095	0.931	15
162	1.115	0.926	16
163	1.223	0.925	21
164	0.94	0.871	12
165	1.046	0.889	15
166	1.1	0.935	15
167	0.982	0.91	12
168	1.187	0.946	18
169	1.101	0.936	15
170	1.07	0.91	15
171	1.013	0.939	12
172	1.153	0.937	17
173	1.146	0.931	17
174	1.129	0.917	17
175	0.902	0.866	11
176	0.96	0.889	12
177	0.992	0.89	13
178	0.99	0.918	12
179	1.168	0.949	17
180	1.16	0.943	17
181	1.175	0.955	17
182	1.202	0.957	18
183	1.095	0.931	15
184	0.965	0.894	12
185	1.123	0.913	17
186	0.915	0.878	11
187	0.945	0.875	12
188	0.939	0.902	11
189	1.063	0.928	14
190	1.158	0.962	16
191	1.101	0.936	15
192	0.996	0.894	13
193	1.091	0.952	14
194	1.182	0.942	18
195	1.118	0.929	16
196	0.97	0.899	12
197	0.985	0.884	13
198	0.973	0.902	12
199	1.133	0.941	16
200	1.056	0.922	14
201	1.168	0.949	17
202	1.03	0.925	13
203	1.195	0.971	17
204	1.134	0.964	15
205	1.095	0.931	15
206	1.164	0.946	17
207	1.151	0.917	18
208	1.114	0.947	15

Sample	Diversity Inde	Evenness Index	Species Richness
209	1.076	0.894	16
210	1.097	0.911	16
211	1.054	0.946	13
212	1.175	0.936	18
213	1.196	0.972	17
214	1.205	0.96	18
215	1.079	0.969	13
216	1.082	0.944	14
217	1.178	0.957	17
218	1.067	0.907	15
219	1.16	0.924	18
220	1.109	0.921	16
Mean	**1.1**	**0.9**	**15.5**
STD	**0.1**	**0.0**	**2.4**

Table 3.2: Diversity indices in Management Units(Ranges)

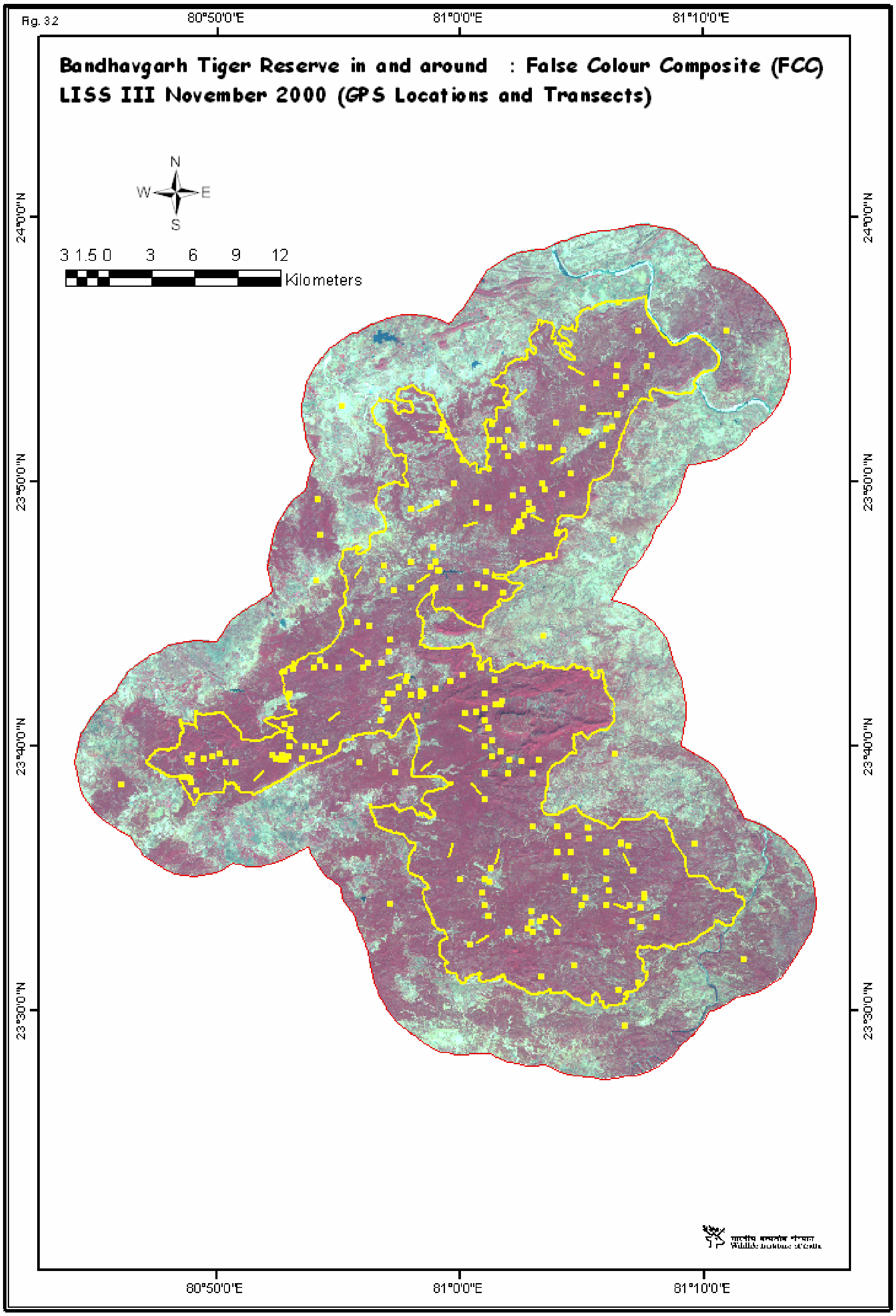
Management Units (Range)	No. of Plot	Species Richness	Evenness	Diversity Index
		(Mean ± SD)	(Mean ± SD)	(Mean ±SD)
Khitauli	50	14.78	0.93	1.09
		2.40	0.02	0.07
Tala	30	16.85	0.93	1.14
		1.75	0.02	0.05
Magdhi	50	15.96	0.93	1.11
		2.36	0.02	0.08
Kallwah	30	15.09	0.92	1.08
		2.45	0.02	0.09
Panpatha	40	15.07	0.93	1.09
		2.16	0.03	0.08
Overall Mean		15.49	0.93	1.10
Overall Std		2.35	0.02	0.08

Species Richness and Diversity Indices are high for Tala and Magdhi Ranges. This is attributable to the relatively low biotic pressures as compared to Khitauli and Panpatha Ranges. Tala Range has the lowest standard deviation among all the ranges in terms of Species Richness. Wildlife values in this range are the highest because of presence good cover and water sources. Khitauli and Panpatha WLS by virtue of their linear shape with extensive boundaries with villages score lower on species richness.

3.7.7 Unsupervised Classification

A modified clustering approach was used by (Fleming *et al,* 1975) to classify the masked MSS image. Unsupervised clustering is routinely used to characterize landcover and landuse from remotely sensed imagery (Ji, 2003). The BTR image was classified using an unsupervised clustering algorithm Interaction Self-Organizing Data Analysis (ISODATA). Twenty-five classes were specified in the unsupervised classification. Printout of unsupervised classification map was carried for ground truthing. In total 200 circular plots (10m radius for tree and 5 m for shrub) were laid randomly in the entire tiger reserve (Figure 3.3). GPS locations were also taken for all sample plots, 200 GPS locations were taken in various plant communities in the entire area. Number of classes and maximum iterations specified in the unsupervised classification were 25 classes respectively for each period. The image was classified in 25 different spectral classes and after, analyzing the image reflectance values, these 25 classes were merged into 12 distinct classes, of which 5 were of different forest types viz. Moist peninsular low level Sal Forest, Northern Dry Mixed Deciduous Forest, Dry deciduous Scrub, Dry Grassland and West Gangetic Moist Mixed Deciduous Forest.

Fig. 3.3 GPS locations and transects used for sampling



3.7.8 *Accuracy Assessment*

For accuracy assessment used all plots were selected and a new annotation layer was created. The annotation was converted to a raster image and raster image was loaded into the accuracy assessment panel and points were created within the field plots. Each point was selected, viewed over the original image and assigned a reference class. 89 % accuracy assessment was observed (Figure 3.5).

3.7.9 Supervised Classification

A printout of unsupervised classification at the scale of 1: 50,000 was taken to field for ground truthing. Five homogeneous sets were selected for each class and their locations were recorded using GPS. Of the total 25 training sets collected from field, 20 were used for defining the spectral signatures. In parametric classification in order to obtain the exact classes' probability distribution, only certain parameters need to be estimated from training samples (Swain and Davis, 1978). In remote sensing there are cases in which classes are spectrally very similar, but present distinct spatial distribution, i.e. different textural characteristics. Image texture becomes then an important source of information in the classification process. The multi-dimensional image data can then be classified by implementing an appropriate supervised classification method (Angelo and Hoertel, 2003). In landcover classification, the satellite sensor data supervised maximum likelihood classification is the most popular statistical algorithm and is widely accepted as a standard approach (Emrahoglu, 2003). Maximum likelihood parametric rule was therefore used for the supervised classification.

Distribution of different landcover classes in 1988, 1994 and 2000

In the study area, 12 distinct landcover classes were identified of which 7 were of different forest types and 5 of non-forest types. It was found that more than 90 % area was under forest cover and the rest included non-forest categories such as habitation, agriculture, scrub, rocky outcrop and water bodies. The final landuse/landcover map is shown in Figure 3.4 (1988); Figure 3.5 (1994) and Figure 3.6 (2000). The distribution of area under different forest types in 1988, 1994 and 2000 are shown in Table 3.3, 3.4 and 3.5 respectively:

Table 3.3: Vegetation and landcover classes in Bandhavgarh TR (km^2) in 1988

Class	Vegetation Types	Area in Bandhavgarh TR (km^2)	Area in Buffer (5km) of Bandhavgarh TR (km^2)	Total Area (km^2)	Percent
1	Sal Forest	113.20	123.57	236.77	13.39
2	Mixed Forest	307.27	408.67	715.94	40.47
3	Open Mixed Forest	49.64	155.80	205.44	11.61
4	Bamboo Forest	120.11	105.61	225.71	12.76
5	Grassland	59.15	53.30	112.46	6.36
6	Scrubland	3.20	67.26	70.46	3.98
7	Riparian	21.22	51.50	72.72	4.11
8	Rocky Outcrops	9.01	24.19	33.20	1.88
9	Plantation	1.05	3.42	4.47	0.25
10	Habitation	4.10	20.18	24.28	1.37
11	Agriculture	6.21	50.80	57.01	3.22
12	Water Bodies	0.51	9.94	10.45	0.59
	Total	**694.68**	**1074.24**	**1768.92**	**100.00**

Table 3.4: Vegetation and Landcover classes in Bandhavgarh TR (km^2) in 1994

Class	Vegetation Types	Area in Bandhavgarh TR (km^2)	Area in Buffer (5km) of Bandhavgarh TR (km^2)	Total Area (km^2)	Percent
1	Sal Forest	112.33	121.91	234.23	13.24
2	Mixed Forest	305.55	406.18	711.74	40.24
3	Open Mixed Forest	48.26	152.21	200.47	11.33
4	Bamboo Forest	120.13	103.18	223.31	12.62
5	Grassland	59.26	53.55	112.82	6.38
6	Scrubland	3.50	68.96	72.46	4.10
7	Riparian	21.62	51.34	72.96	4.12
8	Rocky Outcrop	9.01	24.26	33.27	1.88
9	Plantation	1.06	3.44	4.50	0.25
10	Habitation	5.21	23.56	28.76	1.63
11	Agriculture	8.25	55.79	64.04	3.62
12	Water Bodies	0.50	9.87	10.37	0.59
	Total	**694.68**	**1074.24**	**1768.92**	**100.00**

Table 3.5: Vegetation and Landcover classes in Bandhavgarh TR (km^2) in 2000

Class	Vegetation Types	Area in Bandhavgarh TR (km^2)	Area in Buffer (5km) of Bandhavgarh TR (km^2)	Total Area (km^2)	Percent
1	Sal Forest	110.93	120.19	231.12	13.07
2	Mixed Forest	304.13	402.78	706.90	39.96
3	Open Mixed Forest	46.51	149.92	196.44	11.11
4	Bamboo Forest	120.10	101.82	221.92	12.55
5	Grassland	60.45	54.93	115.38	6.52
6	Scrubland	3.47	70.73	74.20	4.19
7	Riparian	21.73	51.47	73.20	4.14
8	Rocky Outcrops	9.09	24.73	33.82	1.91
9	Plantation	1.07	3.41	4.48	0.25
10	Habitation	6.07	25.98	32.05	1.81
11	Agriculture	10.62	58.61	69.23	3.91
12	Water Bodies	0.52	9.67	10.19	0.58
	Total	**694.68**	**1074.24**	**1768.92**	**100.00**

Each vegetation type categories and their associated species are given below:

Sal Forest: Sal forest occurs in about 60 % of the entire area. At several places pure patches of Sal are found (Plate 3.1).

Mixed Forest: Mixed forest dominates in entire area of Bandhavgarh National Park and Panpatha WLS. Important mixed forest species are *Anogessus pendula, Acacia catechu, Butea monosperma, Anogeissus latifolia, Boswellia serreta, Miliusa velutina and Bauhinia racemosa* etc. and occurs mainly in National Park (Plate 3.2).

Bamboo Forest: Bamboo forest dominates in about 80 % of the Panpatha WLS, and is less in other areas. It occurs with Sal and mixed forest species in National Park and Panpatha WLS.

In Bamboo forest other species found are *Diospyros melanoxylon, Madhuca latifolia, Shorea robusta, Terminalia tomentosa* (Plate 3.3).

Grasslands: Grasslands generally occur in scrub areas. In Bandhavgarh TR 94 grass species are found (Tiwari, 1968). Some of species which occur in entire area are *Aristida setarea, Saccharum spontaneum, Phragmites karka, Apluda aristata, Cynodon dactylon, Cymbopogon martini, Desmostachys bipinnata, Eragrostis interupta, Eulaliopes binata, Themeda triandra and Heteropogon contortus* (Plate 3.4).

Scrub: This forest type occurs in association with *Acacia spp, Anogeissus pendula, Butea monosperma, Zizphus spp., Woodfordia fruticosa* and *Calotropis procera*. Scrub areas are mainly found near habitations in Bandhavgarh National Park and Panpatha WLS (Plate 3.5).

Riparian Forest: Riparian forest occurs mainly along the Charanganga, Damnar, Janar, Halpal, Jarwahi Nala and Bagaiha Nala in Bandhavgarh TR (Plate 3.6).

Rocky Outcrops: Major rocky outcrops are found in the National Park area (Plate 3.7).

Plantation: Plantation occurs mainly in Panpatha WLS. Major species found are Teak and Eucalyptus (Plate 3.8).

Habitation: Habitation occurs mainly in revenue and forest villages situated inside the National Park and Panpatha WLS (Plate 3.9).

Agriculture: Agriculture occurs in Garhpuri, Magdhi, Kalwah, Bagdari, Milli and Mahanwah in BNP, Sejwahi, Gangital, Kusumaha, Kothiya, Bamera, Kaseru, Badhwahi and Bagaiha in PNP WLS. Some of villages *viz.* Bagdari, Magdhi, Milli, Garhpuri, Gangital and Kaseru have extensive agriculture (Plate 3.10).

Water Bodies: Bandhavgarh TR has very good water sources viz. Janar, Umarar, Charanganga, Halpal, Jarwahi Nala, Bagaiha Nala, and other small nalas. The major artificial water bodies are Garhpuri (BNP) and Bamrea dam in PNP WLS (Plate 3.11).

Plate 3.1 Sal Forest (*Shorea robusta)* near Bandhavgarh Fort , Bhatan Circle

Plate 3.2 Mixed Forest in Kallwah Range

Plate 3.3 Bamboo forest in Pataur Circle, Panaptha WLS

Plate 3.4 Grassland near Bhatan , Tala range

Plate 3.5 Scrubland near Magdhi Village, Magdhi Range

Plate 3.6 Riparian Forest in Majhkheta Circle

Plate 3.7 Rocky outcrops in Tala Range

Plate 3.8 Eucalyptus Plantation in Panpatha WLS

Plate 3.9 Habitation Milli Village, Magdhi Range

Plate 3.10 Agriculture in Garhpuri Village, Khitauli Range

Plate 3.11 Water Body in Garhpuri Range

Figure 3.4 Landuse / Landcover map in and around Bandhavgarh Tiger Reserve (1988)

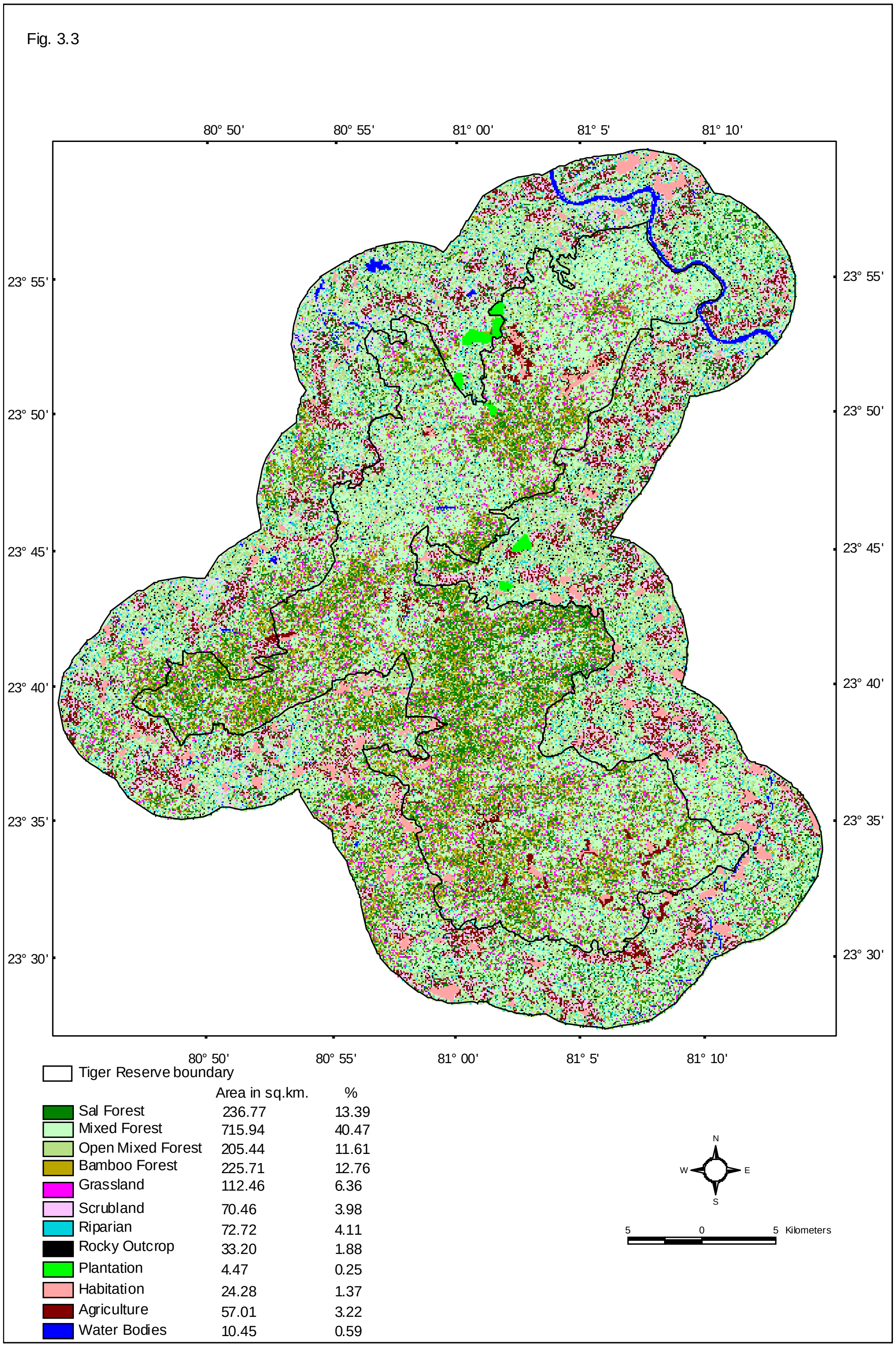


Figure 3.5 Landuse/Landcover map in and around Bandhavgarh Tiger Reserve (1994)

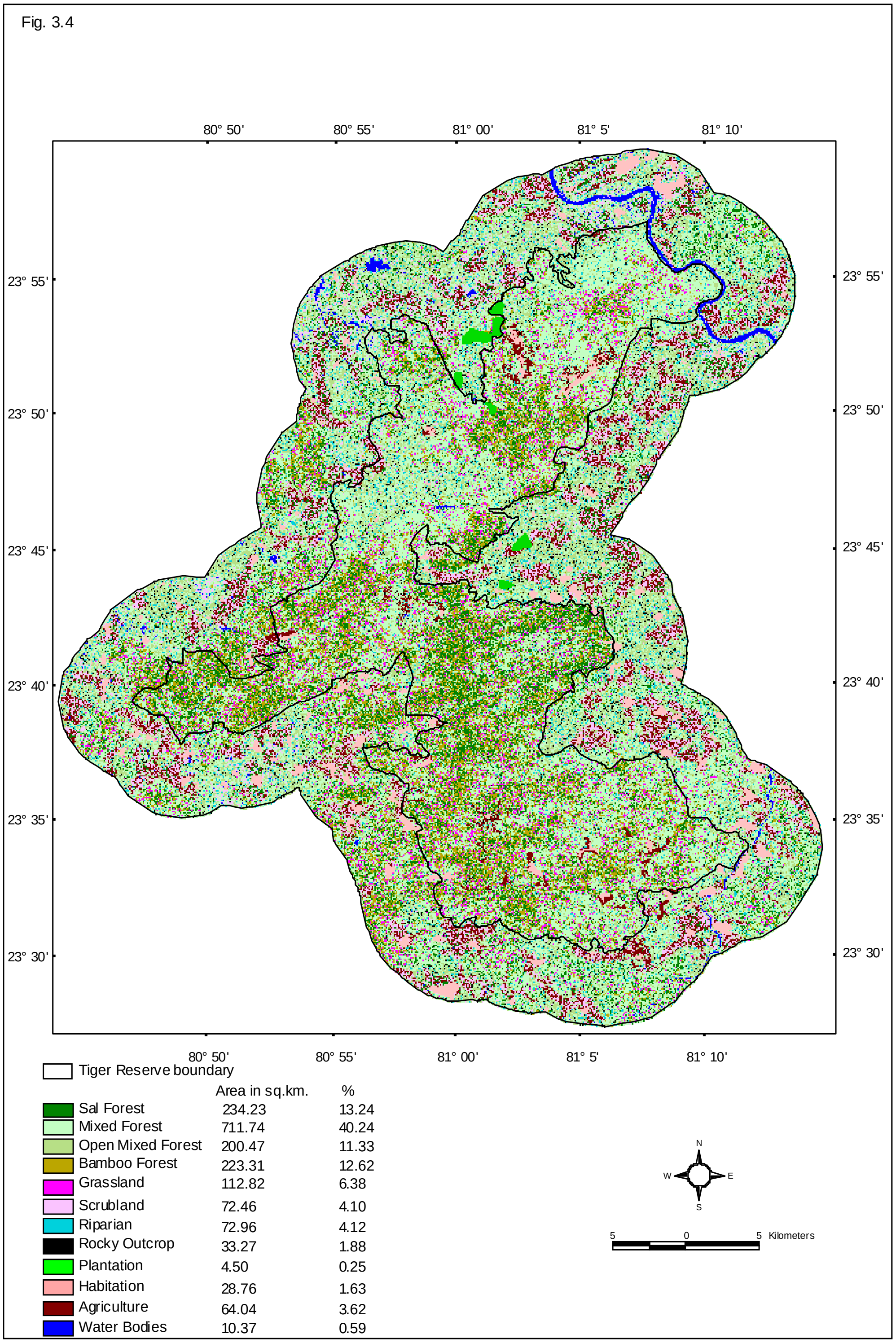
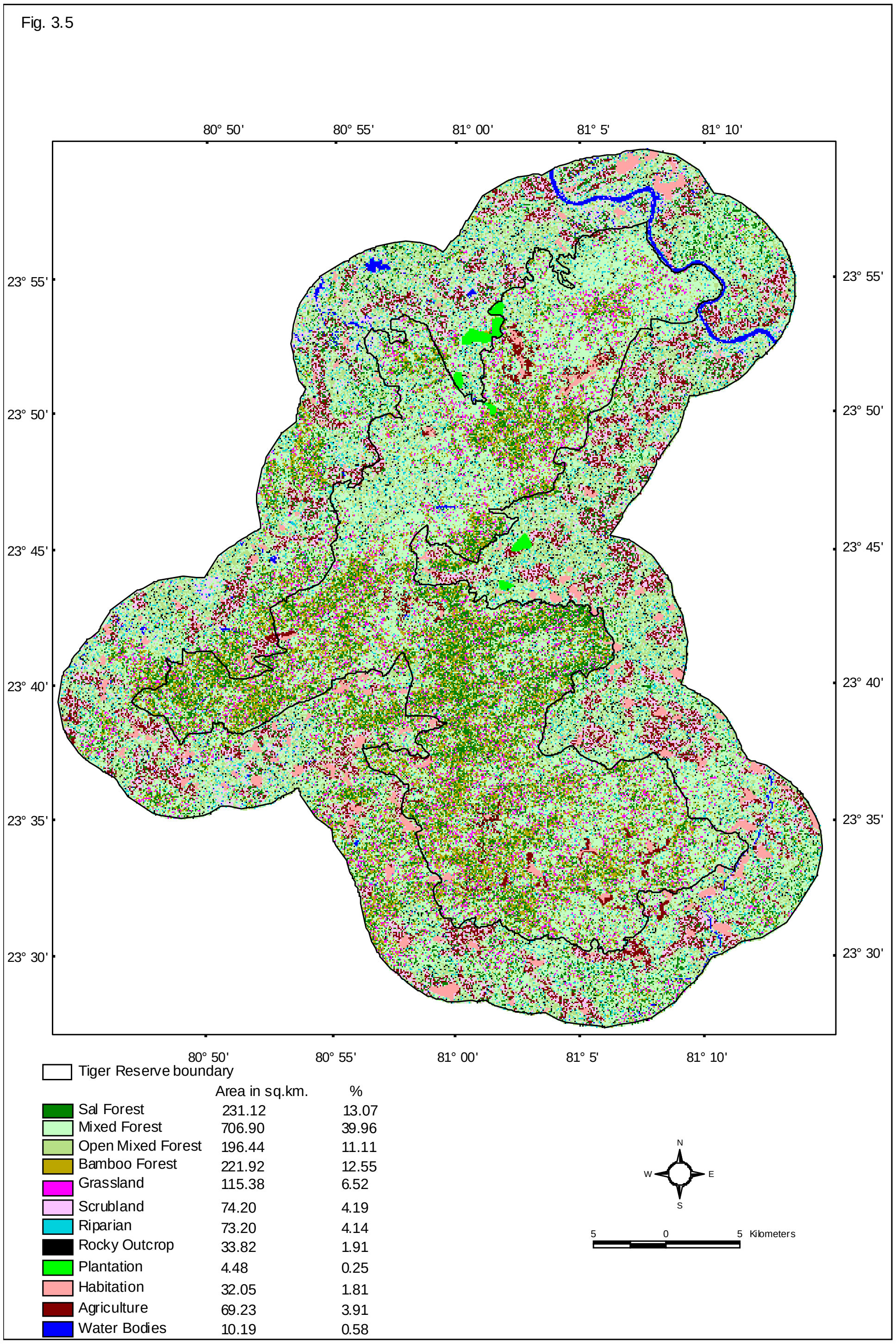


Figure 3.6 Landuse/Landcover map in and around Bandhavgarh Tiger Reserve (2000)



3.8 RESULTS AND DISCUSSION

Through interpretation of satellite data 12 major landuse/landcover were delineated in the study area. Sal and Mixed forests were found distributed in almost the entire area of Bandhavgarh TR. Open Mixed forest were found in the buffer zone and in patches occur within the tiger reserve. Bamboo forest distribution is largely in Panpatha. Grassland patches were observed along the Charanganga river, Damar river, Chachahi Nala, Sukhi Nala and Bhatan range. Major grassland patch occurs in the relocated village (Bhatan), where very large ungulate herds are commonly sighted. Scrubland forests are observed along the roads in Kalwah, Milli, Magdhi, Bagdari, Bamera and Sejwahi villages. Riparian and Rocky outcrops distribution is found in Bhatan, Bagdari, Kudari and Pataur Circle. Plantation are found in Pataur cicle in Panpatha WLS and Umaria Bakel, mainly of teak and Eucalaptus species. Habitation and Agriculture occurs inside Bandhavgarh TR villages Magdhi, Kalwah Bangdari, Gangital, Kusumaha, Kothya, Bamera, Kaseru, Badhwahi, Bagaiha and extensive agriculture is seen in Buffer zone.

The study area is comparatively flat with some plateaus and the Bandhavagarh hill and the fort. Landcover distribution reveals that most of the area in BTR is easily accessible and topography is not a barrier for agriculture and habitation. The lower flat areas are mostly under scrub/grassland whereas plateau areas are either Sal forest, mixed forest and miscellaneous. Landuse pattern defines the distribution of area under different landcover classes and it was observed that area close to roads has more habitations and agriculture compared to inside area. Scrub vegetation is generally found intermingled with the habitation.

Sal forests occupy majority of the landcover classes and occurs in the entire tiger reserve. Sal mixed forest occur in low undulating and plain tract, where there is degeneration in growth and quality. Mixed forests are found on upper slopes mainly due to edaphic factors. The majority of mixed forests are in National Park. Grassy patches occur along the Charanganga river, Damar river, Chachahi, Sukhi, Bandehi, Sone and other nalas. Major grassland occurs in relocated village (Bhatan), where large ungulate herds are seen.

3.9 CONCLUSION

It was observed in the study that a simple reclassification of mixed cluster does not necessary increase classification accuracy or provides more consistent results. Those image products, which provide the best results for one interpreter, might not be the best for another (Kenneth, 1992). Remotely sensed images are a valuable source of landuse/landcover mapping. Landuse/landcover information is most important for decision making and management and to know the present and past status of the vegetation.

Tweleve landuse classes were classified for Bandhavgarh TR. Mixed forest showed dominance by occupying the entire tiger reserve.

Bamboo forests was found mainly in the Panpatha range. Open mixed forest was found in Buffer zone mainly and no single species dominated these forests. It was difficult to separate mixed forests and sal mixed forest due to similar nature of reflectance. In this case, knowledge base classification was done by creating the Area of Interest (AOI) on the classified output. Grassland also shows spectral mixing with scrub forest. In non – forest categories, high spectral similarity was observed between Agriculture and Habitation, with the help of AOI these were delineated. Agriculture areas also show poor seperability from scrubland forest. It is because the agriculture field reflects the same spectral signatures as scrubland due their cropping pattern (agriculture crop with similar scattered trees). The problem of spectral mixing was solved by using GPS points in various locations and post classification refinements were made accordingly. Landcover in 7 forest types and 5 non-forest types were correctly interpreted in this study. In BTR, 90 % of the area is under forest and 10% area is non–forest.

CHAPTER 4

Landuse/Landcover Changes

4.1 INTRODUCTION

Remote sensing data having a range of spatial and spectral resolutions has been useful for the analysis of landuse/cover changes. It is more advantageous when combined with geographical data in digital form (Muhdimyati *et al*, 1996). Space-based sensors that can detect vegetation change include both active and passive types of sensors. Landuse/cover in this study is defined as vegetational and artificial constructions covering the land surface. Remote sensing and GIS are considered as the promising tools for change detection studies. It is a process of identifying differences in the state of object or phenomenon by observing it at different time periods. It is possible to detect change using remotely sensed data because of its repetitive coverage at certain interval and with a consistent image quality. Change detection is useful in such diverse applications as landuse change monitoring of shifting cultivation, assessment of deforestation and other environmental changes.

The ever-increasing population combined with the need for better standard of living leads to indiscriminate use of natural resources like forests, mineral etc. Therefore, there is a need to have inventory, landuse mapping and monitoring of the natural resources on a regular basis (Sudhakar *et al*, 1994; Navin and Foley, 1999).

The study of landuse/cover changes using remote sensing approaches has been conducted by many researchers (Welch and Ehlers, 1987; Thomas *et al* 1987; Nagarathinam *et al*, 1988; Dimyati and Kitamura 1990; Mukai *et al*, 1991; Gomarasca *et al*, 1993; Pathan *et al*, 1993). Remote sensing is a reliable techniques to study, control and monitor the environmental degradation (Mishra *et al*, 1994).

Change detection using satellite data can allow for timely and consistent estimate of changes in landuse trends over large areas (Prakash and Gupta, 1998). What is the distribution of canopy cover, what is the amount of green biomass over the region to answer these and similar questions, remote sensing is the only practical means of obtaining spatially extensive and exhaustive data (Ustin *et al*, 1991). Mapping of forest cover and monitoring its changes with reasonable accuracy in time and space requires large scale temporal data. The advantage of satellite data is that it can be used for detecting short and long term changes in landuse/landcover classes. Updating landuse layers can be viewed as two interrelated processes – detection and delineation of areas of landuse changes and identification of the landuse category. Monitoring variations of Earth's surface by any kind of remote sensing has been an important part as scientific research for decades (Bognar, 2003). The orbital remote sensing with its capability to produce synoptic comprehensive images repetitively has been used to detect dynamic changes and related phenomena (Kunte *et al*, 2003). High spatial resolution satellite remote sensing techniques provide a rapid and powerful tool to detect the co-seismic surface rupture in the remote and high mountain areas (Fu & Lin, 2003). Monitoring and assessment of land condition is one of the key applications of remotely sensed vegetation indices (M.M. Boer, 2003). A fundamental problem of conservation is the need to predict changes in the abundance and distribution of organisms as a result of changes in their habits and therfore remote sensing can be of immense help at landscape level (Mason *et al*, 2003). Remotely sensed data have long been recognized as affording valuable contributions to ecosystem response modelling, wetland monitoring and the detection of indicators of physiological changes (Duppigng *et al*, 2003).

Integrated GIS/image processing systems have the dual advantage of accessing ancillary data sources to aid interpretation/analysis and the ability to directly update landuse information in the GIS. Several systems have been developed (Genazian and Sperry, 1989; Aronoff *et al*, 1987; Derenyi and Pollock, 1990) that integrate GIS with remote sensing. Remote sensing offers a quick and efficient approach to the classification and mapping of landuse/landcover changes over space and time. Information on changes in resource classes, direction, area and pattern of landuse/landcover classes form a basis for future planning.

Data on landuse/landcover patterns, their spatial distribution and changes are the prerequisites for making development plans (Dhinwa *et al*, 1992). Digital classification techniques through stratification approach, with limited ground truth, can be used for mapping broad categories of forest and their density classes (Sudhakar *et al*, 1994). Information with respect to forest cover type classes, density, quality and distribution is needed for conservation planning (Pant *et al*, 1992). Landuse and landcover layers are probably the most common and often the most dynamic components of a GIS database (Avery and Berlin, 1992). Thus efforts at improving the accuracy and timeliness of such data layers, and the efficiency in which they are produced are justified (Ehlers 1990; Stow *et al*, 1990). With the availability of Landsat satellite data collected since 1972, numerous studies (Fuller *et al*, 1994; Stone *et al*, 1994; Bauer *et al*, 1994; Hall *et al*, 1991; Jensen *et al*, 1995) have estimated the extent of landcover types and land cover changes all over the world.

Numerous papers have discussed the various change analysis techniques commonly used (Singh, 1989). There are two general approaches to change detection: (1) comparative analysis of independently produced classifications and (2) simultaneous analysis of multi-temporal data. Examples of the simultaneous analysis techniques include image differencing, ratioing, principal components analysis (PCA), and change vector analysis. Each has its own advantages and disadvantages. The most straightforward technique for detecting change is the comparison of land cover classifications from two dates. The use of independently produced classifications has the advantage of compensating for varied atmospheric and phenological conditions between dates, or even the use of different sensors between dates, because each classification is independently produced and mapped to a common thematic reference. The method has been criticized by some however as it tends to compound errors that may have occurred in the two initial classifications (Gordon, 1980; Stow *et al*.,1980; Singh,1989). The method, however has been widely used, and has successfully been employed for a variety of landcover change investigations, including assessing deforestation (Massart *et al*.,1995) urbanization (Dimyati *et al*.,1996), sand dune changes (Kumar *et al*.,1993), and conversion of semi-natural vegetation to agricultural grassland (Wilcock and Cooper, 1993). Simple image differencing is another technique commonly used for change detection. This technique involves taking the mathematical difference between geo-registered images from two dates. The input data can be radio-metrically calibrated raw imagery, or transformed data such as NDVI imagery. The procedure has been used for coastal zone change detection (Weismiller *et al,*,1977), monitoring forest change (Vogelmann, 1988), and detecting urban expansion (Jensen and Toll, 1983). While often producing excellent results, it has been suggested that image differencing alone may be too simple a procedure to adequately describe many surface changes (Weismiller *et al.*, 1977; Sohl, 1999). Other approaches used successfully to detect land cover change include image ratioing (Howarth and Wickware, 1981) and PCA (Johnston and Haas, 1985; Bryne *et al*., 1980; Ribed and Lopez, 1995). Singh (1989) has discussed the strengths and weaknesses of these approaches. Surface change can also be described by a spectral change vector, which represents the direction and magnitude of change from the first to the second date. An empirically derived or modeled threshold is used to determine the minimum magnitude that represents a change occurrence. Dwyer *et al.* (1997) used data from the brightness-greenness plane (Kauth and Thomas, 1976) in the development of a change vector analysis (CVA). Sohl (1999) successfully used this toolkit in the analysis of change in the United Arab Emirates. Change vector analysis has the advantage of providing a high level of information regarding the magnitude and nature of a surface change, and is well-suited for analyses in which continuous variables are measured, such as vegetation patterns along ecological transitions and gradients. An alternative strategy for detecting change involves spectral mixture modeling, whereby a multi-spectral image is decomposed into spectral end members. There are numerous approaches to stratifying the image into vegetated and non-vegetated components (Foschi and Smith, 1997; Roberts *et al*, 1993; Cochrane and Souza, 1998). The validation of spectral mixture modeling results can be difficult, especially for large areas, and the determination and selection of appropriate spectral end members is critical (Bateson and Curtiss, 1996; Tompkins *et al*, 1997). A number of change detection studies rely on a combination or hybrid approaches that incorporate many of the features of the techniques outlined above, or incorporate techniques that do not easily fit into any of the above categories. Adams *et al*. (1995) measured changes in land cover by classifying images based on spectral end member fractions over a period of 4 years, with class names representing both context and pixel history. Weismiller *et al*. (1977) tested the linking of decision tree classifiers for each of two dates, thereby introducing within the tree logic the detection of the desired changes. Sohl (1999) used simple image differencing in combination with manually interpreted land cover information to describe changes in agricultural and forest cover in the United Arab Emirates. The pre-requisite pre-processing step too many change analysis techniques is to calibrate the images to a common radiometric reference. A viable and widely used alternative is to perform a relative calibration between imagery from different dates. This usually involves the use of a linear transformation in which the additive component corrects for differences in atmospheric path radiance and the multiplicative component corrects for differences in detector calibration, sun angle, Earth-Sun distance, atmospheric attenuation, and phase angle conditions (Dwyer *et al*., 1997). Radiometric control sets representing temporally invariant features are used to derive gains and offsets for the linear transformation. These control sets can be derived from a variety of methods, including various methods identifying pseudo-invariant bright and dark targets (Caselles and Garcia, 1989; Hall *et al*., 1991), the use of ratios of near-infrared to red radiances to identify non-vegetated, non-water elements

(Schott *et al*., 1988), and automated scatter gram-controlled regression (Elvidge *et al*., 1995). A major attribute of the landscape is its spatial pattern and structure. Lambin and Strahler (1994) showed that the detection of land-cover change processes by remote sensing is improved when using both spectral and spatial indicators of surface condition. They suggested that while spectral indicators are more sensitive to fluctuations in primary productivity associated with the inter annual variability in climatic conditions, changes in landscape spatial pattern are more likely to reveal long term and long lasting land cover changes. A wide variety of landscape metrics have been developed (Riitters *et al*., 1995).

Remote sensing has emerged as one of the useful tool to study landcover features (Pant and Kharkwal, 1995). Change detections are one of the key aspects of remote sensing and image analysis. They allow the detection of changes between images (in general two images) acquired at different dates or time periods. Different techniques have been developed to detect changes in the environment (Wong *et al*, 1997). There are a variety of analytical methods that are used to detect ground changes. Basically, they can be separated in two broad classes. Simultaneous analysis of multi-temporal data versus comparative analysis of independently produced classification for different dates (Rigina, 2003). IRS 1A/1C data has been utilized for monitoring the geodynamic changes in a short span of time (Hegde and Raveendra, 2000). Temporal change detection in land cover has now become possible in less time, at lower cost and with better accuracy through remote sensing technology (Kachhwaha, 1985). The information being in digital form can be brought into a Geographical Information System (GIS) to provide a suitable platform for data analysis, update and retrieval. Improvements in satellite remote sensing, global positioning systems and geographic information systems techniques in the past decade have also greatly assisted in the collection of land cover data and the integration of different data types (Star *et al.*, 1997). Land cover change may be the most significant agent of global change as they have important influence on hydrology, climate, and global biogeochemical cycles. In addition to its importance as an input variable to other areas of global change research, it is also an important area of study in its own right. Arguably, land cover change will have a more significant and direct influence on human habitability than climate change over the next 20 to 50 years. It is an issue with far reaching policy implications, either internationally, nationally, or locally. Indeed, land cover change is as inextricably linked to policy and sustainable development as it is to basic research issues.

The present study was initiated to map current status of different land cover categories in Bandhavgarh Tiger Reserve.

4.2 LANDUSE / LANDCOVER

The complete details of the landuse/landcover mapping of the study area have already been discussed in Chapter III. The landuse/landcover map of BTR is given Fig. 3.4 - 1988; Fig. 3.5 - 1994 and Fig. 3.6 - 2000 in chapter III and area estimation under different categories have been provided in Table 3.3 - 1988, 3.4 - 1994, and 3.5 – 2000 in chapter III.

4.3 METHODOLOGY

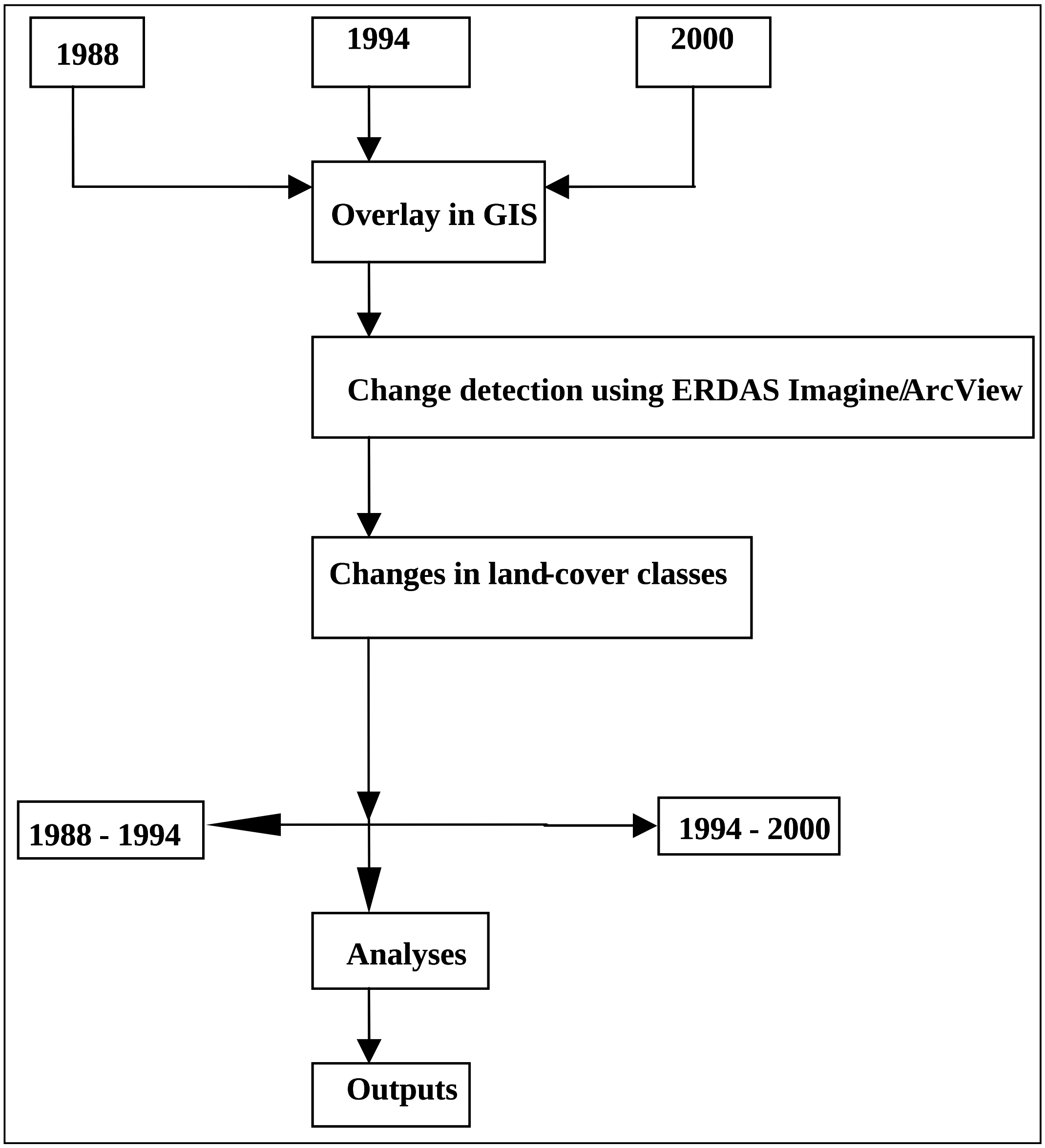
The change detection image is an ideal tool for visual interpretation of change of land cover. ERDAS software was used to compare different layers. Different layers were geo-linked by moving the cursor correspondingly in both windows. This facilitated easy visual interpretation as different layers could be combined to a synthetic image that highlighted changes in different time periods in different colours. Another approach used in detail was to highlight vegetation cover loss, especially near habitation. Normally, a colour image consists of three black and white layers linked to the video monitor three colours - red, green and blue (RGB). However, normally all three layers are recorded at the same time in different period (IRS images). Here, images recorded at different times are each geometrically referenced and mosaiced. Most changes in nearby areas result in vegetation loss. Vegetation creates absorption of sunlight, which results in dark tone in the imagery. After clearing the vegetation, habitation/agriculture or without any vegetation for some time, creates high reflection with resultant light tones in the imagery.

The landuse/landcover maps of BTR in different time periods *viz.* 1988, 1994 and 2000 have been shown in Figure 3.4, 3.5 and 3.6 in Chapter III.

Several approaches used for change detection viz. thresholding of a single spectral feature example difference channel (Saukkola, 1982); linear transformation to merge two temporal data sets (Richards 1980, Collins and Woodcock, 1996); analogue images of bands describing the change (Eyton 1983, Hame 1991); direct classification of a multi-date set (Swain and Davis 1978, Varjo 1994); decision tree classifiers (Lozano – Garcia and Hoffer, 1985); residual computation of a regression model between two images (Frank, 1984; Olsson 1994; Jha and Unni, 1994) and change vector analysis (Malila, 1980; Lambin and Strahler, 1994a).

The methodology used in Landuse/Landcover Change Detection in this study is shown in Fig. 4.0.

Figure 4.0 Flow Chart: Method adopted for landuse/landcover change detection



In this study, the registration of each image was performed using the nearest neighborhood re-sampling algorithm in ERDAS Imagine image processing software. The basic data analysis techniques employed for landuse changes detection are image overlay and binary masking (Pilon *et al*, 1988). Several researchers have attempted various change detection techniques based upon the objective and the area of interest. Of the many transformation available, four have been selected for the present study:

i) image differencing, ii) image rationing,

iii) vegetation index differencing and iv) image regression.

4.3.1 Image differencing

The procedure is to register simply two images and prepare a temporal difference image by subtracting the digital number (DN) for one date from that of the other. The difference in the areas of no change will be very small and areas of change will reveal larger positive or negative value (Lillesand and Kiefer, 1987). Each kind of landcover changes can be detected only in a subset of multi-temporal spectral bands (Bruzzone and Serpico , 1997).

Image differencing is probably the most widely applied change detection algorithm (Singh, 1989). It involves subtracting one date of imagery from a second date that has been precisely registered to the first. In this method, registered images acquired at different times are subtracted to produce a residual image which represents the change between the two dates. Pixels of no radiance change are distributed around the mean, while pixels of radiance change are distributed in the tails of distribution (Singh, 1986).

The images from scenes 2000 and 1994; and 1994 to 1988 were subtracted that represented areas of expected change. The image subtraction ensured that if the value from either input image was 0 that it would be 0 in the output image (EITHER - IF (GT 0 AND GT 0) OR 0 OTHERWISE).

4.3.2 Image rationing

In rationing, two registered images from different date with one or more band in an image are rationed, band by band. The data are compared on a pixel by pixel basis.

Mathematically,

$$R X^k_{ij} = \frac{X^k_{ij}(t_2)}{X^k_{ij}(t_1)}$$

Where $X^k_{ij}(t_2)$ ***is the pixel value of band k for pixel x at row I***

and $R X^k_{ij}$ at time t_1

If the intensity of reflected energy is nearly the same in each image then = 1, this indicates no change. In area of change, the ratio value would be significantly greater than 1 or less than 1 depending upon the nature of changes between two dates. The critical appropriate threshold value in the lower and upper tails of the distribution representing changed pixel values (Mitra, 1991; Pickup and chewings, 1988) showed changes in variance of pixel sub-areas could be the most sensitive indicator of landscape instability.

In registered images year 2000, 1994 and 1988 from different date with one or more band in an image are ratio compared band by band. The data are compared on a pixel by pixel basis.

4.3.3 Vegetation index differencing

Jackson *et al* (1993) defined as ideal vegetation index as one which 'would be sensitive to vegetation insensitive to soil background changes and only slightly influenced by the atmosphere' over the past twenty years. A number of vegetation indices have been developed to aid the interpretation of remotely sensed data (Bouman, 1992). Of all the vegetation indices proposed, the Normalized Difference Vegetation Index (NDVI). Ashley and Rea (1975) has become the most popular NDVI = $\{\lambda_{NIR} - \lambda_{RED}\} / \{\lambda_{NIR} + \lambda_{RED}\}$, NDVI has become the primary tool for description of vegetation changes and interpretation of the impacts of environmental phenomena (Ricotta *et al*, 1996).

In vegetation studies the ratios, commonly known as vegetation indices have been developed for the enhancement of spectral differences on the basis of strong vegetation absorbance in the red and strong reflectance in the near infrared part of the spectrum. It has been shown that a ratio of near infrared band 3 of LISS III and red band 2 of LISS III is significantly correlated with the amount of green leaf biomass (Price, 1992).

$$D_{NDVI} = (IR - R)/(IR + R)t_2 - (IR - R)/(IR + R)t_1$$

Here the normalized difference vegetation index (NDVI) has been used because NDVI differencing techniques was identified by Singh (1989) as among the few most accurate change detection techniques.

Vegetation index differencing techniques was therefore used to analyze the amount of change in vegetation (green) versus non-vegetation (non-green) with the two temporal data. The t_1 and t_2 in the equation denote the two different dates, where t_1 is for the year 1988 and t_2 for 1994, Figure 4.1 and Figure 4.2 depicts the image obtained from vegetation index differencing between the two dates (1988 – 1994) and (1994 – 2000).

Figure 4.1 Bandhavgarh Tiger Reserve, Vegetation Index Differencing (1988-1994)

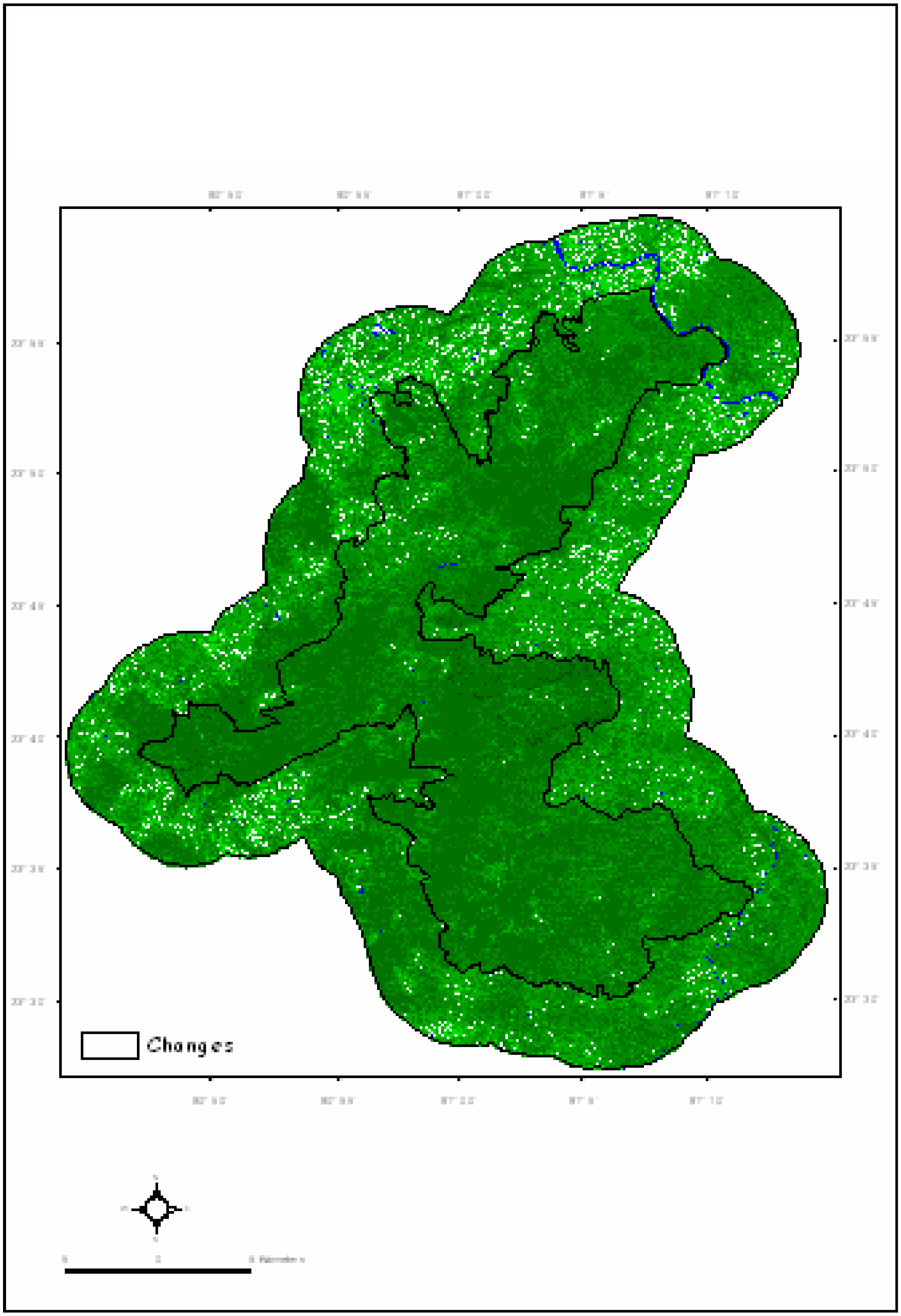
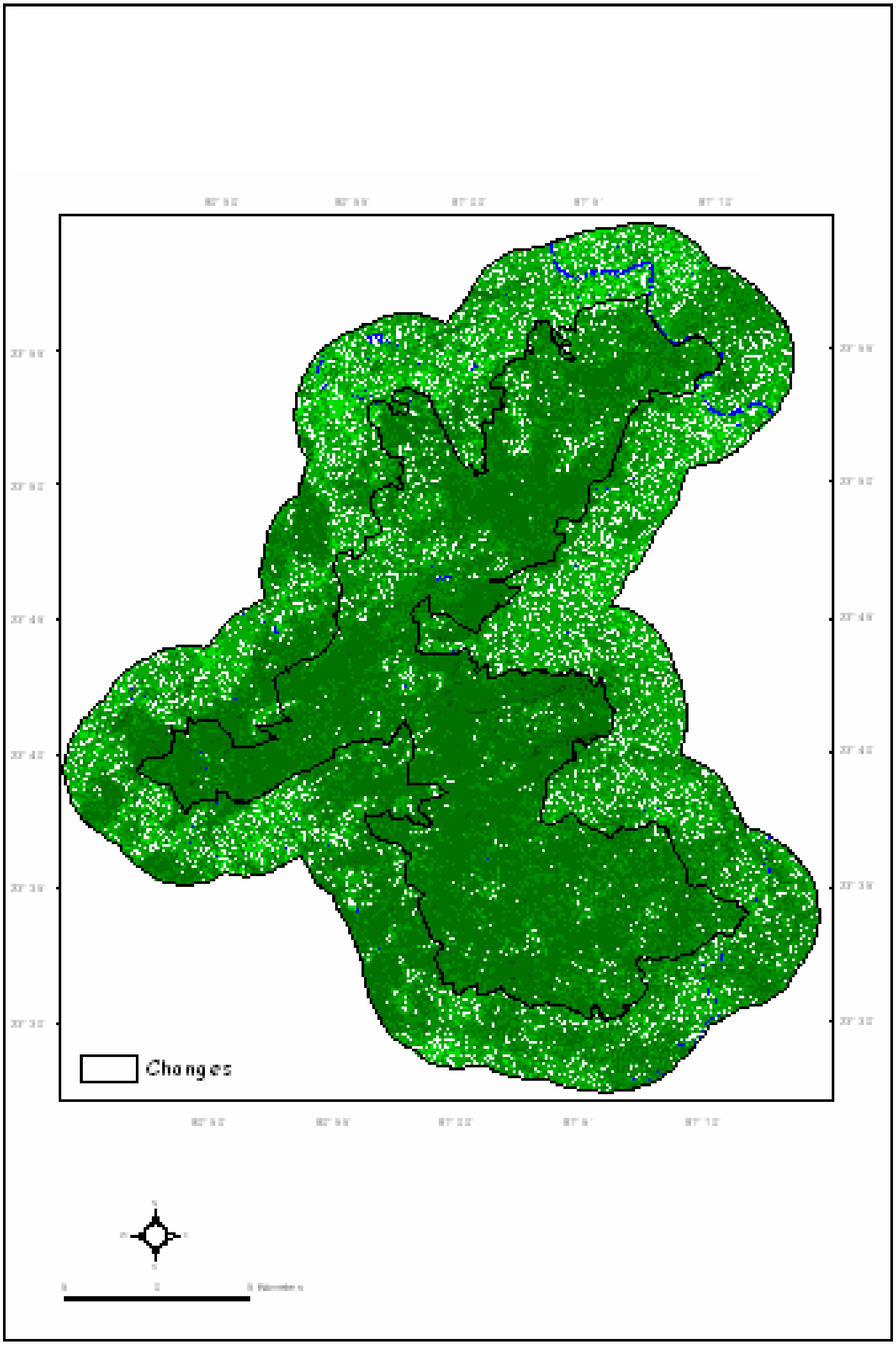


Figure 4.2 Bandhavgarh Tiger Reserve, Vegetation Index Differencing (1994-2000)



4.3.4 *Image regression*

In this method it is assumed that pixel from time t_1 are in a linear function of the time t_2 pixels. So it is possible to regress $X^k{}_{ij}$ (t_1) against $X^k{}_{ij}$ (t_2) using a linear regression. If $X^{\wedge k}{}_{ij}$ (t_2) is the predicated value obtained from the regression line, the difference image can be defined as

$$DX^k{}_{ij} = X^{\wedge k}{}_{ij}\,(t_2) - X^{\wedge k}{}_{ij}\,(t_1)$$

The regression techniques accounts for difference in the mean and variance between pixel value of different dates so that adverse effects from differences in atmosphere condition or sun angle are reduced (Jenson, 1983).

Using IDRISI GIS software, regression analysis was performed for each band (Green, Red and Near-infrared of 1988, 1994 and 2000) and the results are listed in Table 4.1 and Graph has shown.

Table 4.1 Regression Analysis:

X (1988) Independent variable	Y (1994) Dependent variable	S	I	r	R	Std error estimated
Band 2	Band 2	0.9010	0.0552	0.9958	0.9916	0.8305
Band 3	Band 3	1.1898	0.2906	0.9846	0.9694	1.9767
Band 4	Band 4	0.9378	0.0202	0.9976	0.9952	1.3173

X (1994) Independent variable	Y (2000) Dependent variable	S	I	r	R	Std error estimated
Band 2	Band 1	3.3479	0.0722	0.9910	0.9821	4.1136
Band 3	Band 2	1.7099	-0.014	0.9772	0.9549	4.2025
Band 4	Band 3	1.8720	0.1350	0.9927	0.9854	4.3545

S = Slope, I = Intercepted obtained from linear regression,
r = Correlation coefficient, R = Coefficient of determination

Fig. 4.3 Linear regression band infrared (1988 – 1994)

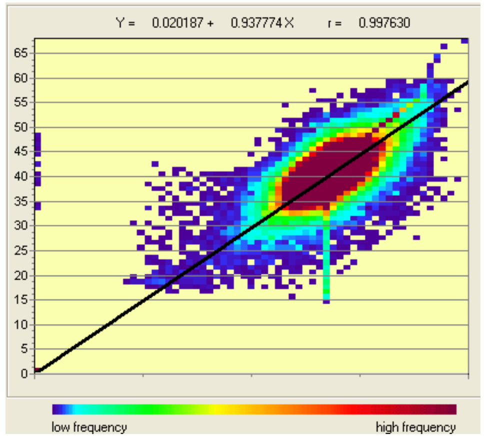


Fig. 4.4 Linear regression band red (1988 – 1994)

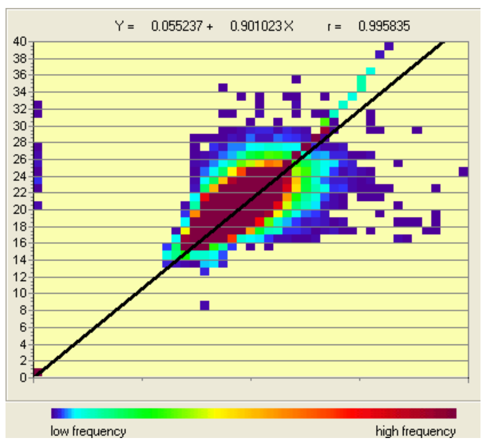


Fig. 4.5 Linear regression band green (1988 – 1994)

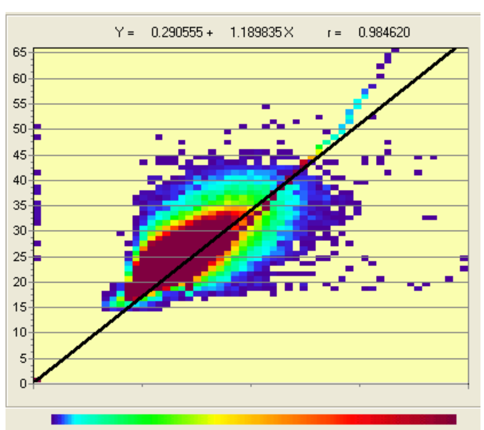


Fig. 4.6 Linear regression band infrared (1994 – 2000)

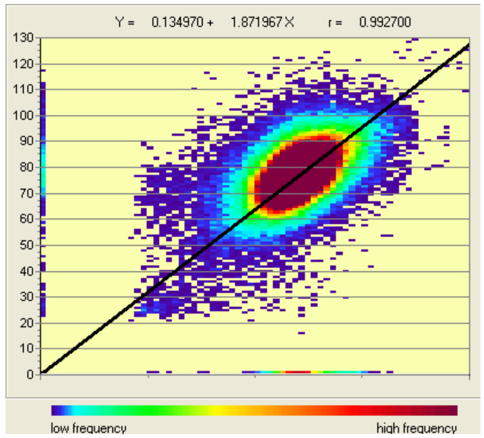


Fig. 4.7 Linear regression band red (1994 – 2000)

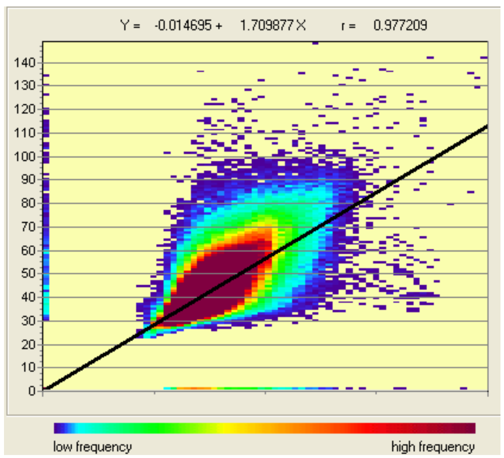
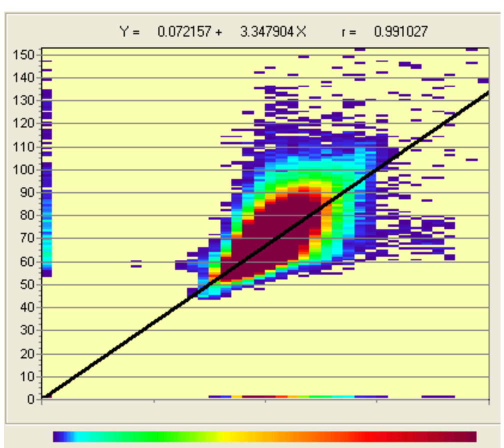


Fig. 4.8 Linear regression band green (1994 – 2000)



It was found that r value of NIR band showed a high correlation, but the other band result showed the pixel were very little scattered. The reason could be the changes in landcover over the period. It was also found between 1988 – 1994 in (NIR & R) to 1994 – 2000 (NIR & R) decrease the relation, which indicate forest areas could be decreased.

4.4 CHANGE DETECTION

The landuse/landcover maps of BTR have shown different time periods *viz.* 1988, 1994 and 2000 in Figure 3.3, 3.4 and 3.5 in Chapter III.

4.4.1 Changes in landuse/landcover classes between 1988 and 1994:

Between 1988 and 1994 there was no change in the total geographical area. The area of Sal with bamboo and mainly bamboo, Grassland, scrubland, habitation and agriculture increased. On the other hand, area under Sal forest, mixed forest, open mixed forest bamboo forest decreased. Bamboo increased in core area but decreased in buffer areas during this period. It was also revealed that of most of landcover classes, maximum changes occured in open mixed forest and mixed forest, least in rocky outcrops and plantation (Table 4.2) The landuse/landcover changes of BTR is given Fig. 4.9 (1988 - 1994) and Fig. 4.10 (1994 – 2000).

Table 4.2: Showing changes in area (km^2) under different land-cover categories between 1988 and 1994.

1988-94

		BTR	**Increase/ Decrease**	**Buffer 5km**	**Increase/ Decrease**
1	Sal Forest	0.87	-	1.67	-
2	Mixed Forest	1.72	-	2.48	-
3	Open Mixed Forest	1.38	-	3.59	-
4	Bamboo Forest	0.02	+	2.42	-
5	Grassland	0.11	+	0.25	+
6	Scrubland	0.30	+	1.70	+
7	Riparian	0.40	+	0.16	+
8	Rocky Outcrops	0.00	+	0.07	+
9	Plantation	0.01	0	0.02	0
10	Habitation	1.10	+	3.38	+
11	Agriculture	2.04	+	4.98	+
12	Water Bodies	0.01	-	0.07	-
	Total	**7.98**		**20.79**	

(- decrease, + increase, 0 no change)

Figure 4.9 Bandhvagarh Tiger Reserve Landuse/Landcover changes (1988 -1994)

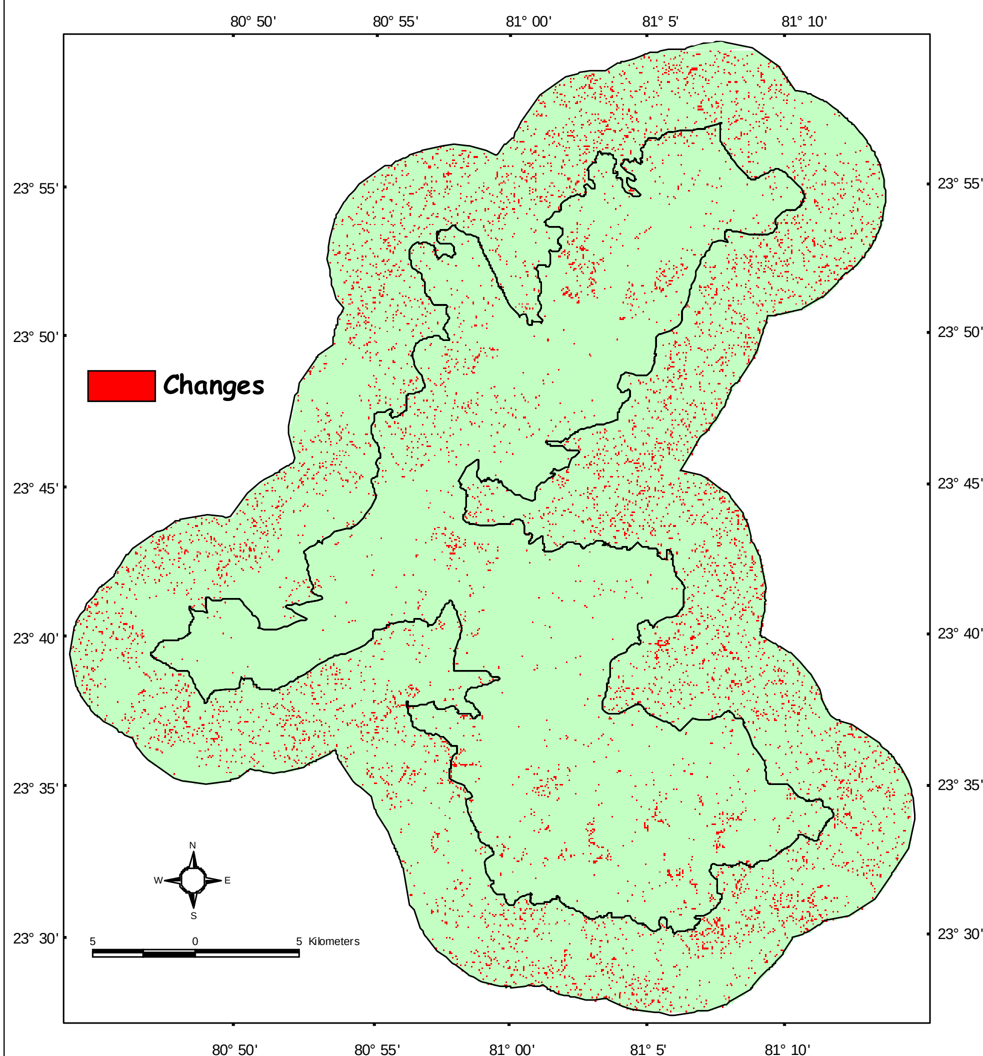
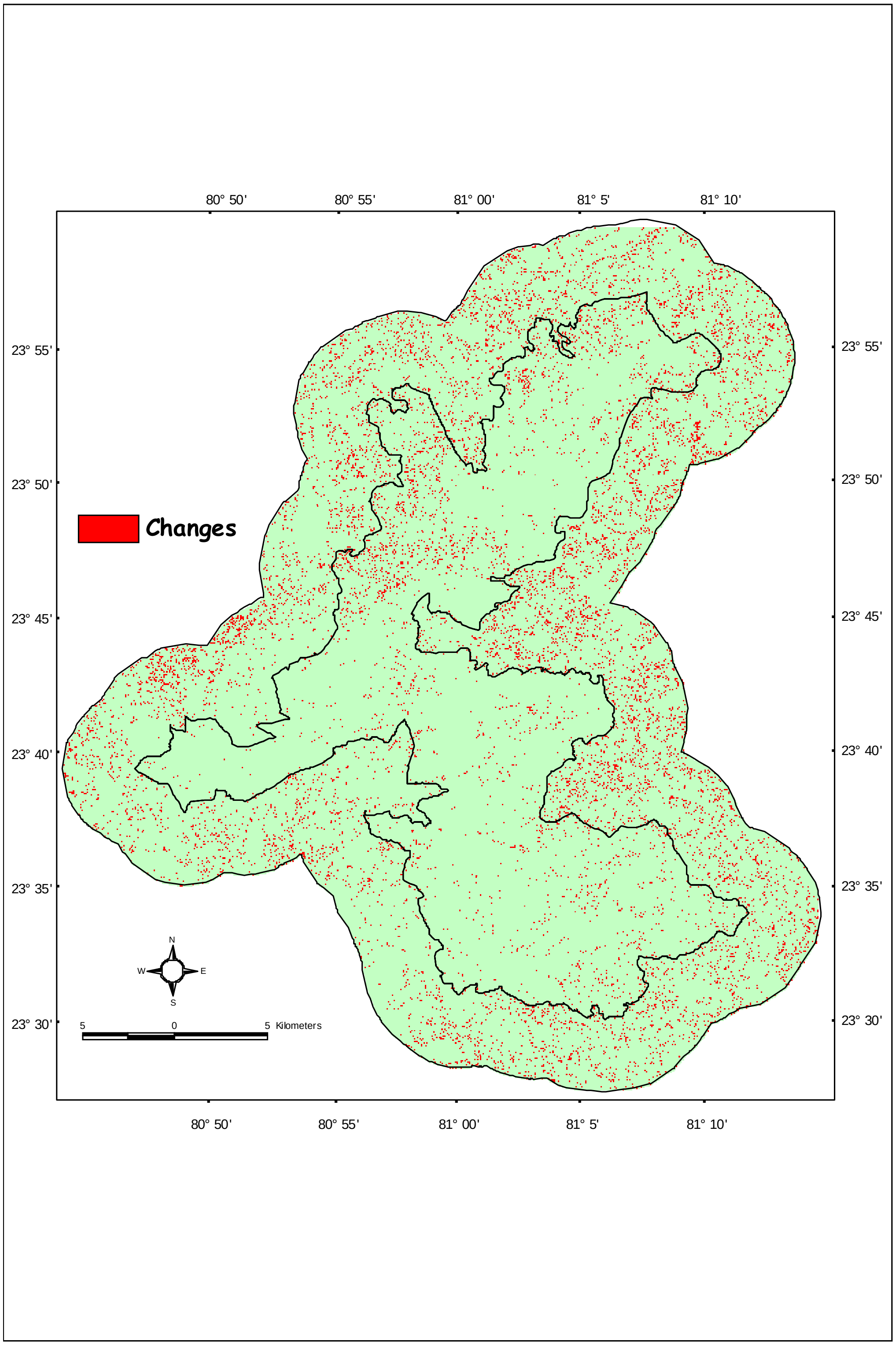


Figure 4.10 Bandhavgarh Tiger Reserve Landuse/Landcover Changes (1994 - 2000)



4.4.2 Changes in landuse/landcover classes between 1994 and 2000:

It was found that between 1994 and 2000 area under Sal forest, Sal mixed forest, Mixed Sal forest, open mixed forest and water bodies decreased, while that under grassland, scrub, habitation and agriculture increased. Bamboo decreased in buffer area but increased in core area. It was also found that most of landcover classes maximum changes took in open mixed forest and Sal mixed forest, least in rocky outcrop and plantation (Table 4.3).

Table 4.3: Showing changes in area (km^2) under different land-cover categories between 1994 and 2000

1994-2000

		BTR	Increase/ Decrease	Buffer 5km	Increase/ Decrease
1	Sal Forest	1.40	-	1.71	-
2	Mixed Forest	1.42	-	3.41	-
3	Open Mixed Forest	1.75	-	2.28	-
4	Bamboo Forest	0.03	+	1.37	-
5	Grassland	1.19	+	1.38	+
6	Scrubland	0.04	+	1.78	+
7	Riparian	0.10	+	0.13	+
8	Rocky Outcrops	0.08	+	0.47	-
9	Plantation	0.00	-	0.03	+
10	Habitation	0.87	+	2.42	+
11	Agriculture	2.38	+	2.82	+
12	Water Bodies	0.02	-	0.20	-
	Total	**9.26**		**18.00**	

(- decrease, + increase, 0 no change)

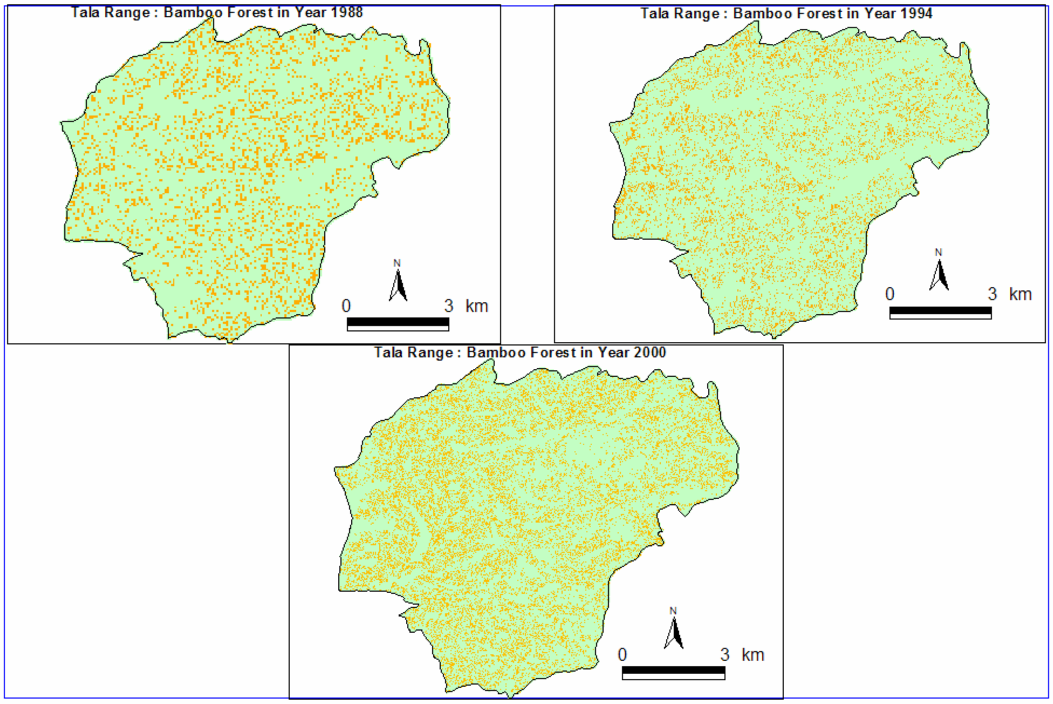
4.4.3 Bamboo forest cover changes in Tala Range

Within Bandhavgarh National Park, Tala Range is one of the most protected forest range. During the mid 1980s, gregarious flowering of bamboo occurred in Umaria district, wherein Bandhavgarh National Park located. An attempt was made to detect the changes in Bamboo forest in the Tala Range during the period 1988 – 1994 and 1994 -2000. It is apparent that post gregarious flowering, dense bamboo thickets have come up. Between 1988 – 94, the increase was 96.79 ha or 4.09 % and between 1994 – 2000 the increase was 102.15 ha or 4.14 % Table 4.4 . This growth of bamboo has proved to be very useful for the ungulate species as the young bamboo provides good forage values.

Table 4.4 Bamboo forest cover changes in Tala Range

Year	Area in hectare	Change in area (1988 –1994)	Change in area (1994 – 2000)
1988	2268.65	96.79 ha (4.09 %)	102.15 ha (4.14 %)
1994	2365.44		
2000	2467.59		

Figure 4.11 Bamboo Forest in Tala Range



4.5 RESULT AND DISCUSSION

By using remote sensing and GIS analyses, the nature, rate and location of Land use/Landcover changes have been analyzed. The integration of remote sensing and GIS is a powerful tool and decision support system for forest management. Change labeling is a multi-step process that converts the change image to a change map that identifies decreases and increases in vegetation cover. The change image is subset into individual forest types (e.g., Sal, Mixed forest and scrubland) by overlaying the vegetation layer and selecting those areas in the change image that have the same forest type. An unsupervised and guided supervised classification is performed on the individual forest type change images resulting in groups of similar levels of brightness, greenness and wetness. These groupings are assigned to one of the twelve change classes. Image appearance, digital interpretation, vegetation and topographic maps aid in assigning the change classes.

BTR has no topographical barrier and most of the area is easily accessable. Landuse patterns define the distribution of area under various land cover classes. It was observed in the present study that areas close to roads were more inhabited compared to those away from road. Scrub was generally found in entire buffer zone and near habitation. In BTR villages are encroaching the habitation and agriculture purposes.

Ecological changes are occurring rapidly owing to high population growth, industrialization, urbanization, mining and quarrying activities (Tripathy *et al*, 1996). Changes in landuse in BTR can be attributed to development activities in the villages. It was found that open mixed forest near habitations have been converted to scrub forest. Relocated village Bhatan from Bandhavgarh National Park has been converted to very good grassland. Some of the bamboo forest in Panpatha WLS near habitation have been converted into agriculture land. In buffer zone, near habitation grassland converted to agriculture land. In BTR, the forest villages are mainly dependent on forest resources and they have several cattle which illegally graze in forest areas. Construction activities have also increased in and around villages. At several places open mixed forest has been converted into open-land. In Panpatha WLS, at several places along the boundary mixed forest have been converted into grassland.

4.6 CONCLUSION

Landuse/landcover changes over time in response to economic, social and environmental forces (Sunar, 1998). Remote sensing images provide excellent opportunities for analysing both vegetation and spatial statistics (Ricotta *et al*, 1996). Remote sensing data also helps in providing precise information on degradation patterns (Ghatol and Karale, 2000). The ground level changes can be easily captured from multi-date satellite data due to the changes in reflectance characteristics. The occurrence of landuse/landcover change was highly correlated with road accessibility. The newly created agriculture areas from forest, which has highest tendency of change among the landuse/landcover classes for the 12 year period from 1988 to 2000, had a higher correlation with increasing village population, cattle numbers and road accessibility than the other landuse/landcover classes and highest changes were near habitation in buffer zone.

The analysis of changes in forest area is based only on remotely sensed data and does not account for other landuse practices. However the most likely cause of forest loss in BTR is probably habitation/agriculture. In this study, four change detection methods were employed to observe and analyses landuse/landcover changes in the BTR with multi-date satellite data. Considerable changes in landuse/landcover in BTR were recorded during the period 1988 – 2000. The study suggests that the impacts of human-caused landcover changes on forest are very important. The monitoring of landcover changes over 12 years time period is a matter of great scientific interest. Some of the Sal, Mixed forests and open mixed forest have become grasslands; grassland and scrublands have become agriculture and habitation. Dynamic transition processes are of key interests in fields such as geography, forest monitoring and sustainability research. Remote sensing and GIS techniques are very useful for differentiating and identifying various landuse/landcover classes and for landuse change detection.

CHAPTER 6

Conclusions

CONCLUSION

The first objective of the study was to map the major vegetation communities of Bandhavgarh TR. For vegetation mapping satellite data was used and digital image processing was done using ERDAS imagine software. Twelve landuse/landcover categories were identified of which seven were forest and five were non forest categories. Sal and Mixed forest communities were observed in the entire area. The buffer area mainly had open mixed forest. Bamboo forest was found in dense thickets in Tala and Panpatha Ranges. Habitation and Agriculture were observed both in core and in buffer zones. The population of villages in BTR is increasing and encroachment of forest land was observed. The vegetation structure, composition and associations in BTR observed in the study have helped in planning vegetation management strategies by the park management.

The second objective was change detection using time series analysis for the period 1988 to 1994 and 1994 to 2000. Several methods were used for change detection. It was found that changes in Buffer zone were maximum due to increase in agriculture and habitation. There is an urgent need to relocate the villages inside the Bandhavgarh TR in order to reduce the biotic pressure on Bandhavgarh TR resources.

The third objective was to develop a resource database in GIS domain for Bandhavgarh TR on 1:50,000 scale. In total twenty three thematic layers were generated including Landuse/landcover. Out of twenty three layers eight, layers were derived and fifteen were primary layers. The entire database in GIS domain has been transferred to the Bandhavgarh TR authorties and technical staff has been trained to use and update the spatial database. The utility of remote sensing used in conjunction with GIS and GPS technologies has been successfully demonstrated in the study. The bamboo forest cover changes in Tala Range during the period 1988 -2000, in which gregarious flowering of bamboo had occurred, has been appropriately quantified using remotely sensed data and change detection techniques.

REFERENCES

Adams, J.B., D.E. Sabol, V. Kapos., R.A. Filho, D.A. Roberts, M.O. Smith, and A.R. Gillespie, (1995). Classification of multispectral images based on fractions of endmembers: Application to land-cover change in the Brazilian Amazon, *Remote Sensing of Environment,* 52: 137-154p.

Alexandre H. Hirzel, Jacques Hausser and Nicolas Perrin (2000). Biomapper 2.0. Laboratory for Conservation Biology, University of Lausanne.

Anderson J.R, Hardy E.E, Roach J.T. and Witmer R.E. (1976) A landuse and landcover classification system for use with Remote Sensor Data, A U.S. Geological Survey Pr. of paper, 964, 28p.

Anon (1997). Exploiting tigers. *Sanctuary Asia*. 17(6): 59 - 63p.

Anon. (1972). Project Tiger. Government of India, New Delhi.

Aronoff S., R.Mosher and R.V. Maher (1987). Operational remotely sensed data GIS' 87. Second Annual International Conference, Exhibits and Workshop on Geographic Information System, San Francisco, California, 216 – 225p.

Ashley M.D. and Rea J (1975). Seasonal vegetation difference from ERTS imagery. *Photogrammetric Engineering and Remote Sensing,* 41, 713 – 719p.

Aspinall R.J. (1990a) Inductive spatial modeling a tool for wildlife habitat evaluation proceeding of the International Union of Forestry research organization XIXth World congress, Montreal 1990 Vol 1, 151 – 162.

Aspinall R.J. (1990b) Use of an inductive modeling procedure based on Bayes' theorem for analysis of pattern in spatial data. Computer modeling in the environmental science Institute of mathematics conference series No. 27, edited by D.G. Farmer and M.J. Rycroft (Oxford : Oxford University Press) 325 - 339.

Avery T.E. and G. Berlin (1992). Fundamental of remote sensing and Air photo interpretation, Fifth edition. Macmillan Publishing company, New York, 472p.

Bateson, A. and B. Curtiss, (1996). A method for manual endmember selection and spectral unmixing, *Remote Sensing of Environment* 55: 229-243p.

Bauer M.E., Burk T.E., Ek A.R., Coppin P.K.,Lime A.D., Walsh T.A., Walter D.K., Befort W. and Heinzen D.F. (1994). Satellite inventory of Minnesota forest resources. *Photogrammetric Engineering and Remote Sensing,* 60, 287 – 298p.

Beaubien J. (1986). Visual Interpretation of vegetation through digitally enhanced Landsat MS image. Remote Sensing Review2: 111 – 143p

Bhan S.K, Ravindran K.V, Tiwari A.K., Kudarat M, Diwakar P.G, Kannappan K.T, Vohra T. P.S. and Vardan K.R.S. (1989a) Potential of IRS 1A data for land resources mapping – Case study from Punjab and Chandigarh. Presented in Regional Workshop on IRS 1A. Mission and its application potential, Ludhiana, April 27, 1989.

Bhan S.K, Ravindran K.V, Tiwari A.K., Kudarat M, Diwakar P.G, Kannappan K.T, Vohra T. P.S. and Vardan K.R.S. (1989ab) Application Potential of IRS 1A data for Geological, Geomorphological and Hydromorphological mapping – Case study Himachal Pradesh. Presented in Regional Workshop on IRS 1A. Mission and its application potential, Shimla, May 24, 1989.

Bhan S.K, Ravindran K.V, Tiwari A.K., Kudarat M, Diwakar P.G, Kannappan K.T, Vohra T. P.S. and Vardan K.R.S. (1989c) Integrated study of Kalka area. Presented in Regional Workshop on IRS 1A. Mission and its application potential, Chandigarh, May 19, 1989.

Boer M.M. and J. Puigdefabregas (2003). Presdicting potential vegetation index values as a reference for the assessment and monitoring and dryland condition. *International Journal of Remote Sensing,* Vol 24, No.5, 1135 – 1141p.

Bognar P. (2003). Correction of the effect of Sun-sensor-target geometry in NOAA AVHRR data. *International Journal of Remote Sensing,* Vol. 24, No. 10, 2153 – 2166p.

Bosworth J., T.Koshimizu and S.T. Action (2003) Multi-resolution segmentation of soil moisture imagery by watershed pyramids with region merging. *International Journal of Remote Sensing,* Vol24, No. 4, 741 – 760p.

Botkin D.B., Estes, J.E.Mc Donald, R.M. and Wilson, M.V., (1984).Studying the Earth s vegetation from the Space.Bioscience, 34:508.

Bouman B.A.M.(1992). Accuracy of estimating the leaf area index from vegetation I ndices derived from crop reflectance characteristics, a simulation study. *International Journal of Remote Sensing,* 13, 3609 – 3084p.

Bruzzone L. and S.B. Serpico (1997). Detection of change in remotely sensed images by the selective use of multi-spectral information. *International Journal of Remote Sensing,* Vol. 18, 3883 – 3888p.

Bryne, G.F., P.F. Crapper, and K.K. Mayo, (1980). Monitoring land-cover change by principal component analysis of multitemporal Landsat data, *Remote Sensing of Environment* 10: 175-184p.

Campbell, J.B. (1987) Introduction to Remote Sensing. The Gulford Press, New York, 497p.

Caselles, V., and M.J. Lopez Garcia, (1989). An alternative simple approach to estimate atmospheric correction in multitemporal studies, *International Journal of Remote Sensing*, 10(6): 1127-1134p.

Champion, H.G. and Seth, S.K. (1968). A revised Survey of Forest Types of India. Manager of Publications, Govt. of India, New Delhi. 143-150p.

Chaurasia R., Closhali D.C., Dhaliwal S.S., Minakshi Sharma P.K., Kudrat M. and Tiwari A.K (1996). Landuse change analysis for agricultural management - a case study of Tehsil Talwandi Sabo, Punjab. *Journal of Indian Society of Remote Sensing*, Vol. 24, No.2. pp. 115-123.

Cochrane, M.A. and C.M. Souza, (1998). Linear mixture model classification of burned forests in the Eastern Amazon, *International Journal Remote Sensing,* 19(17): 3433-3440p.

Collins J.B. and Woodcock C.E. (1996). An Assessment of several linear change detection techniques for mapping forest mortality using multi-temporal Landsat Tm data. *Remote Sensing of Environment,* 56, 66 –77p.

Das K.K, S.Ravan, S.K.Negi, A. Jain and P.S. Roy (1996). Forest cover monitoring using remote sensing and GIS – A case study in Dhaulkhand Range of Rajaji National Park. *Journal of the Indian Society of Remote Sensing,* Vol 24, No. 1, 34p.

Defries R and Townshend J.R.G (1994a) NDVI – derived land cover classification at a global scale. *International Journal of Remote Sensing,* 15, 3567 – 3586p.

Defries R, Hansen M. and Townshend J. (1995) Global discrimination of landcover types from metrics derived from AVHRR pathfinder data. *Remote Sensing of Environment,* 54, 209 –222p.

Derenyi E and R. Pollock (1990). Extending a GIS to support image based map revision. *Photogrammetric Engineering and Remote Sensing,* 56 : 1493 – 1496p

Dhinwa P.S, Pathan S.K., Sastry S.V.C, Mukund Rao, Majumder K.L., Chotani M.L., Premnath Singh J and Sinha R.L.P. (1992). Landuse change analysis of Bharatpur District using GIS. *Journal of the Indian Society of Remote Sensing,* Vol. 20, No. 4, 237 - 250p.

Dimyati M and Kitamura T (1990). The application of digital image processing for residential variation analysis using Landsat MSS and SPOT data. *Asian Pacifica Remote Sensing Journal,* 2, 33 – 44p.

Dimyati, M., K. Mizuno, S. Kobayashi, and T. Kitamura (1996). An analysis of land use/cover change using the combination of MSS Landsat and land use map – A case study in Yogyakarta, Indonesia, *International Journal of Remote Sensing,* 17(5): 931-944p.

Domoghue Daniel N.M and Shenan I (1987) A preliminary assessment of Landsat TM imagery for mapping vegetation and sediment distribution in Wash Estry. *International Journal of Remote Sensing,* 8 (7); 1101 – 1008p.

Dubey, Yogesh. (1999). Application of Geographic Information System in Assessing Habitat, Resource Availability and its Management in Tadoba – Andhari Tiger Reserve - D.Phil. Thesis, Forest Research Institute (Deemed University), Dehradun.

Dupping L.A. – Giroux; C.F. Black Well; S.Bristow and G.M. Olson (2003). Vegetation response to ice disturbance and consecutive moisture extremes. *International Journal of Remote Sensing,* Vol. 24, No. 10, 2105 – 2129p.

Dutta, J.J and Panwar H.S. (1979) Tiger conservation in Madhya Pradesh, International Symposium on Tiger. New Delhi, February 22 –24, 6p.

Dwivedi, G.D.(1985). Population structure and dynamic of Tigers in Bandhavgarh Tiger Reserve.

Dwivedi, G.D.(1987). Population structure and dynamics of Tigers in Bandhavgarh National Park. *Cheetal*. 28(3): 20 - 32p.

Dwyer, J., K. Sayler, and G. Zylstra (1997). Landsat pathfinder data sets for landscape change analysis, Proceedings, International Geoscience and Remote Sensing Symposium, Lincoln, Nebraska, May 17-31, 1996: pp. 547-550.

Elvidge, C.D., D. Yuan, R. Weerackoon, and R. Lunetta (1995). Relative radiometric normalization of Landsat multispectral scanner (MSS) data using an automatic scattergram-controlled regression, *Photogrammetric Engineering and Remote Sensing*, 61: 1255-1260p.

Emrahoglu N., I. Yegingil, V.Pestemalci, O.Senkal and H.M. Kandirmaz (2003). Comparison of a new algorithm with the supervised classification. *International Journal of Remote Sensing,* Vol. 24, No. 4, 649 – 655p.

Eyton J.R. (1983). Landsat multi-temporal color composite. *Photogrammetric Engineering and Remote Sensing,* 49, 231 – 235p.

Fleming, M.D, Berkebile J.S. and Hoffer B.M. (1975) Computer aided analysis of Landsat -1 MSS data : a comparison of three approaches, including a 'Modified Clustering' approach. Information Note No. 072475, Laboratory for applications of Remote Sensing, Purdue University, Indiana.

Forsberg, R.F.(1967) A classification of vegetation for general purpose In:Guide to Check Sheet for IBP Areas (G.F.Peterken, ed) IBP Handbook No.473,Blackwell

Foschi, P.G., and K.D. Smith, 1997. Detecting subpixel woody vegetation in digital imagery using two artificial intelligence approaches, *Photogrammetric Engineering and Remote Sensing*, 63(5): 493-500p.

Frank T.D (1984) Assessing change in the surficial character of a semi arid environment with Landsat residual images. *Photogrammetric Engineering and Remote Sensing,* 50, 471 – 480p.

Fu B. and A. Lin (2003). Spatial distribution of the surface rupture zone associated with the 2001 MS 8.1 Central Kunlun earthquake, northern Tibet, revealed by satellite remote sensing data. *International Journal of Remote Sensing,* Vol. 24, No. 10, 2191 – 2198p.

Fuller R.M., Groom G.B. and Jones A.R. (1994). The landcover map of Great Britain : an automated classification of Landsat Thematic mapper data. *Photogrammetric Engineering and Remote Sensing,* 60, 553 – 562p.

Gernazian A and S.Sperry (1989). The integration of remote sensing and GIS. Advanced imaging, 4 : 34 – 37p.

Ghatol S.G. and Karale R.L. (2000). Assessment of degraded lands of Vidarbha region using Remotely sensed data. *Journal of the Indian Society of Remote Sensing,* Vol 28, No. 2 & 3, 213 – 219p.

Gomarasca M.A, Brivio P.A., Pagnoni F and Galli A (1993). One century of land use changes in the metropolitan area of Milan Italy. *International Journal of Remote Sensing,* 14, 211 – 223p.

Gopal, Rajesh (1992) Pilot survey for pellet group census from random circular millihectare plots.—*Journal of Tropical forestry* ::8:4,P.262-266.

Gopal, Rajesh (1992). An Assessment of population increase of Tiger and some prey Animals. *Journal of Tropical Forestry* Oct – Dec, Vol. 8 (IV), 337p.

Gopal, Rajesh (1992). Pilot survey for Pellet Group census from Random circular Mill hectare Plots. *Journal of Tropical Forestry* July – Sept, Vol. 8 (iii), 262p.

Gopal, Rajesh(1989). Natural regeneration of Bamboo (*Dendrocalamus strictus*)after gregarious flowering and its effect on the forage and browse availability in Bandhavgarh National park. *Journal of Tropical Forestry*. 5(4): 330 – 342p.

Gopal, Rajesh(1991).Ethological observations on the sloth bear (*Melursus ursinus*). *Indian Forester*. 112(10): 915 – 919p.

Gopal, Rajesh(1994). Comparison of species diversity in wild animals of Bandhavagarh National Park, M.P. *Journal of Tropical Forestry*. 10(1): 65 – 71p.

Gordon, S.I., (1980). Utilizing Landsat imagery to monitor land-use change: A case study in Ohio, *Remote Sensing of Environment,* 9: 189-196p.

Gruber G., H.Lamping, W.Lutz, J.Matzaettee, K.Vorlaufer, Schrifteitung R.Muller (1982) Alpinism and Tourism and other problems of the geography of tourism. Proceeding of the meeting of IGU working group : Geography of tourism and recreation. Karuizawa 25 – 30, 8. 1980, 151p.

Haber, W. & Schaller, J. (1988). Ecosystem research Berchtesgadem – spatial relations among landscape elements quantified by ecological balance methods. Paper presented at the Third Annual European ESRI User Conference, Munich. October, 1998.

Hall F.G., Botkin D.B., Strebel D.E., Woods K.D. and Goetz S.J. (1991). Large scale patterns of forest succession as determined by remote sensing. *Ecology,* 72, 628 – 640p.

Hall, F.G., D.E. Strebel, J.E. Nickeson, and S.J. Goetz, (1991). Radiometric rectification: Toward a common radiometric response among multidate, multisensor images, *Remote Sensing of Environment,* 35: 11-27p.

Hall, R.J., Dams R.V. & Lysing, L.N (1991) Forest cut cover mapping from SPOT satellite data. *International Journal of Remote Sensing,* 12 (11): 2193 – 2204p.

Hame T (1991) Spectral interpretation of changes in forest using scanner images. *Acta Forestalia Fennica*, 222, 1 – 111p.

Hatheut S (1988) Landuse Change analysis and prediction of the sub – urban corridor of Winnipeg, Manitoba . *Journal of Environmental Management*, 27 : 325 – 335p.

Hegde and B.Raveendra (2000). Short – term and Long term Geomorphological Dynamics of Mangalore Spits using IRS 1A/1C data. *Journal of the Indian Society of Remote Sensing,* Vol 28, No. 4, 233 – 247p.

Hoffer, R.M. (1986) Digital analysis techniques for forestry applications, Remote Sensing Reviews 2: 61 – 110p.

Hord, M.R and Brooner W (1976) Landuse map accuracy criteria. *Photogrammety Engineering & Remote Sensing*, 425, 671 – 677p.

Houghton, R.A and Woodwell,G.M (1981).Biotic Contribution to the Global Carbon Cycle : The Role of Remote Sensing. Proceeding of the seventh international symposium of Machine Processing of Remotely Sensed Data: 593-602. West Latayette, Indiana.

Howarth, P.J., and G.M. Wickware, (1981). Procedures for change detection using Landsat digital data, *International Journal of Remote Sensing,* 2(3): 277-291p.

Jackson R.D., Slater P.N. and Pinter P.J. (1993). Discrimination of growth and water stress in wheat by various vegetation indices through clear and turbid atmospheres. *Remote Sensing of Environment,* 13, 187 – 208p.

Jensen, J.R. Rutchey, K. Koch, M.S. and Narumalani S. (1995) In land wetland change detection in the everglades water conservation area 2A using a time series of normalized remotely sensed data. *Photogrammetric Engineering and Remote Sensing,* 61, 199 – 209p.

Jensen, J.R. (1996) Introductory digital image processing, A Remote Sensing Perspective, Prentice Hall. 246p.

Jensen, J.R., and D.L. Toll, (1983). Detecting residential land-use development at the urban fringe, *Photogrammetric Engineering and Remote Sensing*, 48(4): 629-643p.

Jenson J.R. (1983). Urban/suburban land use analysis. Mannual of remote sensing, Vol. 2, Second edition (Falls Church, Virginia : *American Society of Photogrammetry)* 1571 – 1666p.

Jeong Chang Seong (2003) Modelling the accuracy of image data reprojection. *International Journal of Geographical Information Systems,* Vo. 24, No.11, 2309 – 2321p.

Jha C.S. (1990) Landuse and Vegetation analysis ofa Dry Tropical Forest Region. Ph.D. Thesis, Banaras Hindu University, Varanasi, India, 125p.

Jha C.S. and Unni N.V.M. (1994). Digital change detection of forest conversion of a dry tropical Indian forest region. *International Journal of Remote Sensing,* 15, 2543 – 2552p.

Ji. M. (2003) Using fuzzy sets to improve cluster labeling in Unsupervised classification. *International Journal of Remote Sensing,* Vol 24, No. 4, 657 -671p.

Johnston, D., and R. Haas, (1985). Change detection in rangeland environments using Landsat MSS data - A quantitative approach, Pecora 10 Proceedings: Remote Sensing in Forest and Range Management, Colorado State University, Fort Collins, Colorado, August 20-22: 60-188p.

Kachhwala T.S (1985). Temporal monitoring of forest land for change detection and forest cover mapping through satellite remote sensing. Proc. Of the 6th Asian Conf. On Remote Sensing. Hyderabad,pp 77-83

Kalique, Abdul(1997).Tiger problem in M.P. - critical corridors. *Sanctuary Asia*. 17(6): 72p.

Kauth, R.J., and G.S. Thomas, (1976). The tasseled cap - A graphic description of the spectral-temporal development of agricultural crops as seen by Landsat, Proceedings of the Symposium on Machine Processing of Remotely Sensed Data, LARS, Purdue University, West Lafayette, Indiana: pp. 4b41-4b51p.

Kenneth C McGwire (1992). Analyst Variability in Labeling of Unsupervised Classifications. *Photogrammetric Engineering & Remote Sensing* Vol 58 No. 12, 1673 – 1677p.

Kumar, M., E. Goossens, and R. Goossens (1993). Assessment of sand dune change detection in Rajasthan (Thar) Desert, India, I*nternational Journal of Remote Sensing*, 14(9): 1689-1703p.

Kunte P.D.; B.G. Wagle and Yasuhiro Sugimori (2003). Sediment transport and depth variation study of the Gulf of Kutch using remote sensing. *International Journal of Remote Sensing,* Vol. 24, No. 11, 2253 – 2263p.

Kushwaha S.P.S & N.V.M. Unni (1986). Application of remote sensing technique on forest cover monitoring and habitat evaluation- A case study in Kaziranga National Park, Assam Proceeding of the Seminar –cum-workshop on wildlife habital evalution using remote sensing techniques 22-23rd October Dehradun India.Pp.238-247.

Kushwaha S.P.S, S. Mukhtuya and P.S. Roy (2000) Geospatial Modelling for Goral habitat evaluation. *Journal of the Indian Society of Remote Sensing,* Vol. 28, No. 4, 293 – 303p.

Lad, P.M.; Gopal, Rajesh(1992).The status of Indian Gaur (*Bos gaurus*)in Bandhavgarh National Park. *Journal of Tropical Forestry*. 8(1): 84 – 95p.

Lall, Jag Jeevan(1988).Hierarchical community classification of Bandhavgarh National Park and Tala forest range, Madhya Pradesh, India. *Tropical Ecology*. 29(1): 79 – 88p.

Lall, Jag Jeevan(1990).Vegetation structure and regeneration studies on two adjacent protected and unprotected tropical forest sites, in Central India. *Indian Forester*. 116(3): 194 – 201p.

Lambin E.F. and Strahler A.H. (1994a). Change vector analysis in multi-spectral space : A tool to detect and categorize land-cover change process using high temporal resolution satellite data. *Remote Sensing of Environment,* 48, 231 – 244p.

Lambin, E.F., and A.H. Strahler (1994). Indicators of land-cover change for change-vector analysis in multitemporal space at coarse spatial scales, *International Journal of Remote Sensing,* 15: 2099-2119p.

Lilesand T.M. and Kiefer R.W. (1987) Remote Sensing and Image Interpretation. Chichester, John Wiley, 696 – 697p.

Lo C.P.and Robert L.Shipman,(1990).A GIS approach to landuse change dynamic Detection. Photogrametry Engineering & Remote Sensing. Vol.56 (11)pp. 1483.

Loveland T.R, Merchant J.W., Ohlen D.O. and Brown J.F (1991) Development of a land-cover characteristics database for the conterminous U.S. *Photogrammetric Engineering and Remote Sensing,* 57, 1453 – 1463p.

Lozano-Garcia D.F and Hoffer R.M (1985). Evaluation of a layered approach for classifying multi-temporal Landsat MSS data. Pecora 10 : Remote Sensing in Forest and Range Resource Management. Proceeding of the 10th William T. Pecora Symposium 20 –22 August, Fort Collins, Colorado (Falls Church, Virginia : American Society of Photogrammetry and Remote Sensing), 189 – 199p.

Madhavanunni N. V., Roy P.S., Jadhav R.N., Tiwari A.K., Sudhakar S., Ranganath B.K and Dabral S.L. (1991) IRS 1A applications in forestry. *Current Science* 61, 189 –192p.

Malila W.A (1980). Change vector analysis : an approach for detecting forest changes with Landsat. Proceedings of the 6th Annual symposium on Machine Processing of remotely sensed data, Purdue University, Indiana (New York : IEEE), 326 – 335p.

Mason D.C.; G.Q. A. Anderson; R.B. Bradbury; D.M. Cobby; I.J. Davenport; M. Vandepoll and J.D. Wilson (2003). Measurement of habitat predictor variable for organism habitat models using remote sensing and image segmentation. *International Journal of Remote Sensing,* Vol. 24, No. 12, 2515 – 2532p.

Massart, M., M. Petillon, and E. Wolff, (1995). The impact of an agricultural development project on a tropical forest environment: The case of Shaba (Zaire), *Photogrammetric Engineering and Remote Sensing,* 61(9): 1153-1158p.

Mathur, V. B. (1991). The ecological interactions between habitat composition, habitat quality and abundance of some wild ungulates in India, D. Phil. Thesis, Oxford, U.K.

Melkania, N.P. (1996) Assessment of Sustainability of Social Forestry Plantations in State of Madhya Pradesh with Emphasis on survival and Ecological Characteristics of Plantation and Energy needs of the Native People. Report Indian Institute of Forest Management. Po. Box 357, Nehru Nagar, Bhopal, 5p.

Mishra J.K, Joshi M.D. and Devi R (1994). Study of desertification process in Aravail environment using remote sensing techniques. *International Journal of Remote Sensing,* 15, 87 – 94p.

Mitra Debashish (1999). Change detection using remote sensing data in a coastal environment. Post conference Proceeding Volume "Geoinformatics : Beyond 2000" , and International conference of Geoinforamtics for natural resources assessment, monitoring and management. 9 – 1 March 1999, IIRS, Dehradun, India 109p.

Mohanthy K.K and Mjumdar T.J. (2003) Comparison of adaptive filter, HIS and Fourieer transform based techniques for IRS -1C PAN/LISS III data merging. *International Journal of Remote Sensing,* Vol. 24, No. 9, 1969 – 1976p.

Muhdimyati, Keimizuno, Shintaro Kobayshi and Ttiaro Kitamura (1996). Analysis of landuse/ cover change using the combination of MSS landsat and landuse map – a case study in Yogyakarta, Indonesia. *International Journal of Remote Sensing* Vol 17 No. 5, 931 – 944p.

Muki M, Nakayama Y. and Maeda K (1991). Change detection of vegetated area in the neighborhood of Kanchanaburi in Thailand. In the application of remote sensing in Asia and Oceania, edited by Shunji Murai (Tokyo) 78 – 80p.

Nagarathinam V., Jayagobi K, Marutaachalam M., Panchanathan S and Palanivelu R (1988). Urban monitoring using SPOT imagery –a case study (Kyoto : ISPRS) com. VII, 322 – 328p.

Naithani, S. (2000). Habitat Characterization in Great Himalayan National Park (GHNP), Himachal Pradesh using Remote Sensing and Geographical Information System (GIS) Technologies with special emphasis on Geobotanical Aspects, Ph. D. Thesis, H.N.B. University, Srinagar Garhwal.

Nath Latika (2000). On Conservation and Management of Tiger, *Panthera tigris tigris*, in Bandhavgarh National Park, India. D. Phil. thesis. University of Oxford, U.K.

National Remote Sensing Agency (NRSA) (1989) Manual of Nationwide landuse/landcover mapping using satellite imagery, Part I, A National Remote Sensing Agency, Hyderabad, Publication of 1989.

National Remote Sensing Agency (NRSA) (1983) Nation wide mapping of forest and non-forest areas using Landsat FCCs for the period 1972 -75 and 1980 – 83, Report, National Remote Sensing Agency, Hyderabad.

National Remote Sensing Agency (NRSA) (1988) Manual for Nationwide Landuse Mapping Using Digital Image Processing. Technical Report NRSA, Hyderabad, India.

Navin Ramankutty and Jonathan A Foley (1999). Estimating historical changes in landcover North American croplands from 1850 to 1992. *Global Ecology and Biogeography,* 8, 381 – 396p.

Nicols J.D. (1975) Characteristics of computerized Soil maps. Soil Science, Society of America Proceeding 9, 927 – 932p.

Oindo B.O., A.K. Skidmore and P.Desalvo (2003) Mapping habitat and biological diversity in the Maasai Mara ecosystem. *International Journal of Remote Sensing,* Vol. 24, No. 5, 1053 1069p.

Olsson H (1994). Monitoring of local reflectance Changes in Boreal forests using satellite data. Swedish University of Agriculture Science Remote Sensing Laboratory, Report 7.

Pabla, H.S. (1998) Development of a user-friendly wildlife monitoring methodology for protected areas in India --Forest Research Institute (Deemed University) - D. Phil. Thesis in Wildlife Management, Dehradun, Forest Research Institute, 1998. 197p

Palaniyandi M. and V.Nagarathinam (1997). Land use/land cover mapping and change detection using space Borne data. *Journal of the Indian Society of Remote Sensing,* Vol. 25, No. 1, 27p.

Pant D.N and Roy P.S. (1990) Vegetation and landuse analysis of Aglar Watershed using satellite remote sensing technique. *Journal of the Indian Society of Remote Sensing* Vol 18, No. 4, 1 – 14.

Pant D.N. and Kharkwal S.C. (1995). Monitoring landuse change and its impact on environment of central Himalaya using Remote sensing and GIS techniques. *Journal of Hill Research,* 8(1), 1 – 8p.

Pant D.N., Das K.K. and Roy P.S. (1992). Mapping of tropical dry deciduous forest and land use a part of Vindhyan range using satellite remote sensing,

Panwar, H.S.(1986). Forest cover mapping for planning tiger corridors between Kanha and Bandhavgarh. In: Seminar-Cum-Workshop on Wildlife Habitat Evaluation using Remote Sensing Techniques October 22-23, (eds. Kamat, D.S. and Panwar, H.S.). Indian Institute of Remote Sensing and Wildlife Institute of India, Dehradun, 209 - 212p.

Pathan S.K. (1992) Remote Sensing in urban land use mapping with data from different sensor, Natural Resources Management – A new perspective, Edited by Karale R.L, NNRMS, Banglore, 371 – 376p.

Pathan S.K., Sastry S.V.C, Dhinwa P.S., Rao Mukund, Majumdar K.L., Kumar D.S., Patkar V.N, and Phatak V.N (1993). Urban growth trend analysis using GIS techniques – a case study of the Bombay metropolitan region. *International Journal of Remote Sensing,* 14, 3169 – 3179p.

Permeshwar S. Chauhan, M.C. Porwal, Lalit Sharma and Jaydev S. Negi (2003) Change detection in Sal forest in Dehradun forest division using remote sensing and GIS. *Journal of the Indian Society of Remote Sensing,* Vol. 31, No. 3, 211 – 218p.

Pickup G and Chewings V.H. (1988). Forecasting patterns of soil erosion in arid land fromLandsat MSS data. *International Journal of Remote Sensing,* 9, 69 – 84p.

Pilon p.G., P.J. Howarth, R.A. Bullock and P.O. Adenlyi (1988) An enhanced classification approach to change detection in semi –arid environments. *Photogrammetric Engineering and Remote Sensing,* 54 : 1709 – 1716p.

Pizzolato Angelo N. and V. Hoertel (2003) On the application of Gabor filtering in supervised image classification. *International Journal of Remote Sensing,* Vol. 24, No. 10, 2167 – 2189p.

Prakash. A and Gupta R.P. (1998). Landuse mapping and change detection in a coal mining area – a case study in the Jharia coalfield, India. *International Journal of Remote Sensing,* Vol. 19, No. 3, 391 – 410, 391p.

Prasad, S.N, Goyal S.P, Roy P.S. and Singh S. (1994) Change in Wild ass habitat condition in Little Rann of Kutch, Gujarat from a remote sensing perspective. *International Journal of Remote Sensing,* 15 (16): 3155 – 3164 p.

Price, J (1992) Estimating vegetation amount from visible and near infrared reflection, *Remote Sensing of Environment,* 14 : 29 - 34p.

Raghubanshi A.S, Jha C.S., Pandey C.B., Singh Lalji and Singh J.S. (1991) Effect of forest conservation on vegetation and Soil carbon and functional trait of resulting vegetation : impact of global climatic changes in photosynthesis and plant productivity : Proceeding of the Indo –US Workshop. New Delhi, 723 – 746p.

Reddy G.P. Obi, K.Chandra Mouli, S.K. Srivastav, C.V. Srinivas and A.K. Maji (2000) Evaluation of ground water potential zones using Remote sensing data – A case study of Gaimukh watershed Bhandra district, Maharashtra. *Journal of the Indian Society of Remote Sensing,* Vol. 28, No. 1, 21 - 32p.

Ribed, P.S., and A.M. Lopez (1995). Monitoring burnt areas by principal components analysis of multitemporal TM data, *International Journal of Remote Sensing*, 16(9): 1577-1587p.

Richards J.A. (1980). Thematic mapping from multi-temporal image data using the principal components transformation. *Remote Sensing of Environment,* 16, 35 – 46p.

Ricotta C., G.C. Avena and F.Ferri (1996) Analysis of human impact on a forested landscape of central Italy with a simplified NDVI texture descriptor. *International Journal of Remote Sensing,* Vol 17, No. 14, 2869 – 2874p.

Rigina O. (2003). Detection of boreal forest decline with high – resolution panchromatic satellite imagery. *International Journal of Remote Sensing,* Vol. 24, No. 9, 1895 – 1912p.

Riitters, K.H., R.V. O'Neill, C.T. Hunsaker, J.D. Wickham, D.H. Yankee, S.P. Timmins, K.B. Jones, and B.L. Jackson (1995). A factor analysis of landscape pattern and structure metrics, *Landscape Ecology*, 10(1): 23-39p.

Roberts, D.A., J.B. Adams, and M.O. Smith (1993). Green vegetation, nonphotosynthetic vegetation, and soil in AVIRIS data, *Remote Sensing of Environment,* 14: 255-269p.

Rodgers, W.A. , and H.S Panwar (1988). Planning a Wildlife Protected Area Network in India (Vol.1 & 2). WII, Dehradun.

Roy P.S, Saxena K.G and Pant D.N. (1986) Analysis of vegetation types using satellite remote sensing techniques for Wildlife habitat evaluation in Kanha National Park. Proceeding of Seminar – cum – workshop on wildlife habitat evaluation using remote sensing techniques.

Roy P.S., Kaul R.N., Roy M.R. and Gabryal S.S. (1985) Forest type stratification and Delineation of shifting cultivation in the Eastern part of Arunachal Pradesh using Landsat MSS data. *International Journal of Remote Sensing,* Vol 6 (3&4), 411 – 418p.

Roy, G.P.,B.K. Shukla and Bhaskar Dutt (1992) Flora of Madhya Pradesh. Ashish Publishing House, New Delhi, p (xiii).

Roy, P.S, C.B.S Dutt, R.N. Jadhav, B.K. Ranganath, M.S.R Murthy, B.Gharai, V.Udaya Lakshmi, A.K Kandya and P.S. Thakker (1996) IRS 1C Data utilization for forestry application. *Current Science* Vol 70 No. 7.

Sabins Floyd F. (1996). Remote Sensing Principles and Interpretation. United States of America 69p.

Saha, S.K. & M Kudrat (1992) Software options for thematic interpretation and mapping using remotely sensed digital data. In: P.Nag (ed) Remote Sensing and Thematic Mapping. Concept Publishing Co. New Delhi, 149 – 157p.

Saukkola P. (1982). (Abstract : Monitoring regeneration fellings by satellite imagery) Technical Research Center of Finland, Research Reports 89, Espoo.

Sawarkar, V.B.(1986). Animal damage: Predation on domestic livestock by large carnivores. *Indian Forester*. 112(10): 858 - 866p.

Schott, J.R., C. Salvaggio, and W. J. Volchok (1988). Radiometric scene normalization using pseudoinvariant features, *Remote Sensing of Environment,* 26: 1-16p.

Sharma, Brijesh (1994). Studies on Eco-Tourism in Madhya Pradesh A Project Report Submitted for the Award of Diploma in Tourism and Travel Management. 41p.

Singh A (1986) Change detection in the tropical forest environment of northeastern India using landsat. In Remote Sensing and Tropical Land Management, edited by M.J Eden and J.T. Parry (London : Jhon Wiley & Sons) 237 – 254p.

Singh A (1989). Digital change detection techniques using remotely sensed data. *International Journal of Remote Sensing,* 10(6) : 989 – 1003.

Singh A. (1989). Review article : Digital change detection techniques using remotely sensed data. *International Journal of Remote Sensing,* 10, 989 – 1003p.

Singh T.P., Sarnam Singh and P.S. Roy (2003) Assessing Jhum – Induced forest loss in Dibang valley, Arunachal Himalayas – A Remote sensing perspective. *Journal of the Indian Society of Remote Sensing,* Vol 31, No. 1, 3 – 9p.

Singh, Parbin (1986). Engineering and General Geology. Katson Publishing House, Ludhiana. 285p.

Singh, R.K. (1994). Pedigree of a Tigress in wild. *Journal of Tropical Forestry*. 10(2): 155 – 157p.

Singh, S.K. (1997). Diurnal raptors of Bandhavagarh National Park and its conservation aspects. *Indian Forester*. 123(10): 935 – 938p.

Sinha, N.K. (1977). Wildlife In Bandhavgarh National Park. *Cheetal*. 19 (23): 3 -12p.

Sinha, N.K.; Singh, R.K. (1982). National Parks of Madhya Pradesh - Part I. *Cheetal*. 24(2): 62-69.

Sohl, T. (1999). Change analysis in the United Arab Emirates: An investigation of techniques, *Photogrammetric Engineering and Remote Sensing,* 65(4): 475-484p.

Sonakia, Ajit (1993). Management Plan for Bandhavgarh National Park for the period 1993-94 to 2002-03, Vol. I

Star, J.L., J.E. Estes, and K.C. McGwire (1997). Integration of geographic information systems and remote sensing. New York, NY: Cambridge University Press.

Stone T.A., Schlesinger R.A., Woodell G.M (1994) A map of the vegetation of South America based on satellite imagery. *Photogrammetric Engineering and Remote Sensing,* 60, 541 –551p.

Stow , D.S. Westmoreled, D Mckinsey, F. Mertz, D. Collins, S. Sperry and D. Nagel (1990). Raster – vector integration for updating land use data. Proceeding of the Twenty – Third International Symposium on Remote sensing of Environment, Bangkok, Thailand, 837 – 844p.

Stow, D.A., L.R. Tinney, and J.E. Estes (1980). Deriving land use/land cover change statistics from Landsat: A study of prime agricultural land, in Proceedings of the 14th International Symposium on Remote Sensing of Environment, Ann Arbor, MI, Environmental Research Institute of Michigan, Ann Arbor, MI: 1227-1327p.

Sudhakar S, Das K.K, Chakraborty D, Bardhan Roy B.K, Raha A.K. and Shukla P. (1994). Stratification approach for forest cover type and landuse mapping using IRS – 1A LISS II data- A case study. *Journal of the Indian Society of Remote Sensing,* Vol. 22, No.1, 21 –29p.

Sunar F. (1998). An analysis of change in multi-date data set : a case study in the Ikitelli area, Istanbul, Turkey. *International Journal of Remote Sensing,* Vol. 19, No. 2, 225 –235p.

Swain P.H. (1980) Image data analysis in remote sensing. In Issues in Digital Image Processing, edited by R.M. Haralick and J.C. Simon, 313 – 339p.

Swain P.H. and S.M. Davis (1978) Remote Sensing : The Quantitative Approach. Mc Graw – Hill, New York, 396p.

Thomas L.L., Benning V.H and Ching N.P. (1987). Classification of Remotely sensed images (Bristol : Adam Higher)

Tiwari A.K., Kudrat M. and Bhan S.K. (1990) Vegetation cover Classification in Sariska National Park and surrounding. *Journal of the Indian Society of Remote Sensing,* Vol 18 No. 3, 43 –51p.

Tiwari, A.K, Kudarat M and Bhan S.K. (1991) Analysis of vegetation and soil association through digital processing of remote sensing data : A case study of a part of Western Himalaya. In: mountain resources management and remote sensing (P.N. Gupta and A.K. Roy, eds.), 149 –157p.

Tiwari, A.K, M.Kudrat and M.L. Manchanda (1996) Remote Sensing and GIS : Indispensable tools for regional ecological. *Tropical Ecology* 37(1) 79-92.

Tiwari, A.K. and Kudarat M. (1988) Analysis of vegetation in Rajaji National Park using IRS data. Presented in National Seminar on IRS 1A Mission and its application Potential, Hyderabad, December 22 – 23, 1988.

Tiwari, S.D.N (1968) Flora of Bandhavgarh, *Journal of Indian Forester* 94 (7).

Tiwari, S.D.N. (1979). The Phyto-Geography of Legumes of Madhya. Pradesh. Bishen Singh Mahendra Pal Singh New, Connaught place Dehradun 51 p.

Tiwari, S.D.N. (1979). The Phyto-Geography of Legumes of Madhya Pradesh. Bishen Singh M.P. Singh, Dehradun . 6p.

Tiwari, S.D.N.(1968). Flora of Bandhavgarh. *Indian Forester*. 94(7): 571 – 584p.

Tiwari, S.K. (1998). National Park of Madhya Pradesh. A.P.H. Publishing Corporation, New Delhi. 241p.

Townshed J.R.G., CO. Justice, C.Gurney and J.Mcmanus (1992) The impact of misregistration on change detection, IEEE Transaction on Geoscience and Remote Sensing, 30(5) : 1054 – 1060.

Townshend J.R.G., Justice C.O. and Kalb V.T. (1987) Characterization and classification of South American landcover types using satellite data. *International Journal of Remote Sensing,* 8 , 1189 – 1207p.

Tripathi, A.K., B.K. Shukla and V.Mudgal (1994) Floral elements of M.P. Ashish Publishing House, New Delhi, 10p.

Tripathy G.K., T.K. Ghosh and S.D. Shah (1996) Monitoring of desertification process in Karnataka State of India using multi-temporal remote sensing and ancillary information using GIS. *International Journal of Remote Sensing,* Vol. 17, No. 12, 2243 – 2257p.

Tucker C.J., Townshend J.R.G. and Goff T.E. (1985) African landcover classification using satellite data. *Science,* 227, 369 – 375p.

Turner, B.L. II and W.B. Meyer (1991). Land use and land cover in global environmental change: Considerations for study, *International Social Science Journal,* 130: 669-677p.

Tyabji, H.N. (1990). A hunting technique of the jungle cat Felis chaus. *Journal of Bombay Natural History Society*. 87(1): 134p.

Tyabji, H.N. (1990). Reaction of a group of Gaur *Bos gaurus* to the presence of an unidentified predator in Bandhavgarh National Park, Madhya Pradesh. *Journal of Bombay Natural History Society.* 87(2): 287 – 288p.

Tyabji, H.N. (1991). Probable sighting of plain backed mountain thrush *Zoothera mollissima* (Blyth)in Bandhavgarh National Park, Madhya Pradesh. *Journal of Bombay Natural History Society*. 88(2): 288 – 289p.

Tyabji, H.N.(1991).Interaction between a male Tiger Panthera tigris and his cubs in Bandhavgarh National Park, M.P. *Journal of Bombay Natural History Society*. 88(1): 107p.

Tyagi, Chandra Mohan (1996-97). Study on eco-development in Bandhavgarh National Park (Madhya Pradesh). 7p.

Unni N.V.M (1983) Forest Survey and Management using Remote Sensing. Edited by B.L. Deekshatulu & Y.S. Ranjan. Ind. Acad. of Science, Bangalore, 115 – 133p.

Ustin S.L., Wessman C.A., Curtiss, B. Kasischke E, Way J. and Vanderbilt V.C (1991) Opportunities for using the EOS imaging spectrometers and synthetic aperture radar in ecological model. *Ecology,* 72, 1934 – 1945p.

Van Gendern, J.L. and Lock B.F. (1977) Testing landscape map accuracy. *Photogrammety Engineering & Remote Sensing* 439, 1135 – 1157p.

Varjo J. (194) Forest change detection by satellite remote sensing in Eastern Finland. Proceedings of the satellite Technology and GIS for Mediterranean Forest Mapping and Fire management International Symposium, Thessaloniki, 4 –6, edited by P.J. Kennedy and M.Karferis, EUR 15861 EN (Luxemburg : European Commission, DGX11), 367 – 377p.

Vogelmann, J.E. (1988). Detection of forest change in the Green Mountains of Vermont using Multispectral Scanner data, *International Journal of Remote Sensing,* 9(7): 1187-1200p.

Wang J.; P.M. Rich and K.P. Price (2003) Temporal responses of NDVI to precipitation and temperature in the central Great Plains, U.S.A. *International Journal of Remote Sensing,* Vol. 24, No. 11, 2345 – 2364p.

Weismiller, R.A., S.J. Kristof, D.K. Scholz, P.E. Anuta, and S.A. Momin, (1977). Change detection in coastal zone environments, *Photogrammetric Engineering and Remote Sensing*, 43(12): 1533-1539p.

Welch R and Ehlers M (1987). Merging multi-resolution SPOT HRV and Landsat TM data. *Photogrammetric Engineering and Remote Sensing*, 52, 301 – 303p.

Wilcock, D. and A. Cooper (1993). Monitoring losses of semi-natural vegetation to agricultural grassland from satellite imagery in the Antrim Coast and Glens AONB, Northern Ireland, *Journal of Environmental Management,* 38: 57-169p.

William D.L and Nelson R.F. (1986) Use of remotely sensed data for assessing forest stand conditions in eastern United States. IEEE Trans. *Geoscience Remote Sensing,* E. 24: 130 – 138p.

Wong R.K., T. Fung., K.S. Leung and Y. Leung (1997). The compression of a sequence of satellite images based on change detection. *International Journal of Remote Sensing,* Vol. 18, No. 11, 2427 – 2436p.

Appendix I

List of Plant Species in Bandhavgarh Tiger Reserve

Vern. Name	**Scientific Name**	**Family**
Kalmegh	*Andrographis paniculata*	ACANTHACEAE
Tadrelu	*Barleria cristata*	ACANTHACEAE
Talmakhana	*Hygrophila salicifolia*	ACANTHACEAE
Vasaka	*Justicia adhatoda*	ACANTHACEAE
Kanaara	*Justicia quinqueangularis*	ACANTHACEAE
Atrilal	*Peristrophe bicalyculata*	ACANTHACEAE
Hasa-arak	*Rungia pectinata*	ACANTHACEAE
Kharmor	*Rungia repens*	ACANTHACEAE
Pandi, Charak kedar	*Thunbergia fragrans*	ACANTHACEAE
Akola	*Alangium salvifolium*	ALANGIACEAE
Chirchira	*Achyranthes aspera*	AMARANTHACEAE
Chaya	*Aerva sanguinolenta*	AMARANTHACEAE
Kateli	*Amaranthus spinosus*	AMARANTHACEAE
Jungli-cholai	*Amaranthus viridis*	AMARANTHACEAE
Kombada	*Celosia argentea*	AMARANTHACEAE
Chiraunchi	*Buchanania lanzan*	ANACARDIACEAE
Jhingan	*Lannea coromandelica*	ANACARDIACEAE
Aam	*Mangifera indica*	ANACARDIACEAE
Marking nut tree	*Semecarpus anacardium*	ANACARDIACEAE
Sita-phal	*Annona squamosa*	ANNONACEAE

Vern. Name	**Scientific Name**	**Family**
Kirua	*Miliusa tomentosa*	ANNONACEAE
Brahmi	*Centella asiatica*	APIACEAE
Ajane	*Hydrocotyle sybthorpioides*	APIACEAE
Chatiyan	*Alstonia scholaris*	APOCYNACEAE
Caraunda	*Carissa opaca*	APOCYNACEAE
Sadabahar	*Catheranthus roseus*	APOCYNACEAE
Dudhkhuri	*Holarrhena antidysenterica*	APOCYNACEAE
Kali-dudhi	*Ichnocarpus frutescens*	APOCYNACEAE
Chandui	*Tabernaemontana divericata*	APOCYNACEAE
Daira	*Wrightia tomentosa*	APOCYNACEAE
Dudhi	*Wrightia tinctoria*	APOCYNACEAE
Vacha	*Acorus calamus*	ARACEAE
Jungli-Arbi	*Colocasia esculenta*	ARACEAE
Cane	*Calamus sp.*	ARECACEAE
Khajuri	*Phoenix acaulis*	ARECACEAE
Khajur	*Phoenix sylvestris*	ARECACEAE
Isharmul	*Aristolochia indica*	ARISTOLOCHIACEAE
Ak	*Calotropis procera*	ASCLEPIADACEAE
Dudhi	*Cryptolepis buchnanii*	ASCLEPIADACEAE
Dudhi	*Cryptolepis elegans*	ASCLEPIADACEAE
Gudmar	*Gymnema sylvestre*	ASCLEPIADACEAE
Kapuri	*Hemidesmus indicus*	ASCLEPIADACEAE
Nasbhanga	*Pergularia daemia*	ASCLEPIADACEAE
Gokhru	*Acanthospermum hispidum*	ASTERACEAE

Vern. Name	**Scientific Name**	**Family**
Gandhela	*Ageratum conyzoides*	ASTERACEAE
Arkajhar	*Bidens pilosa*	ASTERACEAE
Kukurbantha	*Blumea mollis*	ASTERACEAE
Bhringraj	*Eclipta prostrata*	ASTERACEAE
Gobhi	*Elephantopus scaber*	ASTERACEAE
Kirankuri	*Emilia sonchifolia*	ASTERACEAE
Pndpadro	*Gnaphalium polycaulon*	ASTERACEAE
Patherchotti	*Tridax procumbens*	ASTERACEAE
Sadodi	*Vernonia cinerea*	ASTERACEAE
Chota-goghru	*Xanthium strumarium*	ASTERACEAE
Gulmendi	*Impatiens balsamina*	BALSAMINACEAE
Kumbhi	*Careya arborea*	BARRINGTONIACEAE
Longsilawa	*Begonia picta*	BEGONIACEAE
Hawar	*Dolichandrone falcata*	BIGNONIACEAE
Padri	*Stereospermum chelonoides*	BIGNONIACEAE
Semal	*Bombax ceiba*	BOMBACACEAE
Balraj	*Cynoglossum lanceolatum*	BORAGINACEAE
Chamror	*Ehretia laevis*	BORAGINACEAE
Chotta-kulphi	*Trichodesma indicum var.amplexicaul*	BORAGINACEAE
Salai	*Boswellia serrata*	BURSERACEAE
Kharpat	*Garuga pinnata*	BURSERACEAE
Amli	*Bauhinia malabarica*	CAESALPINACEAE
Kanda/ Semla	*Bauhinia retusa*	CAESALPINACEAE
Malghan	*Bauhinia vahlii*	CAESALPINACEAE

Vern. Name	Scientific Name	Family
Chimer	*Cassia absus*	CAESALPINACEAE
Amaltash	*Cassia fistula*	CAESALPINACEAE
Kasondi	*Cassia occidentalis*	CAESALPINACEAE
Aabla	*Cassia pumila*	CAESALPINACEAE
Chakunda	*Cassia tora*	CAESALPINACEAE
Imli	*Tamarindus indica*	CAESALPINACEAE
Malkakni	*Cassine glauca*	CELASTRACEAE
Mal-kangni	*Celastrus paniculatus*	CELASTRACEAE
Jungli-Hurhur	*Cleome viscosa*	CLEOMACEAE
Galgal	*Cochlospermum religiosum*	COCHLOSPERMACEAE
Dhaura	*Anogeissus latifolia*	COMBRETACEAE
	Combretum albidum	COMBRETACEAE
Asan	*Terminalia alata*	COMBRETACEAE
Arjun	*Terminalia arjuna*	COMBRETACEAE
Bahara	*Terminalia bellirica*	COMBRETACEAE
Harra	*Terminalia chebula*	COMBRETACEAE
Musli-siyah	*Murdannia nudiflora*	COMMELINACEAE
Buchna	*Commelina benghalensis*	COMMELINACEAE
Kanjura	*Commelina diffusa*	COMMELINACEAE
Vishnukranti	*Evolvulus alsinoides*	CONVOLVULACEAE
Chinipata	*Evolvulus nummularius*	CONVOLVULACEAE
Behaya	*Ipomoea carnea*	CONVOLVULACEAE
Kumapan-bel	*Ipomoea eriocarpa*	CONVOLVULACEAE
Kaladhana	*Ipomoea nil*	CONVOLVULACEAE

Vern. Name	Scientific Name	Family
Kamalata	*Ipomoea pes-tigridis*	CONVOLVULACEAE
Tarulata	*Ipomoea quamoclit*	CONVOLVULACEAE
Garial	*Ipomoea turbinata*	CONVOLVULACEAE
Musakari	*Merremia tridentata*	CONVOLVULACEAE
Kust	*Costus speciosus*	COSTACEAE
Shivlingi	*Diplocyclos palmatus*	CUCURBITACEAE
Tori	*Luffa cylindrica*	CUCURBITACEAE
Bilari	*Mukia maderaspatana*	CUCURBITACEAE
Akas-bel	*Cuscuta reflexa*	CUSCUTACEAE
Masa	*Bulbostylis barbata*	CYPERACEAE
Nirbishi	*Cyperus kyllingia*	CYPERACEAE
Motha	*Cyperus rotundus*	CYPERACEAE
Bhabhar	*Eriophorum comosum*	CYPERACEAE
Teona	*Dioscorea bulbifera*	DIOSCOREACEAE
Baikandi	*Dioscorea hispida*	DIOSCOREACEAE
Barkanda	*Dioscorea pentaphylla*	DIOSCOREACEAE
Sal	*Shorea robusta*	DIPTEROCARPACEAE
Tendu	*Diospyros melanoxylon*	EBENACEAE
Bistendu	*Diospyros montana*	EBENACEAE
Kuppi	*Acalypha malabarica*	EUPHORBIACEAE
Amrul	*Antidesma acidum*	EUPHORBIACEAE
Khajra	*Bridelia retusa*	EUPHORBIACEAE
Neel-dudhi	*Euphorbia geniculata*	EUPHORBIACEAE
Dudhi	*Euphorbia hirta*	EUPHORBIACEAE

Vern. Name	Scientific Name	Family
Dudhikalave	*Euphorbia hypericifolia*	EUPHORBIACEAE
Dudhi	*Euphorbia prostrata*	EUPHORBIACEAE
Kalchia	*Glochidion velutinum*	EUPHORBIACEAE
Safed-arand	*Jatropha curcas*	EUPHORBIACEAE
Rohini, Sinduri	*Mallotus philippensis*	EUPHORBIACEAE
Amla	*Phyllanthus emblica*	EUPHORBIACEAE
Jar-amla	*Phyllanthus fraternus*	EUPHORBIACEAE
Hazarmani	*Phyllanthus urinaria*	EUPHORBIACEAE
Arandi	*Ricinus communis*	EUPHORBIACEAE
Rati	*Abrus precatorius*	FABACEAE
Phulan	*Aeschynomene indica*	FABACEAE
Palash	*Butea monosperma*	FABACEAE
Lat-palash	*Butea superba*	FABACEAE
Aparajita	*Clitoria ternatea*	FABACEAE
Banmethi	*Crotalaria albida*	FABACEAE
Rose wood	*Dalbergia latifolia*	FABACEAE
Sattadli	*Dalbergia paniculata*	FABACEAE
Salpan	*Desmodium gangeticum*	FABACEAE
Sariban	*Desmodium heterocarpon*	FABACEAE
Kada-katru	*Desmodium laxiflorum*	FABACEAE
Bhumkara	*Desmodium motorium*	FABACEAE
Kudaliya	*Desmodium triflorum*	FABACEAE
Latakarni	*Desmodium velutinum*	FABACEAE
Dhak	*Erythrina suberosa*	FABACEAE

Vern. Name	Scientific Name	Family
Makri	*Flemingia nana*	FABACEAE
Kanphuti	*Flemingia strobilifera*	FABACEAE
Sakena	*Indigofera cassioides*	FABACEAE
Pandar-phali	*Indigofera linifolia*	FABACEAE
Tejomala	*Indigofera linnaei*	FABACEAE
Nil	*Indigofera tinctoria*	FABACEAE
Chapta-matar	*Lathyrus sativa*	FABACEAE
Kivanch	*Mucuna pruriens*	FABACEAE
Sandan	*Ougeinia oogeinsis*	FABACEAE
Karanj	*Pongamia pinnata*	FABACEAE
Bijasal	*Pterocarpus marsupium*	FABACEAE
Vidarikhand	*Pueraria tuberosa*	FABACEAE
Jayanti	*Sesbania bispinosa*	FABACEAE
Sarphenka	*Tephrosia purpurea*	FABACEAE
Mungi	*Vigna trilobata*	FABACEAE
Samrapani	*Zornia gibbosa*	FABACEAE
Nara	*Casearia graveolens*	FLACOURTIACEAE
Kandai	*Flacourtia indica*	FLACOURTIACEAE
Bhirra/ Ghirya	*Chloroxylon swietenia*	FLINDERSIACEAE
Kali-musli	*Curculigo orchioides*	HYPOXIDACEAE
Gopoli	*Anisomeles indica*	LAMIACEAE
Binda	*Colebrookia oppositifolia*	LAMIACEAE
Jaltai	*Lavandula bipinnata*	LAMIACEAE
Hejurchei	*Leonotis nepetifolia*	LAMIACEAE

Vern. Name	Scientific Name	Family
Gumma	*Leucas cephalotes*	LAMIACEAE
Geeta-kushir	*Leucas mollissima*	LAMIACEAE
Ban-tulsi	*Ocimum bassillicum*	LAMIACEAE
Tulsi	*Ocimum sanctum*	LAMIACEAE
Maida-lakdi	*Litsea monopetala*	LAURACEAE
Sukandini	*Lea macrophylla*	LEEACEAE
Kumali	*Leea asiatica*	LEEACEAE
Satawar	*Asparagus racemosus*	LILIACEAE
Safed musli	*Chlorophytum tuberosum*	LILIACEAE
Karihari/ Languli	*Gloriosa superba*	LILIACEAE
Basant-phul	*Reinwardtia indica*	LINACEAE
Banda	*Dendrophthoe falcata*	LORANTHACEAE
Bakli	*Lagerstroemia parviflora*	LYTHRACEAE
Dhaula	*Woodfordia fruticosa*	LYTHRACEAE
Madmalti	*Hiptage benghalensis*	MALPIGHIACEAE
Kanghi	*Abutilon indicum*	MALVACEAE
Puli/ Barang	*Kydia calycina*	MALVACEAE
Ramchana	*Malvastrum coromandelianum*	MALVACEAE
Kharenti	*Sida acuta*	MALVACEAE
Kharenti	*Sida cordata*	MALVACEAE
Bariar	*Sida cordifolia*	MALVACEAE
Sahdevi	*Sida rhombifolia*	MALVACEAE
Ban-kapasi	*Thespecia lampas*	MALVACEAE
Boriyal	*Urena lobata*	MALVACEAE

Vern. Name	Scientific Name	Family
Hatajori	*Martynia annua*	MARTYNIACEAE
Neem	*Azadirachta indica*	MELIACEAE
Akanadi	*Cissampelos pareira var. hirsuta*	MENISPERMACEAE
Giloi	*Tinospora sinesis*	MENISPERMACEAE
Safed-kikkar	*Acacia leucophloa*	MIMOSACEAE
Biswal	*Acacia pennata*	MIMOSACEAE
Chilar	*Acacia torta*	MIMOSACEAE
Katha/Khair	*Acacia catechu*	MIMOSACEAE
Kali-siris	*Albizia odoratissima*	MIMOSACEAE
Safed-siris	*Albizia procera*	MIMOSACEAE
Gandhi-buti	*Glinus lotoides*	MOLLUGINACEAE
Jima	*Glinus oppositifolius*	MOLLUGINACEAE
Bargat	*Ficus bengalensis*	MORACEAE
Gobla	*Ficus hispida*	MORACEAE
Pilkhan	*Ficus infectoria*	MORACEAE
Pippal	*Ficus religiosa*	MORACEAE
Paras-pipal	*Ficus arnottiana*	MORACEAE
Datri	*Ficus gibbosa*	MORACEAE
Gular	*Ficus racemosa*	MORACEAE
Drum-stick, Sajniphal	*Moringa oleifera*	MORINGACEAE
Jamun	*Syzygium cuminii*	MYRTACEAE
Sohar-jamun	*Syzygium heyneanum*	MYRTACEAE
Punarnava	*Boerhavia diffusa*	NYCTAGINACEAE
Jangli-chameli	*Jasminum multiflorum*	OLEACEAE

Vern. Name	Scientific Name	Family
Datiju	*Ludwigia octovalis*	ONAGRACEAE
Rsna	*Vanda tesellata*	ORCHIDACEAE
Lajalu	*Biophytum sensitivum*	OXALIDACEAE
Kati-meethi	*Oxalis corniculata*	OXALIDACEAE
Satyanashi	*Argemone mexicana*	PAPAVERACEAE
Pottali	*Passiflora foetida*	PASSIFLORACEAE
Til	*Sesamum orientale.*	PEDALIACEAE
Lichipata	*Peperomia pellucida*	PIPERACEAE
Chita	*Plumbago zeylanica*	PLUMBAGINACEAE
Basantighas	*Alloteropsis cimicina*	POACEAE
Chofkia basar	*Apluda mutica*	POACEAE
Bamboo	*Bambusa arundinacea*	POACEAE
Job's tears	*Coix lachryma-jobi*	POACEAE
Gandhel-ghas	*Cymbopogon martinii*	POACEAE
Dhoop-ghas	*Cynodon dactylon*	POACEAE
Dhoop-ghas	*Cynodon arcuatus*	POACEAE
Thatch grass	*Imperata cylindrica*	POACEAE
Rice	*Oryza sativa*	POACEAE
Rice	*Oryza rufipogon*	POACEAE
Kodo	*Paspalum scorbiculatum*	POACEAE
Gachli	*Monochoria vaginalis*	PONTEDERIACEAE
Pitti	*Ventilago denticulata*	RHAMNACEAE
Ber	*Zizyphus mauritiana*	RHAMNACEAE
Jaberi	*Zizyphus nummularia*	RHAMNACEAE

Vern. Name	Scientific Name	Family
Makai	*Zizyphus oenoplia*	RHAMNACEAE
Madanghanti	*Borreria pusilla*	RUBIACEAE
Aeinphal	*Catunaregam spinosa*	RUBIACEAE
Pappar	*Gardenia latifolia*	RUBIACEAE
Phetra/Pendra	*Gardenia turgida*	RUBIACEAE
Haldu	*Haldina cordifolia*	RUBIACEAE
Daman-pappar	*Hedyotis corymbosa*	RUBIACEAE
Dondro	*Hymenodictyon excelsum*	RUBIACEAE
Kura/ Undi	*Ixora parviflora*	RUBIACEAE
Kaini	*Mitragyna parvifolia*	RUBIACEAE
Padera/ Padar	*Spermadictyon suaveolens*	RUBIACEAE
Bel	*Aegle marmelos*	RUTACEAE
Jamiri-nimbu	*Citrus limon*	RUTACEAE
Beli	*Limonia acidissima*	RUTACEAE
Karipatta	*Murraya koenigii*	RUTACEAE
Kanphatta	*Cardiospermum halicacabum*	SAPINDACEAE
Kusum	*Schleichera oleosa*	SAPINDACEAE
Mohva	*Madhuca indica*	SAPORTACEAE
Kutra	*Limnophila rugosa*	SCROPHULARIACEAE
Maharukh	*Ailanthus excelsa*	SIMARUBACEAE
Chobchini/ Ramdattun	*Smilax zeylanica*	SMILACACEAE
Datura	*Datura metel*	SOLANACEAE
Bandapariya	*Physalis minima*	SOLANACEAE
Makoi	*Solanum nigrum*	SOLANACEAE

Vern. Name	**Scientific Name**	**Family**
Kuteli	*Solanum surattense*	SOLANACEAE
Mararphali	*Helicteres isora*	STERCULIACEAE
Kulu/ Karhar	*Sterculia urens*	STERCULIACEAE
Clearing nut tree/ Nirmali	*Strychnos potatorum*	STRYCHNACEAE
Narcha	*Corchorus capsularis*	TILIACEAE
Pharsa	*Grewia tiliaefolia*	TILIACEAE
Dhokelan	*Grewia villosa*	TILIACEAE
Papri	*Holoptelia integrifolia*	ULMACEAE
Khagshi/Kuri	*Trema politoria*	URTICACEAE
Gand-baharangi	*Clerodendrum serratum*	VERBENACEAE
Lantana	*Lantana camara*	VERBENACEAE
Parijat	*Nyctanthes arbor-tristis*	VERBENACEAE
Nirgandi	*Vitex negundo*	VERBENACEAE
Pudu	*Viscum articulatum*	VISCACEAE
Pani-bel/Katti-bel	*Ampelocissus latifolia*	VITACEAE
Pani-bel	*Cissus repanda*	VITACEAE
Jungli-haldi	*Curcuma zedoaria*	ZINGIBERACEAE
Chotta-gokhru	*Tribules terrestris*	ZYGOPHYLLACEAE