HABITAT SUITABILITY FOR RHINO (*Rhinoceros unicornis*) AND UTILIZATION PATTERN IN RAJIV GANDHI ORANG NATIONAL PARK OF ASSAM

ABSTRACT

By

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DEPARTMENT OF GEOGRAPHY

THESIS

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENET OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

2010

DEPARTMENT OF GEOGRAPHY

SCHOOL OF HUMAN AND ENVIRONMENTAL SCIENCES

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INTRODUCTION

The forests are identified as one of the major natural resources in India having immense influence directly or indirectly on the biosphere. These forest covers are disappearing due to merciless felling of trees and extensive grazing and other human related activities. Areas of human settlement, agriculture and industries are expanding at the expense of wildlife habitat. These threats can be overcome by an effective and efficient management of the forests which, in turn, depends on reliable and up to date information on forest resources and wildlife habitats. Remote sensing, with its synoptic coverage and finer spatial, spectral, temporal and radiometric resolution, is found to be an effective tool for collecting information on forest resources. Such satellite driven database may relate to forest type, crown density, biomass, habitat evaluation of wildlife, etc.

The application of geo-spatial technology in wildlife habitat evaluation and habitat suitability analysis is a relatively young discipline. Many studies have revealed that geo-spatial technology is quite useful for wildlife habitat evaluation and habitat suitability analysis. At the same time conservation biologists and managers need a range of both classical analyses and specific modern tools to face the increasing threats to biodiversity.

In this current study an attempt has been made to evaluate the rhino habitat, its seasonal variation of habitat utilization pattern and habitat suitability assessment of Rajiv Gandhi Orang National Park (hereafter, written as **RG Orang NP)** using geo-spatial technology. Furthermore the land cover change dynamics of the park was done over a period of thirty years using historic and current satellite datasets. Habitat suitability assessment for rhino in the park has been done using a modeling approach in GIS environment that will help the park authority to manage and expand the suitable areas for rhino. This will also help the park managers to protect the habitat in a more scientific manner, which will further enhance the rhino conservation in the state of Assam.

STATEMENT OF THE PROBLEM:

The North East India is a globally recognized as biodiversity hotspot and is by far the richest reserves of flora and fauna in India. This is the only region where the density as well as the population of one-horned rhino is highest in the world. The major rhino bearing areas of this region are Kaziranga National Park, RG Orang NP and Pabitora Wildlife Sanctuary. Though this region has the highest density and population of the flagship species like one horned rhino but till date very limited and comprehensive scientific research has been carried out to analyze the habitat suitability pattern and threats perception of the habitat due its changing land use pattern. Similarly there lacks up-to-date database on rhino and their habitat pattern which is a prime requirement to relocate and rehabilitate the one horned rhino in other areas of the region and in the country.

The RG Orang NP is one of the prime habitats of Indian rhino. This park is facing tremendous problems from the poachers, invasive species like *Mimosa invesa* and over grazing of the cattle from the nearby villages that declining the number of rhino population. The record shows that there were 97 rhinos in the year 1991 and 64 rhinos in the year 2009. The observation from 1983 to 2009, shows that 122 rhinos were poached, 63 rhinos were dead naturally in RG Orang NP. A comparative data of natural death and poaching of rhino in RG Orang NP from 1983 to 2009 is shown in the table I. The impact of invasive species like *Mimosa invesa* is very common in the RG Orang NP. Due to the pressure of *Mimosa invesa,* the habitat of RG Orang NP has changed drastically because of the reduction of wet alluvial grassland in the park. It is also observed that degraded grassland in the park is increasing day by day because of the impact of *Mimosa invesa* and due to the over grazing of the cattle's of nearby villages. The siltation is another major problem of the wetlands is due to seasonal flood. As RG Orang NP lies in the bank of river Brahmaputra, during monsoon season most of the park wetlands are submerged under the floodwater and thus siltation is widespread. As the rhinos, other wild animals and birds extensively use wetlands in all seasons of year has an adverse effect on wildlife habitat of the park, which is causing straying of rhinos outside the park area.

Table I – Poaching and Natural death of rhino in RG Orang NP

Year	Poaching			Natural Death	Total Death
	Gun Shot	Poison	Pit		
1983	8	0	0	4	12
1984	3	1	2	1	7
1985	2	0	6	1	9
1986	1	0	2	0	3
1987	1	0	0	2	3
1988	1	1	2	0	4
1989	1	0	1	1	3
1990	0	0	0	0	0
1991	1	0	0	2	3
1992	1	0	0	3	4
1993	1	0	1	2	4
1994	4	0	2	4	10
1995	10	0	1	6	17
1996	8	0	1	4	13
1997	10	0	1	3	14
1998	11	0	0	4	15
1999	7	0	0	0	7
2000	8	0	0	5	13
2001	1	0	0	0	1
2002	0	0	0	1	1
2003	1	0	0	1	2
2004	0	0	0	2	2
2005	3	0	0	1	4
2006	3	0	0	6	9
2007	3	0	0	4	7
2008	6	0	0	3	9
2009	6	0	0	3	9
Total Death	101	2	19	63	185

Source: Department of Forest and Environment, Govt. of Assam.

The study on the evaluation of rhino habitat in RG Orang NP is an important one to prepare a concrete plan to protect this prehistoric pachyderm.

In this study, the researcher analyzed the land cover change dynamics of RG Orang NP using past and present satellite imagery and field survey to find a habitat suitability model in relocating rhinos. The researcher also intends to identify the factors, which have direct and indirect impact on the different land cover types of RG Orang NP. Similarly seasonal variation of habitat utilization pattern of one horned rhino has been analyzed, which is considered as good baseline information for further research on rhino habitat. A habitat suitability model was prepared integrating field data and Geographic Information System (GIS) tools showing the areas, which are highly suitable, moderately suitable and less suitable. This will provide possibility of relocating and rehabilitation of rhinos in different parks in other parts of the state and country.

Study area:

The RG Orang NP is situated in the north bank of the river Brahmaputra and within the administrative boundary of Darrang and Sonitpur districts of Assam, India. The park has been often regarded as the man made forest that lies within the geographical limits of 26° 29' N to 26° 40' N latitude to 92° 16' E to 92° 27' E longitude. The study area is located about 130 km from the capital city Guwahati and included under the jurisdiction of Mangaldoi Wildlife Division, Department of Environment and Forest, Government of Assam, India. The figure I b) shows the geographical location of RG Orang NP. The RG Orang NP is a flood plain area. The park is surrounded by human population or villages in the northern, eastern and western directions. The northern side is bounded by Nalbari and Rongagora villages of Darrang district. The eastern side is bounded by Borsola villages and river Pachnoi. The western side is bounded by river Dhansiri and Bogoribari village and the southern side is bounded by the river Brahmaputra.

The RG Orang NP is comprises of alluvial floodplain of the River Brahmaputra. In fact, the complete study area is an alluvial terrace and the entire park could be divided into two halves i.e. lower Orang and upper Orang. The lower Orang portion is recent origin, whereas the upper Orang portion to its north is separated by high bank, traversing the park from east to west. The terrain is generally slopping from north to south. The altitude of the study area ranges between of 17m -78m above sea level.

The climate of the RG Orang NP is meso-thermal humid climate of Brahmaputra valley type. On the basis of the seasonal variation of temperature, rainfall and humidity, the climate could be divided into four distinct seasons – Pre-monsoon, Monsoon, Re-treating Monsoon and Winter season.

a) **Pre-monsoon (March – May)**: The minimum and maximum temperature during this season was ranged between 20° C to 30° C. The average relative humidity was 67% to 85% and the average rainfall was 360 mm during the study period.

b) **Monsoon (June-September):** The monsoon season is the characteristics type of rainy season of the year with an average rainfall of 1200mm. The minimum and maximum temperature ranged between 25° C to 36° C. The average relative humidity was 81% during this season.

c) **Retreating Monsoon (October-November):** The minimum and maximum temperature ranged between 20° C to 30° C. Rainfall slightly lowered in this season and attained up to 110 mm and average humidity was 80% during the study period.

d) **Winter (December – February)**: The winter season is characterized by cool weather and fog. Average minimum and maximum temperature ranges between 12° C to 25° C respectively. The average relative humidity ranges between 65% to 75%. The average rainfall was 20mm only during the study period.

OBJECTIVES:

The four objectives selected for this study are –

e) To study the changes in land use/ land cover, habitat and its impact on rhino habitat pattern in RG Orang NP;

f) To study the seasonal variation in habitat utilization pattern of rhino in the park;

g) To develop an ideal habitat suitability model for rhino in the park using remote sensing and GIS tools for conservation and management purpose;

h) To study the feasibility of the model to relocate and rehabilitate the one-horned rhino in different locations and other parks.

Research questions:

The research questions that were taken to understand the land cover change dynamics; habitat utilization and suitability analysis for rhino in RG Orang NP were as follows.

a) Is changing land use/land cover pattern of the park threatening rhino habitat and suitability?

b) Has rhino been able to adopt all types of grasslands in all over the park area?

c) Is RG Orang NP is being conserved and managed for Rhino habitation?

d) How are remote sensing, GIS and GPS technology been used to identify the rhino habitat and suitability locations?

Database and Methodology:

Data Source & Methodology for Land Cover Change Analysis

Multi date satellite imageries were used to analyze the land cover change dynamics in RG Orang NP. Besides this, the Survey of India topographical sheet no. 83 B/6 at 1:50,000 scale and maps available with state forest department of Assam were used for delineation of forest boundary and to generate baseline information for the study area. Satellite imageries of Landsat TM of 1987 and 1999 and IRS P6 LISS III of 2008 were used to analyze the land cover change dynamics in the RG Orang NP. The open source Landsat TM of 1987 and 1999 were downloaded from the National Aeronautics and Space Administration's (NASA) Global Land Cover Facilitator's (GLCF) website (www. glcfapp.umiacs.umd.edu) and satellite imagery of 2008 was procured from National Remote Sensing Centre (NRSC), Hyderabad. The imageries were projected to UTM – WGS 84 projection system using Landsat ETM image as reference. Sub-pixel image to image registration accuracy was achieved through repeated attempts. Radiometric corrections of all the images were done using dark pixel subtraction technique (Lillesand, *et al.* 2004). Re-sampling of IRS P6 LISS III imagery was carried out at 30 m. pixel size as the other imageries (Landsat TM 1987 and 1999) were of 30 m. resolution. Subset operation of satellite imageries of 1987, 1999 and 2008 were carried out by creating an area of interest (AOI) layer of the vector layer of forest boundary of RG Orang NP, which was digitized from the published maps of department of forest and environment, Govt. of Assam at 1:50,000 scale. After sub setting, the images of the study area were processed through spectral enhancement technique using ERDAS Imagine 9.2 software. Principal component analysis (PCA) was carried out to all the images. All the images were converted into three principal components. PCA is often used as a method of data compression. It allows redundant data to be compacted into fewer bands—that is, the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen, 1996; Faust, 1989). After generating the hybrid PCA images for all the years a supervised classification technique was used using maximum likelihood algorithm to assess the land cover change dynamics in RG Orang NP from 1987 to 2008. Since supervised classification is a process where the image analyst supervised the pixel categorization process by specifying to the computer algorithm, numerical descriptors of the various land cover types present in a scene. Many researchers have been using supervised classification technique to extract the features from the remotely sensed imagery, as it demonstrates the classification that can incorporate both the spectral and spatial features of the pixels in the image resulting in better defined categories in terms of its homogeneity. Ground truth verification was made during the period from September 2008 to September 2009 and based on the ground verification data, classes were assigned in the PCA based images. Nine land cover types were identified from the field observation and training sets of the land cover classes were gathered using handheld GPS receiver. After classifying all the images of 1987, 1999 and 2008 the post classification comparison method was used to detect the changes of land cover types in RG Orang NP. The method consists of overlaying, cross operation, comparison of two images and classification. The cross operation allows the analyst to know the extent and nature of the changes observed, in other words, the transition between different land cover classes and the corresponding areas of change. Applying this method finally, land cover change analysis of RG Orang NP was done. The output resolutions of all the classified images were at 30 m. resolution. All these image-processing operations were carried out in ERDAS Imagine 9.2 software.

To get the erosion and depositional scenario of RG Orang NP satellite images of 1987, 1999 (Landsat TM) and 2008 (IRS P6 LISS III) were used. Delineation of the river banks for the year 1987, 1999 and 2008 was done using onscreen digitization for respective years using Arc GIS 9.3 software. A union tool was used to all the different river bank layers for the year 1987, 1999 and 2008 in the software to determine the erosion and depositional changes in RG Orang NP.

Data Source & Methodology for Habitat Utilization Pattern of Rhino

A direct method of monitoring the movement of the one-horned rhino was used to find out the seasonal variation of habitat utilization pattern of one-horned rhino in RG Orang NP. The tall grasses and dense woodland of RG Orang NP make observations exercises difficult particularly during monsoon season when much of the study area are flooded. Rhinos were observed on foot, on elephant backs, on field vehicles and from watch towers of RG Orang NP. The visibility of rhinos changes in different seasons depending on the height of the grasses and the frequency of the rhinos wallowed in open swamps. First of all, the entire study area was divided in to certain equisized blocks based on different habitat types, camp locations and availability of other resources like trained elephants. A continuous ground survey for twelve months, considering five days in each month, was conducted with the help of trained elephants provided by the state forest department, Govt. of Assam. The survey was done in all the seasons of the year 2008-2009 i.e. pre-monsoon (Mar-May), monsoon (June-Sept), retreating monsoon (Oct-Nov) and winter (Dec–Feb) to get the accurate data of habitat utilization pattern of one horned rhino in RG Orang NP. A map was prepared prior to entering the park for collection of primary data, showing the survey blocks and was distributed to all block members to reduce the chance of overlapping of same block during the survey period. Altogether, eighteen blocks were prepared based on habitat pattern, camps location and availability of other resources like trained elephants. The survey was carried out in each of the blocks at the same Indian Standard Time (IST) i.e. 6:00 AM and was use to complete at the same IST i.e. 10:00 AM to reduce the percentage of error. A data sheet was prepared where date of survey, habitat pattern, vegetation species, number of rhino count and number of dung piles count were recorded systematically. Finally, all these block wise primary data were entered into GIS domain to plot the data and get the map of seasonal variation of habitat utilization pattern of one horned rhino in RG Orang NP. The 64 rhinos of RG Orang NP were came in to notice for 183 times throughout the year long survey in RG Orang NP in different habitat types.Chi-square goodness of fit statistical analysis was carried out to understand the significance of habitat utilization pattern of rhino in Orang NP.

Data Source & Methodology for Habitat Suitability Analysis for Rhino

A wildlife habitat provides the necesssray combination of climate, sub-strate and vegetation that each animal species require. Within a habitat, the functional area that an animal occupies is referred to as its niche. Throughout evolution process, various species of animals adapted to various combinations of physical factors and vegetation.The adaptation of each species suits to a particular habitat and rules out to its use of other places. The number and type of animals that can be supported in a habitat are determnined by the amount and distribution of food, shelter, and water in relation to the mobility of the animal. By determining the food, shelter and water charecteristics of a particular area, general inference can be drawn about the ability of that area to meet the habitat requirement of different willife species (Lillesand, *et.al.* 2004). Habitat suitability modelling is a key way of defining an ideal habitat range of a species with the help of geo-spatial technology (Remote Sensing, GIS and GPS). The model is expected to assist the park managers to adopt adpative management to provide maximum suitable habitats to rhino. A year-long field survey was conducted in RG Orang NP from September 2008 to September 2009 to understand the habitat utilization pattern of rhino in different seasons of a year. GPS locations of the direct evidences like sighting and indirect evidences like dung piles, foot print of rhino was taken and plotted over the boundary layer of the park, which was digitized from the map available with state forest department of Assam. A habitat suitability model for one horned rhino was prepared based upon the field observation of rhino and its habitat relationship. A co-relation regression method was used to understand the relationship between rhino and their habitat. Based upon this extensive observation on rhino and its relations with habitat types, some habitat parameters were identified for rhino like cover type, slope, water availability, location of human settlement, distance from roads and their impacts on rhinoceros. The habitat parameters were discussed elaborately in the chapter VI of this thesis. Based upon all these parameters, a habitat suitability model for rhino was prepared for RG Orang NP using Arc GIS 9.3 software. Spatial analysis tools like, buffer, erase, select, intersect; union, etc were used to prepare the habitat suitability model for rhino in RG Orang NP.

Research Findings:

a) Land cover change in Rajiv Gandhi Orang National Park:

The entire land cover of RG Orang NP was categorized into nine classes based upon field knowledge and collection of training sets of vegetation types. The nine classes are as follows:

i) Eastern Himalayan Moist Mixed Deciduous Forest (Dense)
ii) Eastern Himalayan Moist Mixed Deciduous Forest (Open)
iii) Dry Savannah Grassland
iv) Wet Alluvial Grassland
v) Seasonal Swamp Forest
vi) Degraded Grassland
vii) Water Body / River
viii) Moist Sandy Area
ix) Dry Sandy Area

Changes in Land Cover Types in RG Orang NP:

a) Land cover change dynamics:

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. The real time land use/land cover information along with their spatial distribution is a pre requisite for planning and formulation of policies and programs. The current research shows tremendous changes in land cover pattern in RG Orang NP. The following table shows the changes of land cover pattern in the park. Analysis of the recent history and present patterns of forests offers a present day baseline for assessing future landscape patterns and their consequences. In this study analysis of land cover change dynamics in RG Orang NP, three datasets of satellite imageries were used pertaining to the year 1987, 1999 (Landsat TM) and 2008 (IRS P6 LISS III). A supervised classification technique has been used to prepare the land cover types of RG Orang NP from 1987 to 2008. From the land cover change analysis of RG Orang NP it has been observed that Eastern Himalayan mixed moist deciduous forest (dense) has an increasing trend from 6.8 km^2 (8.62%) in the year 1987 to 8.63 km^2 (10.95%) in the year 1999 and it has increased up to 9.84 km^2 (12.49%) in the year 2008. The Eastern Himalayan moist deciduous forest (open) has also an increasing trend from 1987 to 2008. The area covered by Eastern Himalayan moist deciduous forest (open) in the year 1987 was 7.6 km^2 (9.46%) and it increased up to 10.54 km^2 (13.37%) in the year 2008. In case of dry savannah grassland, an increasing trend from 6.88 km^2 (8.73%) to 12.41 km^2 (15.75%) and up to 14.17 km^2 (17.98%) in the years of 1987, 1999 and 2008 respectively has been observed. In case of wet alluvial grassland, a decreasing trend has been observed from 1987 to 2008 covering areas of 30.63 km^2 (38.87%) to 20.54 km^2 (26.06%) respectively. This decrease of wet alluvial grassland in the park is mainly due to the impact of the invasive species named as *Mimosa invesa*. . In case of degraded grassland there is an increasing trend from 6.86 km^2 (8.70%) in the year 1987 to 10.35 km^2 (13.13%) in the year 1999. Similarly, from 1999 to 2008 it has witnessed an increasing trend and reached up to 12 km^2 (15.23%) of area. In case of seasonal swampy forest, it was found that it reduced from 3.1 km^2 (3.93%) in the year 1987 to 2.51 km^2 (3.18%) in the year 1999. It has also a decreasing trend from 1999 to 2008 covering an area of 1.36 km^2 (1.72%) . In case of water body, it was found that it reduced from 5.76 km^2 (7.31%) in the year 1987 to 3.13 km^2 (3.97%) in the year 1999. However, from 1999 to 2008 it increased up to 6.48 km^2 (8.22%), which is mainly due to erosion caused by river Brahmaputra, Dhansiri and Pachnoi. In case of river sand or sandy area there is a decreasing trend from the year 1987 to 2008. Study shows that the sandy areas were drastically decreased from the year 1987 to 2008 in the RG Orang NP.

b) Erosion and Depositional Changes in RG Orang NP:

Study shows an increasing trend of silt deposition in the park by the river Brahmaputra during the year 1987 to 2008. It was observed that from 1987 to 1999 only 0.23 km^2 was eroded in RG Orang NP whereas 9.48 km^2 was deposited during that period in the park. Similarly from 1999 to 2008 almost 2.54 km^2 was eroded in the park and 0.18 km^2 was deposited by the river Brahmaputra in the park during the same period. It shows that the depositional trend is more prominent during the period from 1987 to 1999 in comparison to 1999 to 2008.

c) Seasonal variation of habitat utilization pattern of Rhino:

The study reveals that the rhino prefers mostly wet alluvial grassland in RG Orang NP throughout the year 2008 – 2009. The study also shows that in all seasons significantly highest number of rhinos were sighted in wet alluvial grasslands in RG Orang NP during 2008-2009 (**χ^2 = 134.09, df = 4, $p<0.01$**). It indicates that rhino prefers mostly wet alluvial grasslands in all seasons of a year (59.56%). It is evident from the present study that, the

Indian rhino in RG Orang NP prefers wet alluvial grasslands throughout the year, followed by dry savannah grassland, woodland and wet lands.

d) Rhino Habitat Suitability Modeling:

From this study it has appeared that only 19.81 km^2 (25.14%) area is most suitable in the park, 10.74 km^2 (13.63%) is moderately suitable and 48.45 km^2 (61.48%) area is less suitable for rhino. It has also appeared from this study that the suitability condition for rhino in the park is gradually decreasing because of land cover change.

Summery and Conclusion:

From this current research following conclusion and recommendation can be made for conservation and management of rhino and its habitat in RG Orang NP.

- The land cover change in RG Orang NP has adversely affected the rhino habitat and its suitability pattern.
- The wet alluvial grassland is drastically reduced in the park from 1987 to 2008 which leads to decrease of most suitable habitat for rhino in the park.
- Degraded grassland and woodland are increasing at an alarming rate in the park, which is a serious concern for rhino conservation effort in the park.
- Impact of invasive species like *Mimosa invesa* is quite prominent in the park.
- Deposition by river Brahmaputra is more prominent than erosion in RG Orang NP from 1987 to 2008.
- Rhino uses maximum wet alluvial grassland in all the seasons of the year 2008 – 2009 followed by dry savannah grassland, woodland and wetlands in RG Orang NP
- The most suitable habitat in RG Orang NP is gradually decreasing from 1987 to 2008 because of the changing nature of the land cover pattern.
- Only 25.14% of the total area is most suitable for rhino in RG Orang NP.

- Measures should be taken immediately to increase the most suitable habitat in the park.

- Massive protection measures should be taken immediately to prevent cattle grazing and encroachment in the park.

- Uprooting of invasive species like *Mimosa invesa* should be done immediately for conservation of rhino habitat in the park.

- The habitat management practices in RG Orang NP should improve for conservation of rhino and other wild animals.

- Patch burning should be encouraged in the park for conservation of rhino habitat.

- A spatial decision support system of RG Orang NP was developed by the researcher entitled as Orang National Park Information System and it will be helpful for park authority for conservation and management of rhino and its habitat in the park

- Finally through this research it is evident that Geo-Spatial technology is quite useful for wildlife habitat evaluation and also to understand the species specific suitability condition at micro level.

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I, Mr. Pranjit Kumar Sarma, do hereby declare that the subject matter of the thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institute.

This is being submitted to the North-Eastern Hill University for the Degree of Doctor of Philosophy in Geography.

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ACKNOWLEDGEMENTS

I owe a deep sense of respect and gratitude to my supervisor and guide **Professor B.S.Mipun,** Department of Geography, North-Eastern Hill University, Shillong for his untiring guidance throughout my research work. I am thankful for his uninhibited guidance and encouragement and constant monitoring of the progress of my work to give successful completion of the research and his untiring help in the preparation and completion of this manuscript.

I express my heartiest thanks to all my teachers, office staff of Department of Geography, North-Eastern Hill University for their inspiration, encouragement, and valuable suggestions in matters which were beyond my perception.

I also express my heartiest thanks to **International Foundation for Science, Sweden and Asian Rhino Project, Australia** for providing me necessary fund for the field work and also for procuring necessary equipments required for this study.

I am highly indebted to **Dr. Bibahb Kumar Talukdar**, Secretary General, Aaranyak, a Scientific and Industrial Research Organization (SIRO) based at Guwahati, Assam for sharing his invaluable knowledge and expertise in matters related to the study area and the subject of research, and also for providing GIS facilities and necessary materials.

I also express my gratitude to **Dr. Kiranmoyee Sarmah**, Department of Environmental Management, Guru Gobind Singh Indraprastha University, Delhi for his continuous encouragement and support during the study period.

I am also thankful to Dr. Rajan Amin of Zoological Society of London for his continuous encouragement and support during the preparation of this manuscript.

I am special thankful to **Mr, Jayanta Deka**, Ex-Range Officer of Rajiv Gandhi Orang National Park, **Mr. Sukumar Momin**, Ex-Divisional Forest Officer, Mangaldoi Wildlife Division, Mr. Sushil Kumar Daila, Divisional Forest Officer, Mangaldoi Wildlife Division and all the staff of the Rajiv Gandhi Orang National Park for their support and encouragement during field survey period.

Last but not the list, I acknowledge my indebtedness to my parents, my wife, my daughters Nistha and Tanistha and all other family members and collogues for their moral support and patients throughout the duration of the research.

Place: Shillong, Meghalaya

Date: 05.08.2010 **Pranjit Kumar Sarma**

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CHAPTER – I

Chapter I

Introduction

1.1 Background:

The forests are identified as one of the major natural resources in India having immense influence directly or indirectly on the biosphere. The forest cover is disappearing due to unabated felling of trees, extensive grazing and other human related activities. Areas of human settlement, agriculture and industries are expanding at the expense of wildlife habitats. These threats can be overcome by an effective and efficient management of the forests which, in turn, depends on reliable and up to date information on forest resources and wildlife habitats. Remote sensing, with its synoptic coverage and finer spatial, spectral, temporal and radiometric resolution, is found to be an effective tool for collecting information on forest resources. Such satellite driven database may relate to forest type, crown density, biomass, habitat evaluation of wildlife etc.

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An attempt has been made in the current study to evaluate the rhino habitat, its seasonal variation of habitat utilization pattern and habitat suitability assessment of Rajiv Gandhi Orang National Park (hereafter, written as **RG Orang NP)** using geo-spatial technology. Furthermore, the land cover change dynamics of the park was done over a period of thirty years using historic and current satellite datasets. Habitat suitability assessment for rhino in the park has been done using a modeling approach in GIS environment that will help the park authority to manage and expand the suitable areas for rhino. This will also help the park managers to protect the habitat in a more scientific manner, which will further enhance the rhino conservation in the state of Assam.

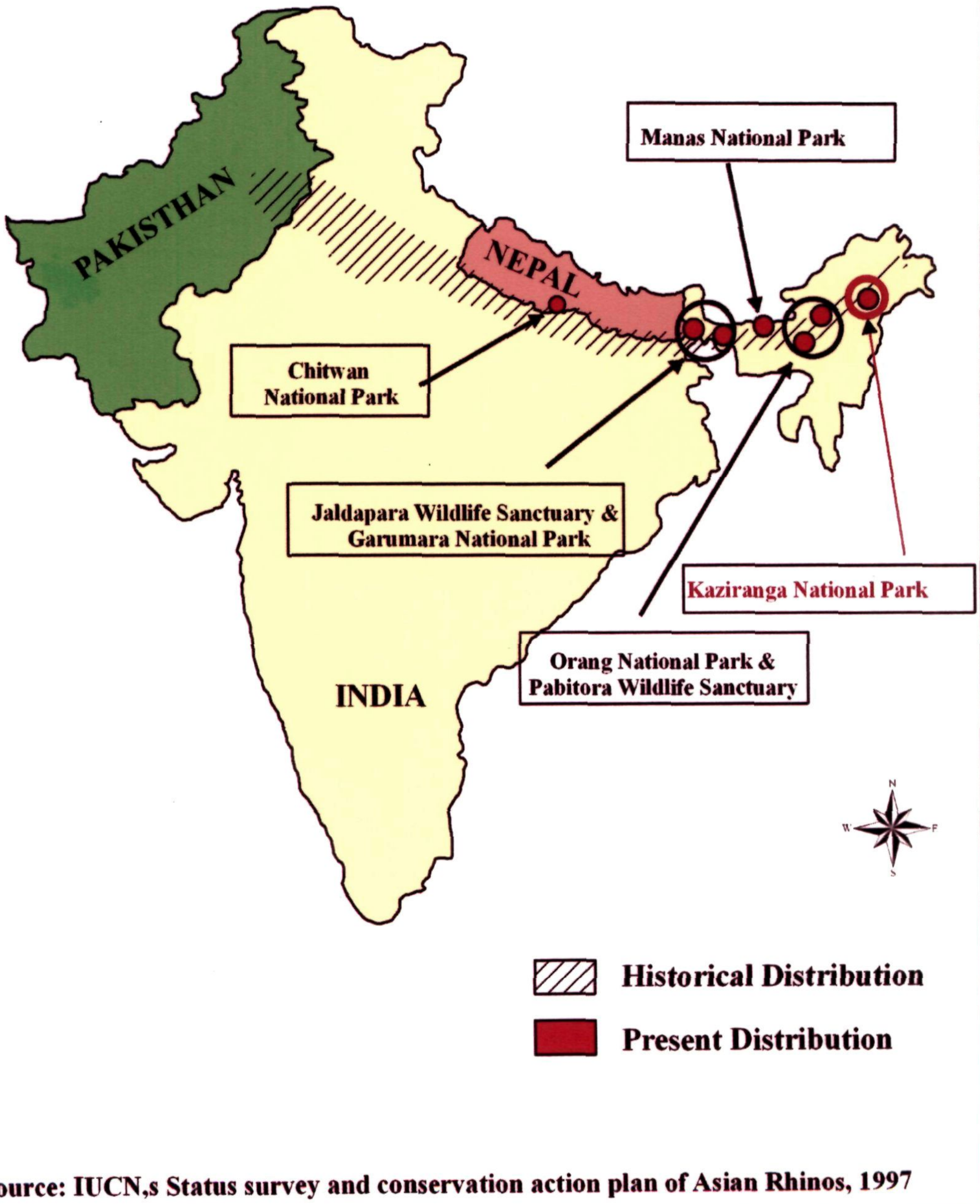
1.2 The Greater One-horned Rhino:

Though the Greater One-horned rhino *(Rhinoceros unicornis)* is considered as vulnerable by IUCN (B1ab (iii)), it is still in high risk for its survival in Assam because of constant threats from poachers, wildlife trafficking, fragmentation and degradation of its habitat in past couple of decades. Assam is one of the last strongholds of Indian rhino. The state has the highest population of one-horned rhino in the world that is estimated at

2201 wild rhinos by the Assam Forest Department in the year 2009.The Indian rhino is severely threatened by hunting owing to superstitious belief about medicinal qualities of its horn that has high demand and commands high value in the clandestine national and international markets of wildlife parts.

Although Indian rhinos were originally found in the northern part of India, Pakistan, Nepal, Bhutan, Myanmar and some parts of South East Asian countries until 1600 AD, they are now found only in a few pocketed areas of India and Nepal. The historic and present distribution of Indian rhinos is shown in the Map No. - 1.

Historical & Present Distribution of Greater One-Horned Rhino



Source: IUCN,s Status survey and conservation action plan of Asian Rhinos, 1997

Map No. 1

Indian rhinos are characterized by a single horn, usually about 53 cm long, with height from 5.75 to 6.5 feet and length from 10 to 12.5 feet. Weights vary from 4,000 to 6,000 pounds. Their main habitat is riverine (floodplain) grasslands as they are primarily grazers, but adjacent woodlands are occasionally utilized. Although they feed from more than 100 species of plants, grass makes up more than 70% of their diet. Other food includes browse, shrubs and aquatic plants. While not grazing on land, they immerse themselves in the water and thus rhinos need permanent water bodies as well as marsh in winter when the seasonal wetlands become dry. Flat terrain is ideal, but they also use some highlands as their shelter during flood periods. Though Indian rhinos are found in high altitude in Nepal, but in India they are seen up to 500 m of altitude. In general, the range of rhinos is around 3km though their ranges can overlap (Laurie, 1978).The present distribution status, habitat occurrences and population size of Indian rhino is given in the table I a.

Table I a. – The present distribution status, habitat occurrences and population size of Greater One-horned Rhino in the world

Location			Existence of rhino	Habitat Characteristics		Population size
Country	**State**	**Protected Area**		**Flood plain**	**Grassland types**	
Nepal		Chitwan NP	Y	Y	Terai	418
		Bardia NP	Y	Y	Terai	20
India	**Uttar Pradesh**	Dudhwa WLS	Y	N	Terai	29
	West Bengal	Jaldapara WLS	Y	N	Terai & Riverine	125
		Garumara NP	Y	Y	Terai & Riverine	30
	Assam	Kaziranaga NP	Y	Y	Riverine	2048 (2009)
		Manas NP	Y	Y	Terai & Riverine	5 (2009)
		RG Orang NP	Y	Y	Riverine	64 (2009)
		Pabitora WLS	Y	Y	Riverine	84 (2009)
		Laokhowa WLS	N	Y	Riverine	Locally extinct during 1983
		Burhachapori WLS	N	Y	Riverine	Locally extinct during 1983
		Sonai-Rupai WLS	N	Y	Terai & Riverine	Locally extinct long back
		Total				2823

(Data Source: IUCN/SSC Asian Rhino Specialist Group Report, 2010)

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(Data Source: IUCN/SSC Asian Rhino Specialist Group Report, 2010)

1.3 Rhinos of RG Orang NP:

The rhino conservation paradigm in RG Orang NP was started with about 35 rhinos in the year 1972 (Talukdar, 2000). There was tremendous fluctuation of rhino population in RG Orang NP from 1972 to 2009. The detail rhino population estimates in RG Orang NP since 1972 is summarized in table I b.

Table- I b. - Population comparison of rhino in different census from 1972 to 2009 in Orang NP

Years	Adult			Sub-Adult			Calf	Total
	Male	Female	Un-sex	Male	Female	Un-sex		
1972	10	13	3	3	2		4	35
1985	23	23	-	7	2		10	65
1991	28	41	5	-	1	14	8	97
1999	17	17	1	3	2	-	6	46
2006	28	27	-	-	-	4	9	68
2009	16	22	1		2	7	16	64

Source: Divisional Forest Office, Mangaldoi Wildlife Division, Darrang, Assam

The RG Orang NP has witnessed several poaching threats during 1994 to 2000 when half of its rhino population was poached by well organized gangs of poachers. However the officials and the local NGOs took serious note of gravity of the situation and proposed to upgrade the then Orang Wildlife Sanctuary to a National Park in 1999.

1.4 Statement of the problem:

The North East India is a globally recognized as biodiversity hotspot and by far the richest reserves of flora and fauna in India (Talukdar, *et. al.* 2007). This is the only region where the density as well as the population of one-horned rhino is highest in the world (Talukdar, *et. al.* 2007). The major rhino bearing areas of this region are Kaziranga National Park, RG Orang NP and Pabitora Wildlife Sanctuary. Though this region has the highest density and population of the flagship species like one horned rhino but till date very limited and comprehensive scientific research has been carried out to analyze the habitat suitability pattern and threats perception of the habitat due its changing land use pattern. Similarly there is lack of up-to-date database on rhino and their habitat pattern which is a prime requirement to relocate and rehabilitate the one horned rhino in other areas of the region and in the country.

The RG Orang NP is one of the prime habitats of Indian rhino. This park is facing tremendous problems from the poachers, invasive species like *Mimosa invesa* and over grazing of the cattle from the nearby villages. All these factors have contributed to the declining rhino population in the Park. The record shows that there were 97 rhinos in the park in the year 1991 and 64 rhinos in the year 2009. The observation from 1983 to 2009 shows that 122 rhinos were poached while 63 rhinos died naturally in RG Orang NP. A comparative data of natural death and poaching of rhino in RG Orang NP from 1983 to 2009 is shown in the table I c. The impact of invasive species like *Mimosa invesa* is very common in the RG Orang NP. Due to the pressure of invading *Mimosa invesa,* the habitat of RG Orang NP has changed drastically because of the reduction of wet alluvial grassland in the park. It is also observed that degraded grassland in the park is increasing day by day because of the impact of *Mimosa invesa* and due to the over grazing of the cattle's of nearby villages. The siltation due to seasonal flood is another major problem of the wetlands. As RG Orang NP lies on the bank of the river Brahmaputra, during monsoon season most of the park wetlands are submerged under the floodwater of the mighty river and thus siltation is widespread. As the rhinos, other wild animals and birds extensively use wetlands in all seasons of year, the siltation has an adverse effect on wildlife habitat of the park and forces rhinos to stray outside the park area.

Table I c. – Poaching and Natural death of rhino in RG Orang NP

Year	Poaching			Natural Death	Total Death
	Gun Shot	Poison	Pit		
1983	8	0	0	4	12
1984	3	1	2	1	7
1985	2	0	6	1	9
1986	1	0	2	0	3
1987	1	0	0	2	3
1988	1	1	2	0	4
1989	1	0	1	1	3
1990	0	0	0	0	0
1991	1	0	0	2	3
1992	1	0	0	3	4
1993	1	0	1	2	4
1994	4	0	2	4	10
1995	10	0	1	6	17
1996	8	0	1	4	13
1997	10	0	1	3	14
1998	11	0	0	4	15
1999	7	0	0	0	7
2000	8	0	0	5	13
2001	1	0	0	0	1
2002	0	0	0	1	1
2003	1	0	0	1	2
2004	0	0	0	2	2
2005	3	0	0	1	4
2006	3	0	0	6	9
2007	3	0	0	4	7
2008	6	0	0	3	9
2009	6	0	0	3	9
Total Death	101	2	19	63	185

Source: Department of Forest and Environment, Govt. of Assam.

The study on the evaluation of rhino habitat in RG Orang NP is an important one to prepare a concrete plan to protect this prehistoric pachyderm.

In this study, the researcher has analyzed the land cover change dynamics of RG Orang NP using past and present satellite imageries and field survey to find a habitat suitability model in relocating rhinos. The researcher also intends to identify the factors, which have direct and indirect impact on the different land cover types of RG Orang NP. Similarly, seasonal variation of habitat utilization pattern of one-horned rhino has been analyzed, which is considered as good baseline information for further research on rhino habitat. A habitat suitability model was prepared integrating field data and Geographic Information System (GIS) tools showing the areas, which are highly suitable, moderately suitable and less suitable. This will provide possibility of relocating and rehabilitation of rhinos in different parks in other parts of the state and country.

1.5 Objectives:

The four objectives selected for this study are –

a) To study the changes in land use/land cover, habitat and its impact on rhino habitat pattern in RG Orang NP;

b) To study the seasonal variation in habitat utilization pattern of rhino in the park;

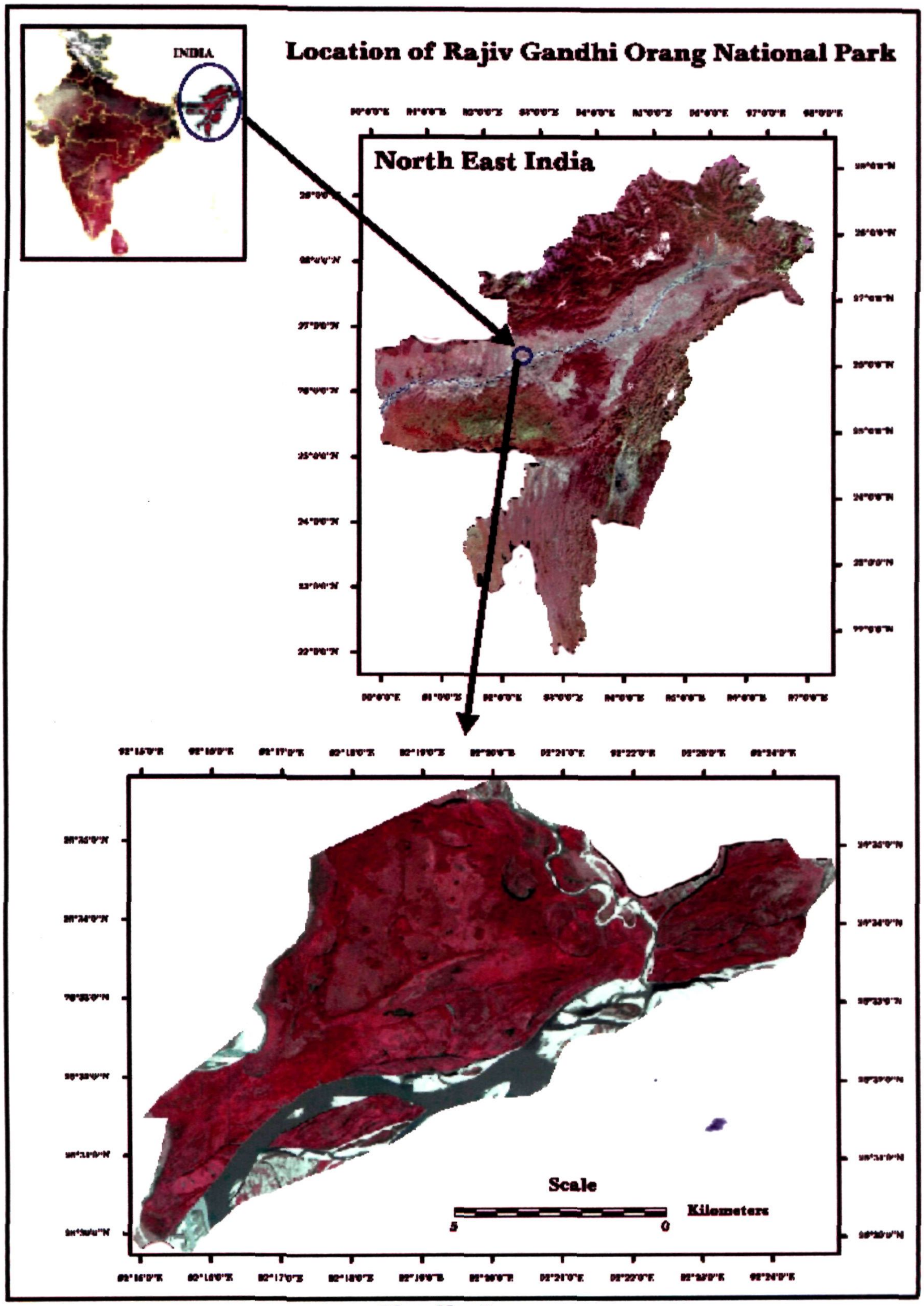
c) To develop an ideal habitat suitability model for rhino in the park using remote sensing and GIS tools for conservation and management purpose;

d) To study the feasibility of the model to relocate and rehabilitate the one-horned rhino in different locations and other parks.

1.6 Study area:

1.6.1 Location:

The RG Orang NP is situated in the north bank of the river Brahmaputra and within the administrative boundary of Darrang and Sonitpur districts of Assam, India. The park has been often regarded as the man made forest that lies within the geographical limits of 26° 29' N to 26° 40' N latitude to 92° 16' E to 92° 27' E longitude. The study area is located about 130 km from Assam's capital city of Guwahati and included under the jurisdiction of Mangaldoi Wildlife Division, Department of Environment and Forest, Government of Assam, India. The Map No. - 2 show the geographical location of RG Orang NP.


Location of Rajiv Gandhi Orang National Park
INDIA
North East India
Scale
Kilometers
5
0

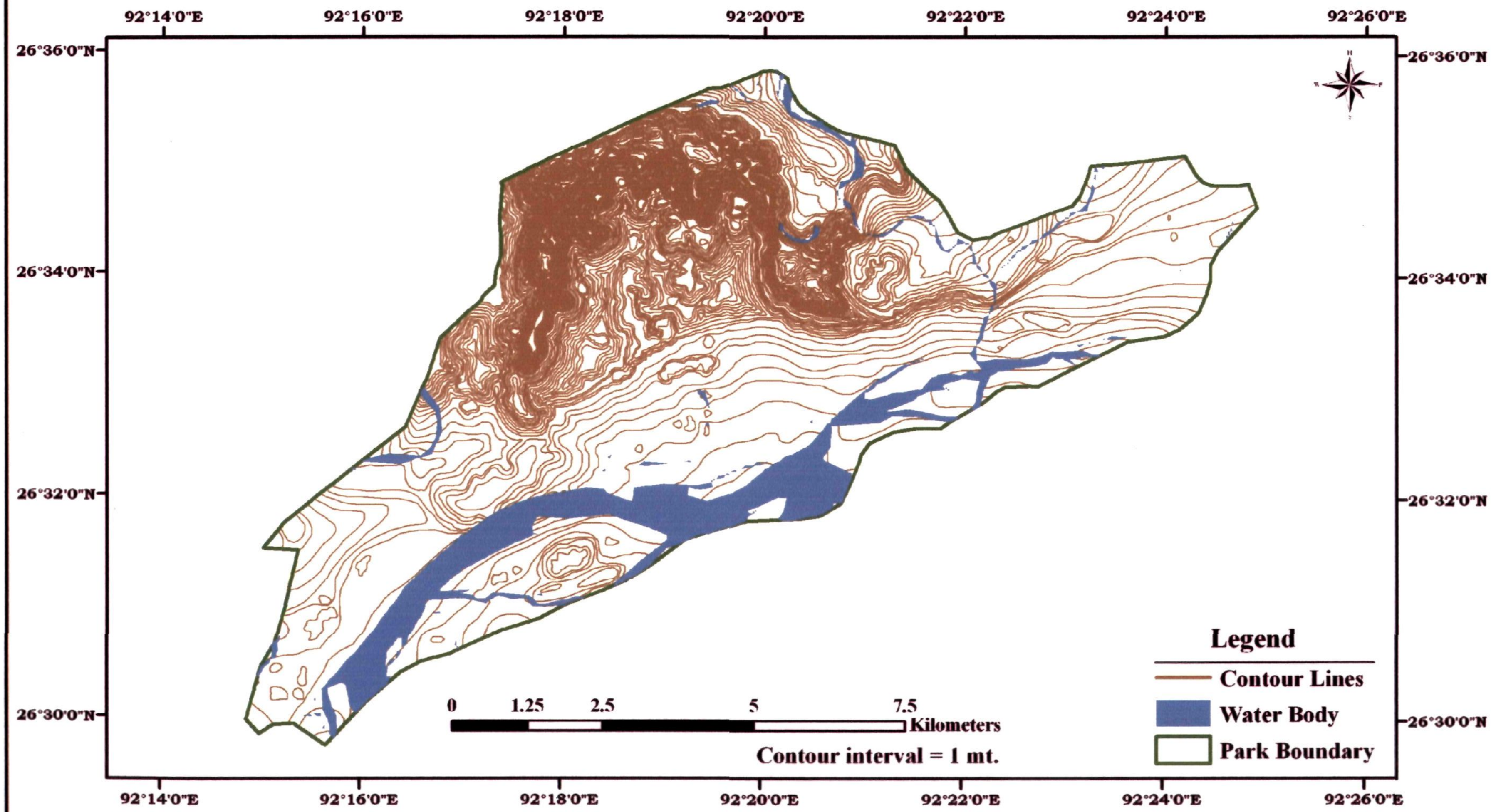
Map No. 2

1.6.2 Physiography:

The RG Orang NP is a flood plain area. The park is surrounded by human population or villages in the northern, eastern and western directions. The northern side is bounded by Nalbari and Rongagora villages of Darrang district. The eastern side is bounded by Borsola villages and river Pachnoi. The western side is bounded by river Dhansiri and Bogoribari village and the southern side is bounded by the river Brahmaputra.

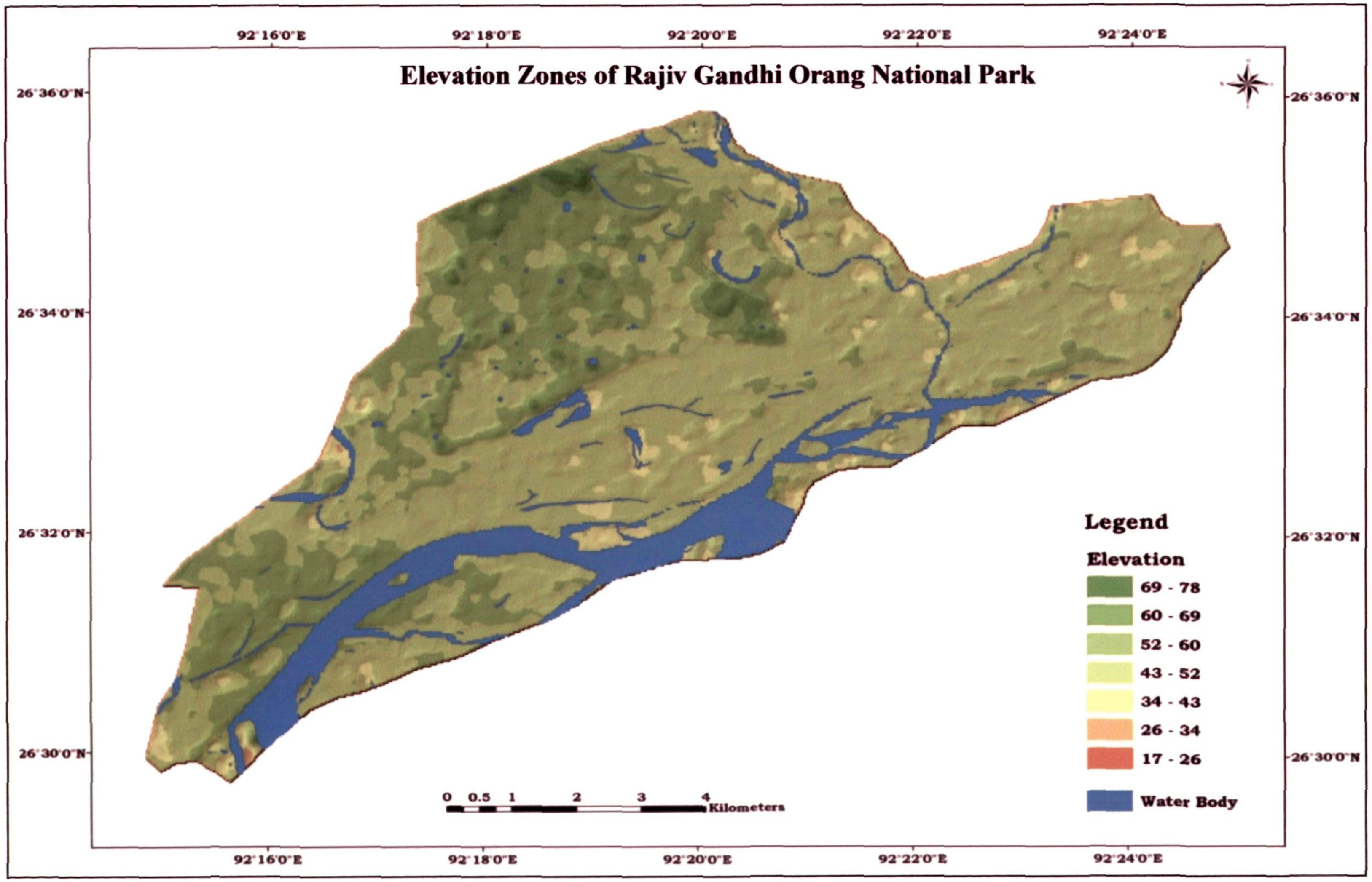
The RG Orang NP comprises of alluvial floodplain of the river Brahmaputra. In fact, the complete study area is an alluvial terrace and the entire park could be divided into two halves i.e. lower Orang and upper Orang. The lower Orang portion is of recent origin, whereas the upper Orang portion to its north is separated by high bank, traversing the park from east to west. The terrain is generally slopping from north to south. The altitude of the study area ranges between of 17m -78m MSL. The Map No. - 3 and Map No. - 4 show the contours and elevation zones of RG Orang NP.

Contour Map of Rajiv Gandhi Orang National Park



Source: SOI Toposheet 83 B/6 & ASTER DEM

Map No. 3

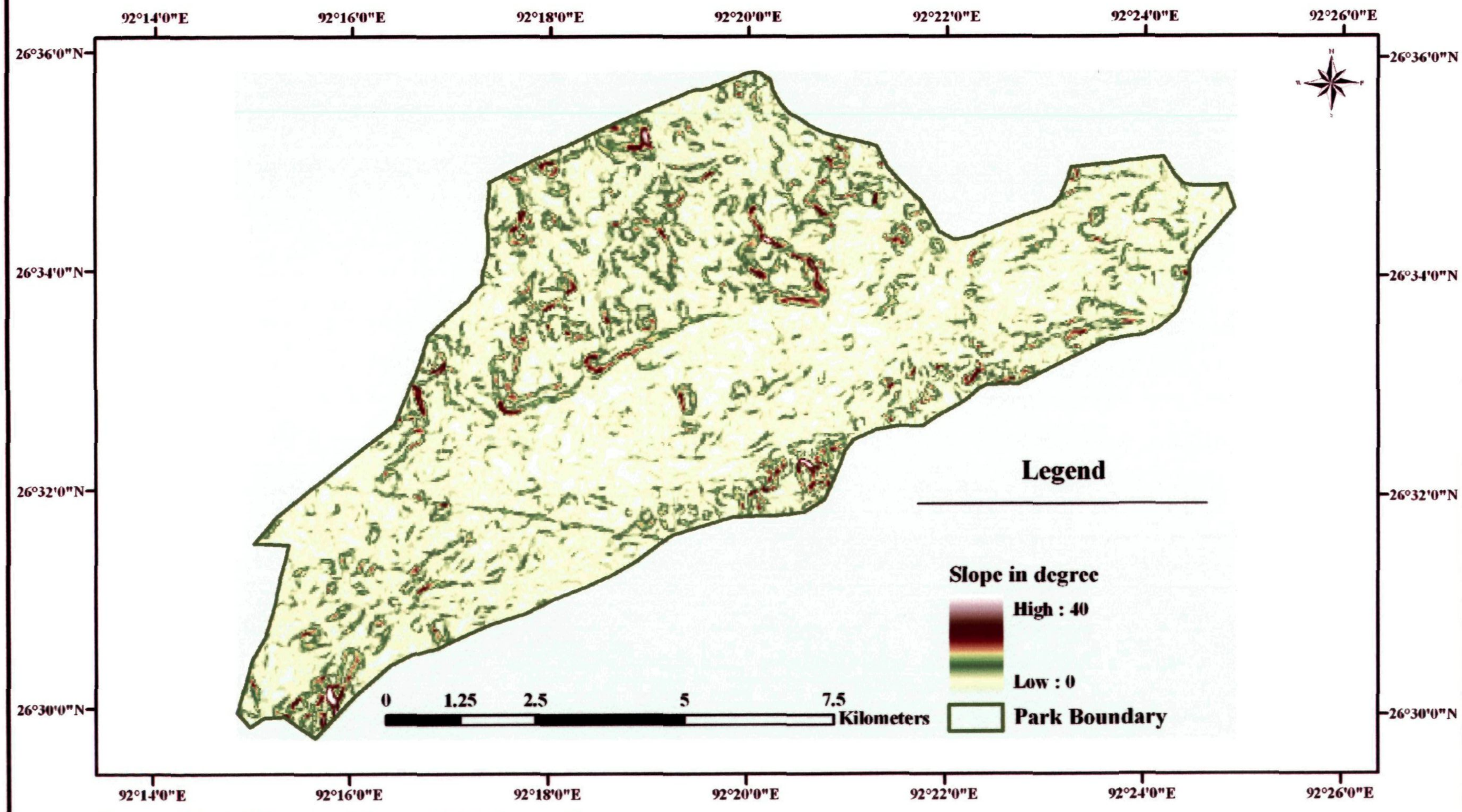


Source: Contour Map of RG Orang NP. Map No. - 4

1.6.3 Slope:

Slope can be defined as the degree of deviation of a surface from the horizontal plane, usually measured in a percent, degrees or numerical ratio. A slope map of Orang NP was prepared using DEM of RG Orang NP. The slope values of RG Orang NP were measured in degrees. It has been observed that the most of the park area of RG Orang NP is of gentle slope. The maximum slope in Orang NP is 40°. Map No. - 5 show the slope pattern of RG Orang NP.

Slope Map of Rajiv Gandhi Orang National Park



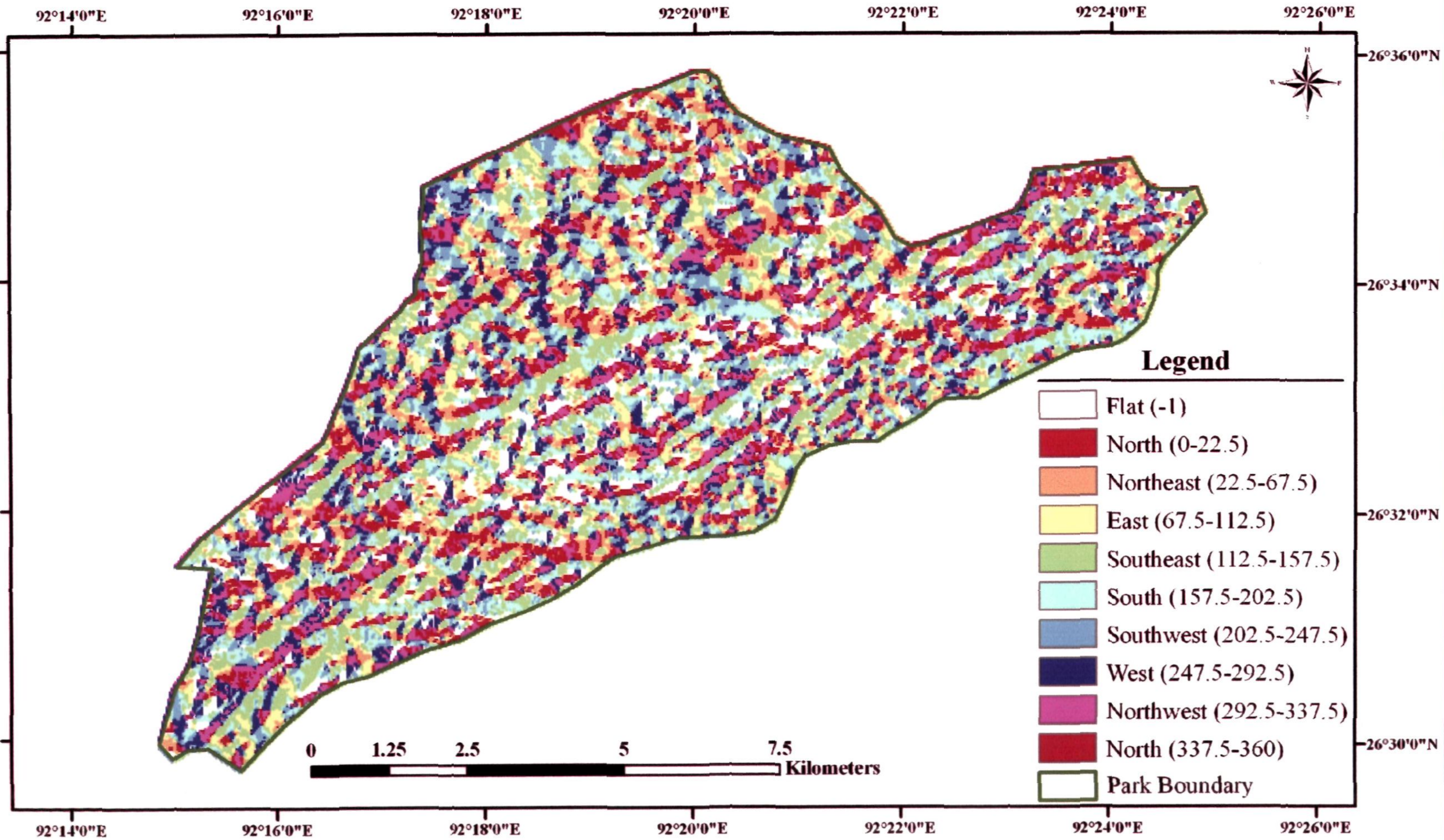
Source: Digital Elevation Model of RG Orang NP

Map No. 5

1.6.4 Aspect:

Aspect generally refers to the azimuth to which a mountain slope faces. An aspect map of RG Orang NP was generated using the DEM. The aspect map shows the azimuth to which the surface slope of the park faces. Map No. - 6 show the aspect pattern of RG Orang NP.

Aspect Map of Rajiv Gandhi Orang National Park



Source: Digital Elevation Model of RG Orang NP

Map No. 6

1.6.5 Climate:

The climate of the RG Orang NP is meso-thermal humid climate of Brahmaputra valley type. On the basis of the seasonal variation of temperature, rainfall and humidity, the climate could be divided into four distinct seasons – Pre-monsoon, Monsoon, Re-treating Monsoon and Winter (Borthakur, 1986).

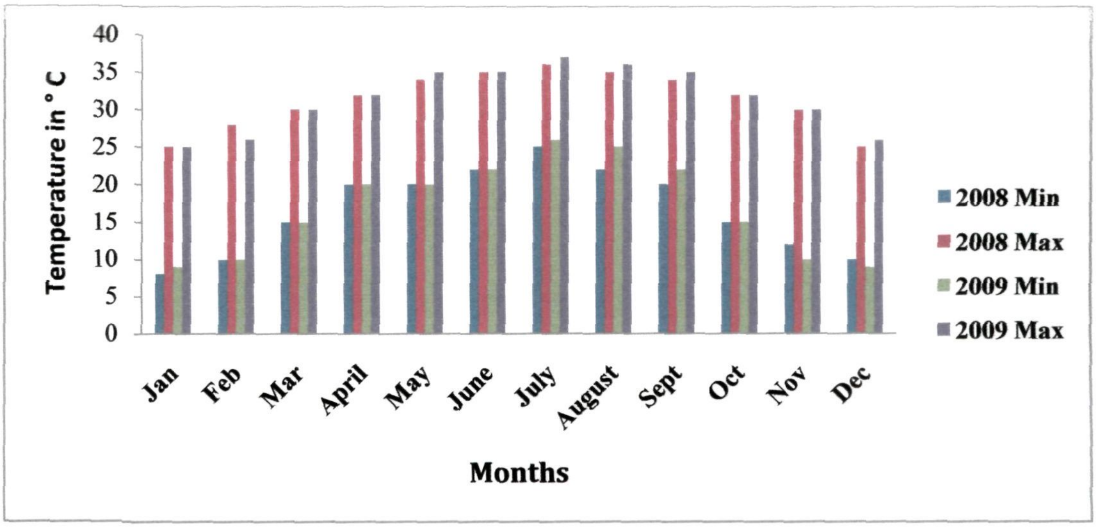
a) **Pre-monsoon (March – May):** It is a transitional period relatively dry winter and hot summer and its characterized by a rapid rise and fall of temperature. The minimum and maximum temperature during this season was ranged between 20° C to 30° C. The average relative humidity was 67% to 85% and the average rainfall was 360 mm during the study period.

b) **Monsoon (June-September):** The monsoon season is the characteristics type of rainy season of the year with an average rainfall of 1200mm. The minimum and maximum temperature ranged between 25° C to 36° C. The average relative humidity was 81% during this season.

c) **Retreating Monsoon (October-November):** In retreating monsoon, the temperature gradually falls and moving mist and fog appears. The minimum and maximum temperature ranged between 20° C to 30° C. Rainfall slightly lowered in this season and attained up to 110 mm and average humidity was 80% during the study period.

d) **Winter (December – February):** The winter season is characterized by cool and foggy weather. Average minimum and maximum temperature ranges between 12° C to 25° C respectively. The average relative humidity ranges between 65% to 75%. The average rainfall was 20mm only during the study period.

The figure I a. shows the maximum and minimum temperature of the study area during the study period from September 2008 to September 2009.



Data source: Kaupati Tea Estate, Kaupati, Dalgaon, Darrang, Assam

Fig. I a. - Maximum and minimum temperature of the study area during the period of 2008-2009

1.6.6 Historical background:

The name "Orang" owes its origin from Assamese word "**OOR**" which means '**the end**' (Saikia, 2005). Historically, it was the end of Eastern boundary (demarcated by river Panchnoi) of king *"ARIMATTA or VAIDYADEVA"*, who reigned after the *PAL DYNASTY* during 12th century A.D. in former Kamrup district, whose capital was 'Rangiya' (Gait, 1967; Choudhury, 1987). According to some local people of the study area, the name 'Orang' came from the ethnic group of "Tea Labour" brought from Orissa by the British Tea planters, whose ancestors are still residing at the outskirts of the RG Orang NP. The entire protected area was a human habitat area till the last decade of 19th century (Talukdar and Sarma, 1995). Prior to declaration of Orang as a "Game Reserve" in 1915, different ethnic groups occupied the entire area. The existence of 26 man-made ponds and the 'Shiva Temple' inside the park are the evidences of the past human settlements within the present study area. The prevalence of water-borne epidemic type of disease forced them to abandon the area prior to 1900 A.D. (Talukdar and Sarma, 1995). As the inhabitants abandoned the villages, the whole area was converted into an excellent habitat for various wildlife species. Two large tributaries of river Brahmaputra, namely Dhansiri and Panchnoi are associated with number of streams and nullah that crisscross the park and became the source of water for the entire habitat.

The RG Orang NP is the last refuge of Indian Rhino (*Rhinoceros unicorni*) (Talukdar, *et al.* 2007) in the north bank of river Brahmaputra, Assam, India. The area harbours 64 numbers of Indian rhinos in the year 2009, according to the census conducted by the Department of Forest and Environment, Govt. of Assam, India.

1.6.7 Present scenario as protected area:

The present protected area (Rajiv Gandhi Orang National Park) was first declared as a 'Game Reserve' covering an area of 80.54 km^2 in the year 1915, and was a part of Mazbat Forest Range under Darrang Forest Division, Assam. In the year 1931, an area of 17.29 km^2 had been de-reserved from the northern boundary of the Reserve to settle some immigrants from Mymensingh district of East Pakisthan (now Bangladesh) under the scheme of 'Grow more food'. From the year onward (i.e. from 1931), the Bor's working plan (Taungya system) was started (Saikia, 2005). As per the norms of the system, an area was allotted to each family for plantation purpose in exchange of fodder and grazing facilities for their cattle. Subsequently, softwood tree plantations were started from 1942-52 and 1952-62 respectively. This process continued till 1962 through Afforestation Division of Hojai (Nagaon, Assam). During 1972, the planted area was handed over to Wildlife wing of the State Forest Department and ultimately, the area was included as an 'Auxiliary area' of the Project Tiger. During 1985, the Game Reserve was upgraded to a state of Wildlife Sanctuary covering an area of 75.60 km^2. During the year 1991, an area of 3.21 km^2 was added to it by evicting encroachment from government land and ultimately, total area became 78.81 km^2. Finally, the sanctuary was upgraded to a National Park in 1999.

1.6.8 Major flora of RG Orang NP

According to Champion and Seth (1968) the habitat of RG Orang NP is composed of mainly Eastern Himalayan Moist Deciduous forest (3C/C3b), Eastern Seasonal Swamp forest (4D/SS1), Khair-Sisoo Forest (5/1S2), Eastern Wet Alluvial Grassland (4D/2S2) and Plantations. The principal species which are commonly found in RG Orang NP are *Legerstroemia parviflora, Terminalia belerica, Sterculia villosa, Salmalia malabarica, Semecarpus anacardium, Schima wallichi, Zizyphus mauritiana* etc. Among the grasses *Phragmites karka, Saccharum procerum, Saccharum spontaneum, Imperata cylindrica,* etc.

1.6.9 Major fauna of RG Orang NP

The Greater One-Horned Rhino *(Rhinoceros unicornies)* is the flagship species of the RG Orang NP. The other fauna sharing the habitat are Royal Bengal Tiger (*Penthera tigris),* Asiatic Elephant (*Elephas maximus)*, Hog Deer (*Axis porcinus),* Wild Pig (*Sus scrofa)* etc. The park also witnesses a diverse range of avifaunal diversity. It is also an important habitat of Bengal Florican (*Houbarospsis bengalensis)*, which is a highly endangered bird species in the world. Among the reptiles, *Genus Python, Kachuga tecta, Ophiophagus Hannah, Lissemys punctata* are the common varieties. In case of amphibian three new species of anuran amphibians have been found and one rediscovery after a gap of nearly ninety years in the park (Ahmed, 2002).

1.7 Research question:

The research questions that were taken to understand the land cover change dynamics; habitat utilization and suitability analysis for rhino in RG Orang NP were as follows:

a) Is changing land use/land cover pattern of the park threatening rhino habitat and suitability?

b) Has rhino been able to adopt all types of grasslands in all over the park area?

c) Is RG Orang NP is being conserved and managed for Rhino habitation?

d) How are remote sensing, GIS and GPS technology been used to identify the rhino habitat and suitability locations?

1.8 Literature Review:

1.8.1 Land Cover change dynamics:

The study related to land cover change dynamics like forest cover change, assessment of deforestation, wildlife habitat evaluation and change detection has important issue for all environmental and biodiversity conservation activities in different parts of the world, since the 19th century. As early as 1864, George Perkins Marsh, in his book *Man and Nature*, documented his observation of landscape changes resulting from human and natural activities. Richards (1990) estimated that more forests were cleared between 1950 and 1980 than in the early 18th and 19th centuries combined. Such accelerated changes have been accompanied by local and global environmental problems, and various writers such as John Muir, Henry David Thoreau, Rachel Carson, Aldo Leopold and Paul Ehrlich have contributed to the rise of consciousness about environmental issues caused by land use and land cover change at global level. In 1956, the book *Man's Role in Changing the Face of the Earth* (Thomas Jr. 1956), the outcome of an international conference, documented major changes of the planet's landscapes. More recently, books such as *The Earth as Transformed by Human Action* (Brookfield *et al.* 1990), various report of the World Resources Institute (e.g., *People and Ecosystem: The Fraying Web of Life*, http://pubs.wri.org/pubs_pdf.cfm?PubID=3027), the United Nations Environment Program (e.g., One Planet, Many People: Atlas of our Changing Environment, http:// www.na.unep.net/OnePlanetManyPeople/index.php; Global Environmental

Outlooks 3, http:// www.unep.org/geo/geo3/) , the World Watch Institute (e.g., State of the World 1996; Brown *et al.* 1996) and the Millennium Ecosystem Assessment (*Ecosystem and Human Well-being Millennium Ecosystem Assessment 2005*) have lent further credence to the notion that one of the most obvious global changes in the last three centuries has been the direct human modification and conversion of land cover.

A recent study by the World Conservation Service estimated that the "human footprint" covers 83% of the global land surface (Sanderson *et al.* 2002). However, the presence of human does not necessarily imply that landscapes are degraded, and that the ecosystem services they offer are diminished. Indeed, another study more optimistically estimated that roughly half of the world's land surface is still covered by "wildness" areas (Mittermeier *et al.* 2003). In an another study by Millennium Ecosystem Assessment 2003 , it was said that one need to move beyond subjective terms such as "wilderness" and "human footprints", and evaluate the trade-offs between ecosystem goods and services extracted by humans through their land-use practices, and any resulting ecosystem degradation. Same kind of study and recommendation was also made by DeFries, *et al.* (2004).

Extensive research on land cover change analysis in tropical Asia is available for the period 1880-1980. Flint and Richards (1991) studies the land cover change analysis of an area of 8 million km^2 and 13 countries (India, Sri Lanka, Bangladesh, Myanmar, Brunei, Singapore, Indonesia and Philippines).

They estimated that in these countries forest/woodland and wetlands declined over the hundred years period by 131 million hectors (47%). They also estimated that during the same time cultivated area increased by 106 million hectors, nearly double that of 1880. Flint and Richards (1990) estimated a forest loss of 40% over India during 1880 to 1980. They also recognized the important driven factors of this deforestation. They have identified that during that period there is an increase of 42 million hectors (40%) of agricultural land or cultivation land in India.

Brookfield et al. 1990 studied the land cover change in Malaysia. He had estimated that the forest cover of Malaysia was reduced around 73% in the yearly 1950s to 51% in 1982. Malingreau *et al.* (1985) studied the forest cover change in Indonesia for the period of 1982-83 and 1997-98. They mainly studied the impact of El Nino over the forest cover of Indonesia.

Numerous studies have described historical changes of land cover pattern in North America. U.S. Department of Agriculture (1998) studies the agricultural change in North America. They studied the agricultural pattern of North America from 1898 to 1914 and from 1930 to 1950. They also make comparative study of land use / land cover change of North America before and after of World War I and II. Helfman 1962; Menzies 1973; Schlebecker 1973; 1975; Yates 1981, Richards 1990, Sisk 1998 studied the land cover change dynamics and its impact on environment in North America. They also studied the changes of agricultural practices in North America before and after 1930's prolonged drought in the southern great plain of North America.

Kimble (1962) studied the land cover change in Sub-Saharan Africa. He stated that before 19th century, land in Sub-Saharan Africa was used largely for hunting, gathering, herding and shifting cultivation. The Food and Agriculture Organization of United Nations (FAO, 2004) also made one study on land cover change in Sub-Saharan Africa and estimated that cropland area in Sub-Saharan Africa had increased from 119 million hectors in 1961 to 163 million hectors in 2000.

With the recognition that land use/ land cover change is an important driver of global environment change, numerous studies in the last two decades have estimated the rates of tropical deforestation and other kinds of land cover change around the world. FAO in 2001 using remote sensing technique made the global forest resource assessment and estimated that a net decrease in forest area of 9.4 million hectors from 1990 to 2000. They identified that during that period most of the deforestation occurred in the tropics, while most of the natural forest re-growth occurred in Western Europe and eastern North America. The total net forest change was positive for temperate region and negative for tropical region. Achard *et al.* (2002) estimated deforestation rates for the humid tropics and DeFries *et al.* (2002) estimated the deforestation rates for the entire tropics using satellite imagery.

At a global scale, land use changes are cumulatively transforming land cover at an accelerating pace. These changes in terrestrial ecosystem are closely linked with the issue of the sustainability of socio-economic development since they affect essential parts of our natural capital such as climate, soil, vegetation, water resources and biodiversity. Today there is increased recognition that land use change is a major driver of global change, through its interaction with climate, ecosystem process, biogeochemical cycles, biodiversity and even importantly human activities (Nagaraja *et al.* 2003). To understand these issues an international project i.e. Land Use Cover Change (LUCC) – a join initiative of IGBP and IHDP has been working since 1995 to address important global change questions on the local, regional and global scale.

Over the years, environmental historians and historical ecologists have reconstructed fairly accurate depictions of landscape changes around the world; however, these local studies did not comprehensively cover the entire globe and could not be pieced together to get a global synoptic view. With the advent of remote sensing and computer based geographic information system, it became possible to obtain a consistent, global picture of the world's landscapes (Lambin *et al.* 2003). However, global remotely-sensed data are only available for four decades into the past. In the last four decades, the advent of remote sensing satellites with different spatial, spectral, temporal and radiometric resolution has led to the development of instruments to systematically monitor land cover from space.

Turner *et al.* 2003 studied the land cover change dynamics and assess the species richness of South East Asian countries using multi temporal satellite imagery. They used MODIS, TM, ETM and IKONOS imageries to assess the land cover change in South East Asian countries.

Kaya *et al.* (1998) had estimated the forest damage assessment in Istanbul of Turkey using multi temporal satellite imagery. They had used Landsat TM to assess the forest cover change in Istanbul. Their result shows that there was a decline of 31.83 km^2 area in forest cover from 1984 to 1997. Enkhtuvshi *et al.* (1994) did the forest cover change analysis for Mongolia using multi temporal satellite imagery. They had used satellite imagery of SPOT-XS of 1986 and SPOT-PAN of 1989 and Landsat TM of 1988 to assess the forest cover change in Mongolia.

In India remote sensing and GIS techniques are extensively used to assess and estimate the land cover change in the last four decades. Numerous researches on forest cover change and land use / land cover change have been carried out in India using multi temporal satellite imagery. Using Landsat MSS data of 1972-75 and 1980-82 periods, National Remote Sensing Agency (NRSA), now National Remote Sensing Centre (NRSC) carried out vegetation mapping on 1:1 million scale for the entire country, which showed a substantial decrease in forest cover. A similar study was conducted by Forest Survey of India (FSI), Ministry of Environment and Forest (MOEF) for the year 1981-82 which was published in the year 1987. Since 1987, the forest cover of the country is being assessed biennially by Forest Survey of India (FSI) using remotely senses data (Gautam, *et al.* 2003). Lele *et al.* (2008) analyzed the deforestation rate, spatial forest cover changes and identification of critical areas for forest cover changes in North East India. They had extensively used remote sensing data to understand the forest cover change in North East Indian states from 1972 to 1999.

Srivastava *et al.* (2002) did the assessment of large-scale deforestation in Sonitpur district of Assam using satellite imagery of Landsat TM of 1994, 1999 and IRS 1C LISS III of 2001. They estimated that 66.55 km^2 area was deforested in Sonipur district of Assam from 1994 to 2001. Kushwaha *et al.* (2000) studied the landmass dynamics and habitat suitability analysis of Kaziranga National Park of Assam using multi temporal satellite imagery. Kushwaha *et al.* (2004) made an assessment of elephant habitat loss in Kameng and Sonitpur Elephant Reserve of Arunachal Pradesh and Assam using satellite imagery of 1994, 1999 and 2004. Here they discussed the massive deforestation in Sonitpur district of Assam due to encroachment inside the elephant reserve areas of both the states of Arunachal Pradesh and Assam.

Sarma *et al.* (2008) did the land use / land cover change and its future implication analysis in Manas National Park of Assam using satellite imagery of Landsat TM and IRS 1D LISS III. They have identified massive changes of land cover pattern in Manas National Park. Sarma *et al.* (2008) also did the study on land use / land cover change in Golaghat district of Assam using multi-temporal satellite imagery. They have used Landsat MSS, Landsat TM and IRS 1D LISS

III images to assess the forest cover changes in elephant habitat in Golaghat district of Assam. Sarma *et al.* (2008) also did land cover change analysis of Barnadi Wildlife Sanctuary of Assam using multi temporal satellite imageries. Again Sarma *et al.* (2010) analyzed the land cover change dynamics of Pabitora Wildlife Sanctuary, one of the major rhino bearing areas of Assam using Landsat MSS, Landsat TM and IRS P6 LISS III satellite imagery. Here he identified a massive land cover change in rhino habitat of Pabitora Wildlife Sanctuary.

Hazarika *et al.* (2009) made a study on land cover change dynamics of Kaziranga National Park using remotely sensed data. In this study, they used multiple satellite imageries with different spatial and spectral resolution. They had use Landsat TM, IRS 1D/1C LISS III, Landsat ETM, and ASTER imagery for analysis of land cover change dynamics in Kaziranga National Park of Assam, India. Chakraborty (2009) did a study on forest cover change detection in Barak valley of Assam using remote sensing data. She had used MODIS, IRS WiFS, IRS 1D LISS III and IRS P6 LISS IV imagery for change dynamics analysis in forest cover of Barak valley of North East India.

1.8.2 Habitat utilization patter:

The information regarding the habitat utilization pattern of Indian rhino is very limited. The lone study on this aspect was carried out by Hazarika (2007) in RG Orang NP. Bhattacharya (1982, 1992) describes about the home range and daily movement pattern of Indian rhino at Jaldapara Wildlife Sanctuary, Gorumara National Park and Orang NP of West Bengal and Assam. Choudhury (1966), Brahmachary (1969), Dinerstein and Wemmer (1988) and Dinerstein (1991) studied the food habits and seed dispersal pattern of the Indian rhino in India and Nepal. Bairagee (2004) describes the food preferences of Indian rhino in the grassland habitat of Pabirota Wildlife Sanctuary of Assam. The diet and habitat use by the Indian rhino during dry season was studied by Fjellstad and Steinheim (1996) in Royal Bardia National Park of Nepal. Dinerstein and Price (1991) studied the demographic and habitat use pattern of the Indian rhino in terai grassland habitat. Kushwaha *et al.* (2000) studied the landmass dynamics and habitat suitability analysis for Indian rhino in Kaziranga National Park of Assam. A brief description on the behaviour and habitat utilization pattern of Indian rhino was described by Gee (1953a & b). Mary *et al.* (1998) studied the feeding and territorial bahaviour of Indian rhino in Kaziranga National Park of Assam.

Although, several researchers have studied the Indian rhino in different aspect, the detailed information regarding its seasonal variation of habitat utilization pattern, behaviors and ecology is very scanty. One of the remarkable studies on the ecology, behaviour and habitat utilization pattern of rhino was conducted by Laurie (1978, 82) in Nepal. But such study is still lagging behind in Assam though it has the world's highest population of Greater One-horned Rhino. Laurie covered all the aspects of ecology and behaviour such as population dynamics, diurnal time budgeting, food and feeding, reproductive and social behaviour of the Greater one-horned rhino in Chitwan National Park of Nepal.

Similar kind of study was also conducted by Ghosh (1991) at Jaldapara Wildlife Sanctuary of West Bengal in his doctoral research. Jnawali (1995) studied the population ecology, dietary composition, variation of home ranges of male and female rhino in Royal Bardia National Park of Nepal and compared the food plants with the Chitwan National Park for his doctoral research. All those studies in Nepal were done at Terai grassland habitat. However, no such in-depth studies on rhino and its habitat utilization pattern were done in Brahmaputra flood plain habitat. Bhattacharyya (1991), in his doctoral research emphasized only biological aspect, but provided very little information on seasonal variation of habitat utilization pattern of rhino in Kaziranga National Park. Bhattacharyya (1983) in his dissertation suggested a brief description on rhino habitat pattern of RG Orang NP. Patar (1977) in his M.Sc dissertation discussed on food habit of rhino in Kaziranga National Park. Banerjee (2001) in her M.Sc dissertation works on chemical composition of the selected food plant species of rhino in Kaziranga National Park. Deka (2003) has evaluated the nutritional contents of prime forage items of the rhino in Pabitora Wildlife Sanctury and Assam State Zoo cum Botanical Garden.

1.8.3 Habitat suitability modeling:

Many studies to date have used remote sensing and GIS for wildlife habitat analysis and their suitability evaluation. Since the early 1980s, remote sensing has been used to localize the distribution of areas suitable for wildlife.

Cannon *et al.* (1982) used Landsat MSS to map areas suitable for lesser prairie chicken. Wiersema (1983) mapped snow cover using Landsat MSS to identify snow free south facing slopes forming the winter habitat for the alpine ibex. Hodgson *et al.* (1987) used Landsat TM for mapping wetland suitable for wood stork foraging. Congalton *et al.* (1993) used Landsat TM based vegetation map to classify the suitability of land for deer. Rappole *et al.* (1994) used Landsat TM to assess habitat availability for wood thrush. More recently (Seoane *et al.* 2006) did habitat assessment and suitability analysis of Dupont's lark (*Chersophilus duponti*), Doko (2007) tried to modeling of species geographic distribution for assessing present needs for the ecological networks for Fuji region and Tanzawa region of Japan. Kayijamahe (2008) tried to analysis the habitat suitability of mountain gorilla for the Republic of Congo using satellite imagery and GIS. Larson *et al.* (2003) studied the landscape level habitat suitability model for twelve species in Southern Missouri using remote sensing data and GIS. Diemar (2003) tried to analyze the environmental suitability for Asian Elephant in Southern India using remote sensing and GIS. She had identified the suitable habitat for elephant in Mudumalai Wildlife Sanctuary and National Park and also its adjoining southern areas of Karnataka and Kerela. Marcot (2006) prepare habitat suitability model for biodiversity conservation using remote sensing and GIS tools. Syartinilia *et al.* (2008) prepare GIS based habitat suitability model for Javan Hawk-Eagle. Hirzel *et al.* (2002) analyzed the ecological niche factor analysis and he also discussed about how to prepare habitat suitability model in the absence of data. Park *et al.* (2003) used GIS and remote sensing extensively to prepare the habitat suitability model for wild bore in the Mt. Baekwoonson of Korea. Nackoney *et al.* (2000) did a study on preparation of habitat suitability model for African forest elephant in the Congo basin. Lui (2001) had prepared a habitat suitability model for Giant Pandas using remote sensing and GIS tools.

In India, many studies were done on habitat evaluation using remote sensing and GIS technologies. Kushwaha *et al.* (2000 and 2002) have used remote sensing and geospatial modeling to evaluate the habitat for one-horned Indian rhino in Kaziranga National Park, Sambar in Kanha National Park and goral and elephant in Rajaji National Park. Raut *et al.* (2000) used IRS-IC LISS III data to study the elephant habitats and corridors in Orissa and part of Bihar. Sarma *et al.* (2002) tried to identify a corridor for elephants of Jarkhand. Kushwaha *et al.* (2004) statistically analysed the habitat use pattern of sambar (*Cervus unicolor*) and muntjak (*Muntiacus muntjack*) by Principal Component Analysis (PCA), Discriminant Function Analysis (DFA) and Binomial Multiple Logistic Regression (BMLR) to evaluate their habitats in Chaubatia Reserve Forest. Hazarika (2003) studied about the habitat analysis of Asian Elephant and their suitability modeling using remote sensing and GIS in Sonitpur district of Assam.

Considering the rhino habitat suitability analysis and evaluation extensive study was carried out in Nepal. Thapa *et al.* (2002) tried to evaluate the rhino habitat and suitability analysis in Royal Bardia National Park using remote sensing and GIS tools. Thapa (2005) in his M.Sc dissertation evaluate the rhino habitat and its suitability analysis in Royal Chitwan National Park using satellite imagery and geo-statistical tools. All these studies on rhino habitat and its suitability were done of Terai landscape habitat.

In case of Brahmaputra flood plain habitat of Assam, very limited study on rhino habitat evaluation and suitability modeling is carried out till date, though it has the proud legacy of having the highest one-horned rhino population in the world. Hazarika (2005) tried to identify the suitable habitat for rhino in Kazirang National Park of Assam using remote sensing and GIS techniques. He also identified the changes in habitat suitability in Kaziranga National Park using multi temporal satellite data. Kushwaha *et al.* (2000) tried to analyze the landmass dynamics and habitat suitability analysis in Kaziranga National Park using remote sensing and GIS tools. He had adopted an area based suitability model to identify the suitable habitat for rhino in Kaziranga National Park.

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CHAPTER – II

Chapter II

Database and Methodology

The objective of this study is to examine the patterns of changes by using Remote Sensing (coupled with ground survey) and GIS to distinguish among different land cover states (Reeves *et al.* 2001; Jakubauskas *et al.* 1998; Lucas *et al.* 1993; Jensen *et al.* 1995; Jensen, 2000) and also to identify the factors, affecting the land cover changes in RG Orang NP. This study is also to evaluate the seasonal variation of rhino habitat utilization pattern and their habitat suitability analysis in the park. The database and methodology used in this research is discussed in this chapter.

2.1 Data Source & Methodology for Land Cover Change Analysis

2.1.1 Data Source:

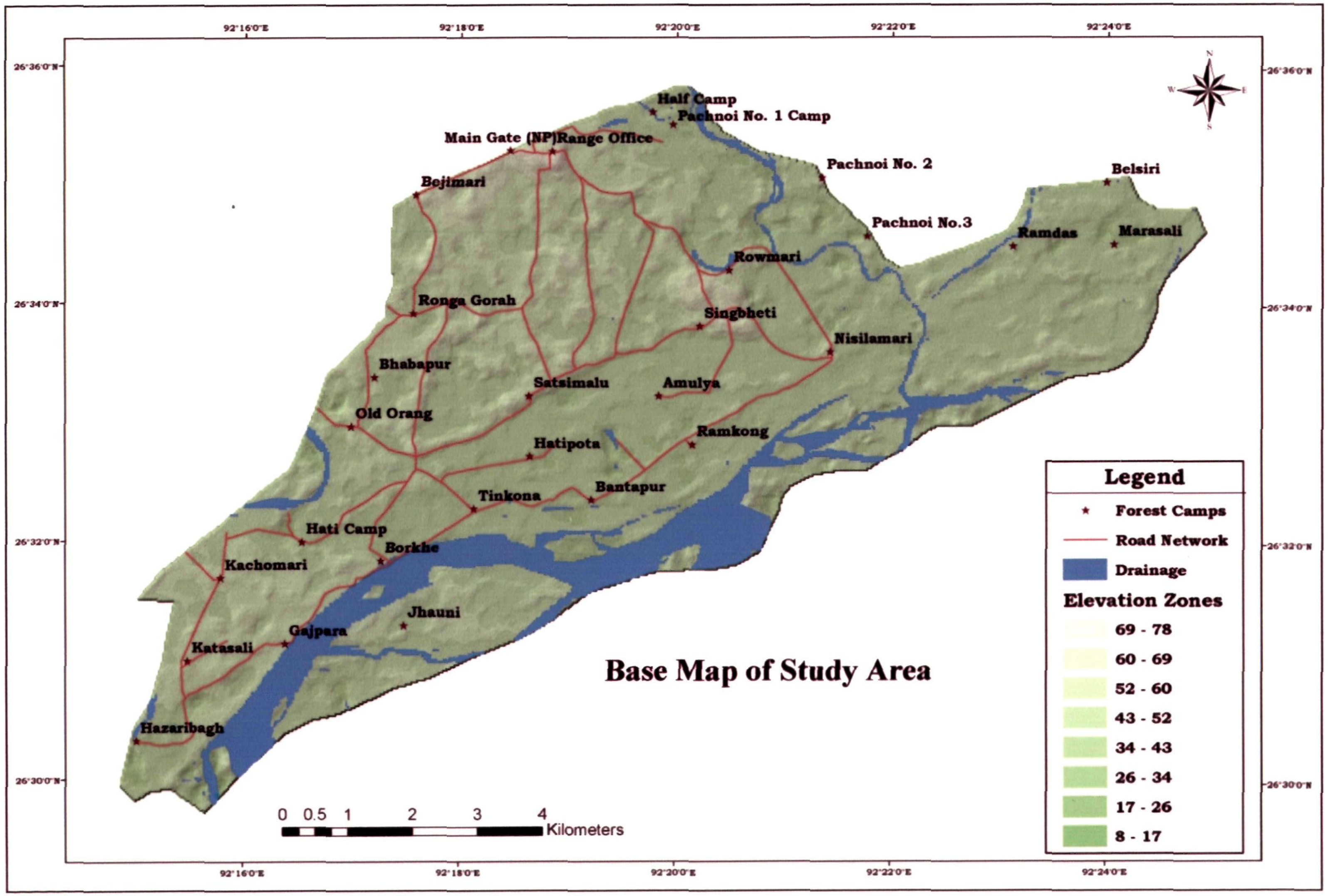
Landscape is the function of structure, process and stage (Davis, 1909, Thornbury, 1990). Landscapes are not static, there are numerous exogenetic and endogenetic forces continuously operating over the landscapes and because of this landscapes are dynamic in nature.

Multi date satellite imageries were used to analyze the land cover change dynamics in RG Orang NP. Besides this, the Survey of India topographical sheet no. 83 B/6 at 1:50,000 scale and maps available with state forest department of Assam were used for delineation of forest boundary and to generate baseline information for the study area. The details of the datasets used in this study are shown in table-II a.

Table II a. - Datasets used

Data Type	Path/ Row	Date of acquisition
Landsat TM	136/42	26th December 1987
Landsat TM	136/42	19 December, 1999
IRS LISS III	110/52	08 November, 2008
Survey of India toposheets	No. 83 B/6 (1:50,000 scale)	1974
Maps of State Forest Department	1:50,000 scale	1985

Source: Researcher

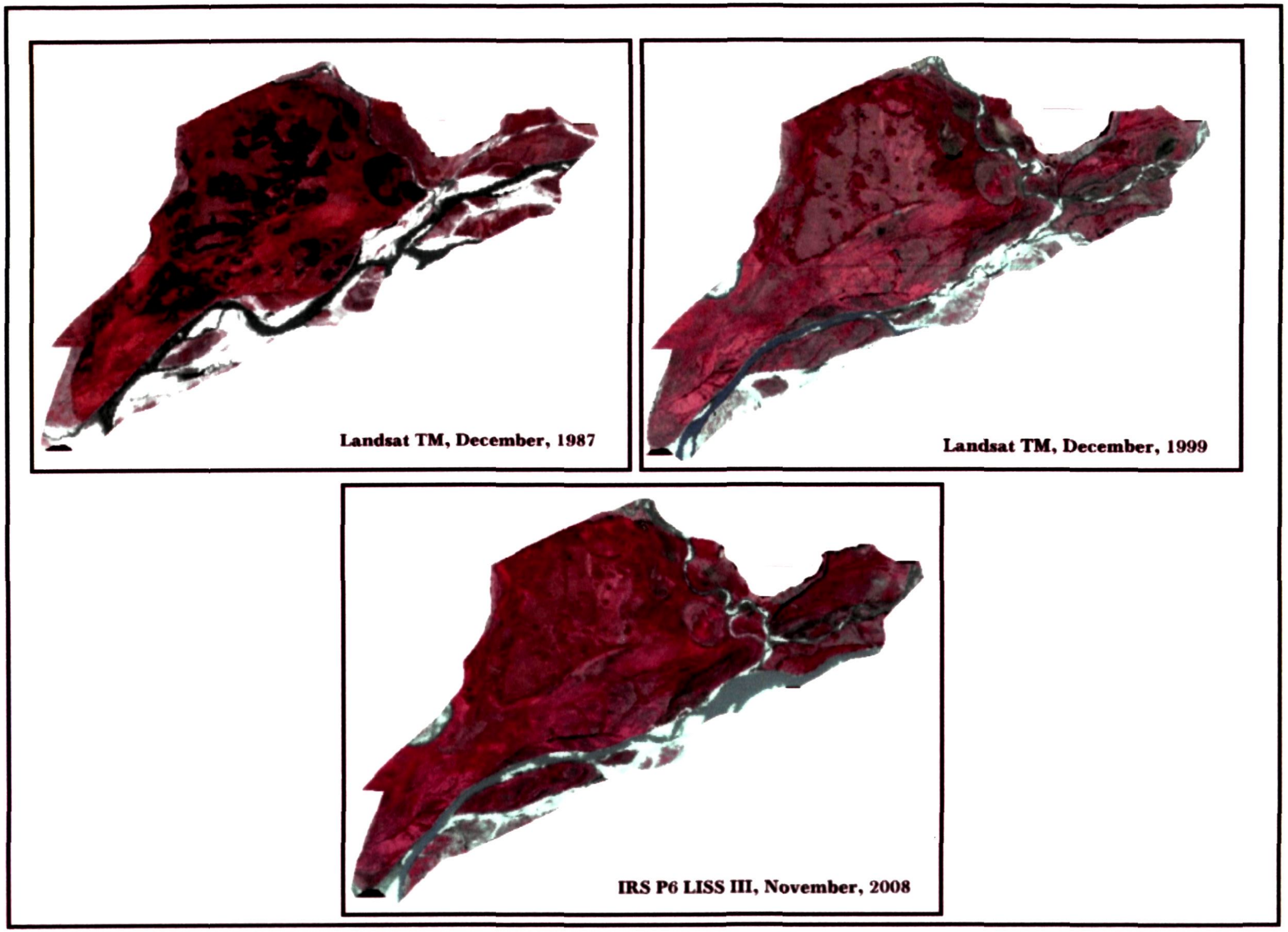


Source: Digital Elevation Model of RG Orang NP.

Map No. - 7

2.1.2 Methodology:

Satellite imageries of Landsat TM of 1987 and 1999 and IRS P6 LISS III of 2008 were used to analyze the land cover change dynamics in the RG Orang NP. The open source Landsat TM of 1987 and 1999 were downloaded from the National Aeronautics and Space Administration's (NASA) Global Land Cover Facilitator's (GLCF) website (www. glcfapp.umiacs.umd.edu) and satellite imagery of 2008 was procured from National Remote Sensing Centre (NRSC), Hyderabad. The imageries were projected to UTM – WGS 84 projection system using Landsat ETM image as reference. Sub-pixel image to image registration accuracy was achieved through repeated attempts. Radiometric corrections of all the images were done using dark pixel subtraction technique (Lillesand, *et al.* 2004). Re-sampling of IRS P6 LISS III imagery was carried out at 30 m. pixel size as the other imageries (Landsat TM 1987 and 1999) were of 30 m. resolution. Subset operation of satellite imageries of 1987, 1999 and 2008 were carried out by creating an area of interest (AOI) layer of the vector layer of forest boundary of RG Orang NP, which was digitized from the published maps of department of forest and environment, Govt. of Assam at 1:50,000 scale.



Source: Global Land Cover Facilitator's & National Remote Sensing Centre.

Map No. - 8

After sub setting, the images of the study area were processed through spectral enhancement technique using ERDAS Imagine 9.2 software. Principal component analysis (PCA) was carried out to all the images. All the images were converted into three principal components. PCA is often used as a method of data compression. It allows redundant data to be compacted into fewer bands—that is, the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen, 1996; Faust, 1989). After generating the hybrid PCA images for all the years a supervised classification technique was used using maximum likelihood algorithm to assess the land cover change dynamics in RG Orang NP from 1987 to 2008. Since supervised classification is a process where the image analyst supervised the pixel categorization process by specifying to the computer algorithm, numerical descriptors of the various land cover types present in a scene (Lillesand, *et al.* 2004). Many researchers have been using supervised classification technique to extract the features from the remotely sensed imagery, as it demonstrates the classification that can incorporate both the spectral and spatial features of the pixels in the image resulting in better defined categories in terms of its homogeneity (Fortain, *et al.*, 1999, Dubeni, *et al.* 2008). Ground truth verification was made using a vegetation survey datasheet (Appendix I a) during the period from September 2008 to September 2009 and based on the ground verification data, classes were assigned in the

PCA based images. Nine land cover types were identified from the field observation and training sets of the land cover classes were gathered using handheld GPS receiver. After classifying all the images of 1987, 1999 and 2008 the post classification comparison method was used to detect the changes of land cover types in RG Orang NP. The method consists of overlaying, cross operation, comparison of two images and classification. The cross operation allows the analyst to know the extent and nature of the changes observed, in other words, the transition between different land cover classes and the corresponding areas of change. Applying this method finally, land cover change analysis of RG Orang NP was done. The output resolutions of all the classified images were at 30 m. resolution. All these image-processing operations were carried out in ERDAS Imagine 9.2 software.

To get the erosion and depositional scenario of RG Orang NP satellite images of 1987, 1999 (Landsat TM) and 2008 (IRS P6 LISS III) were used. Delineation of the river banks for the year 1987, 1999 and 2008 was done using onscreen digitization for respective years using Arc GIS 9.3 software. A union tool was used to all the different river bank layers for the year 1987, 1999 and 2008 in the software to determine the erosion and depositional changes in RG Orang NP. The methodology used for land cover change dynamics analysis is given in the flow chart figure II a.

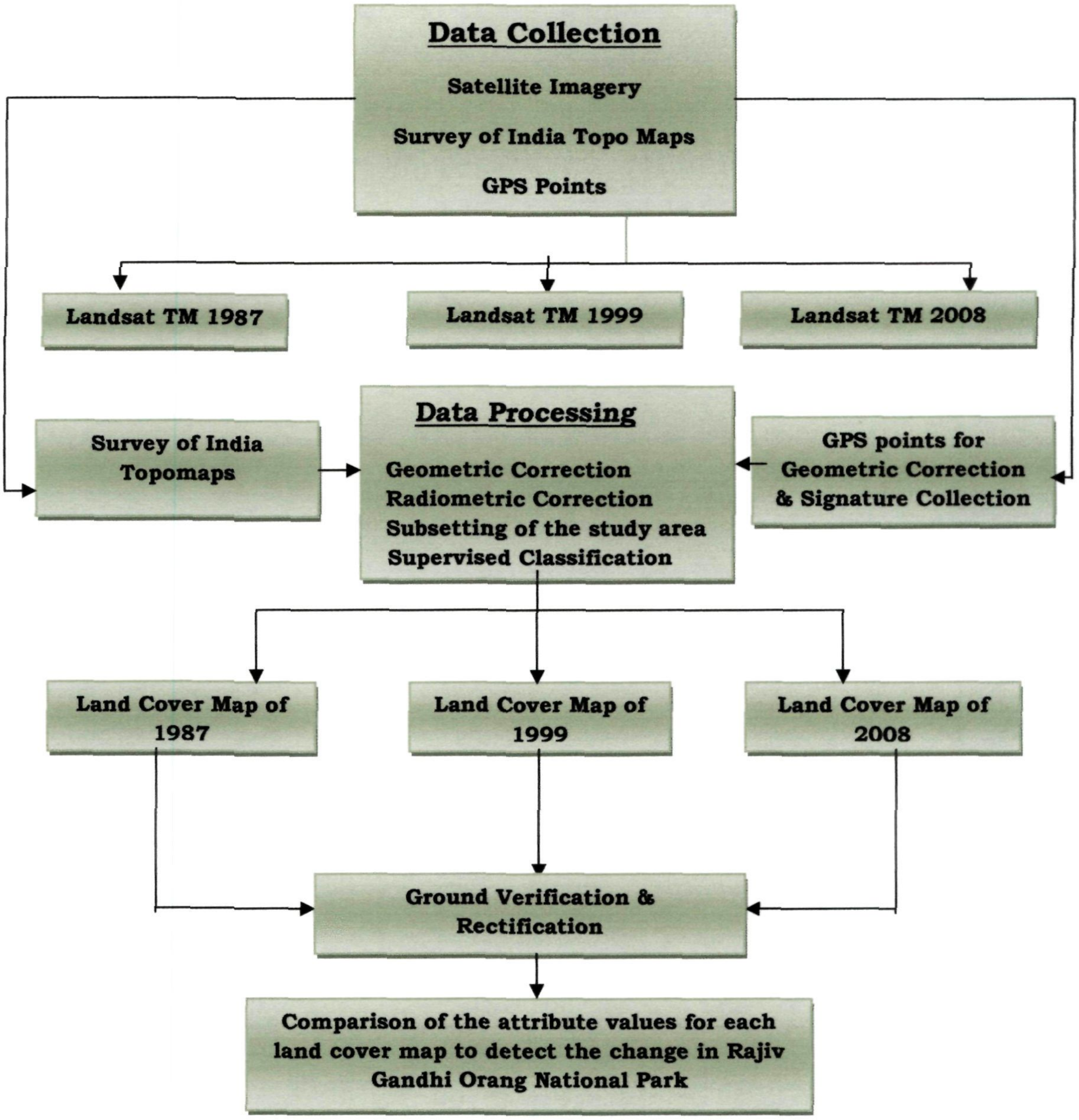
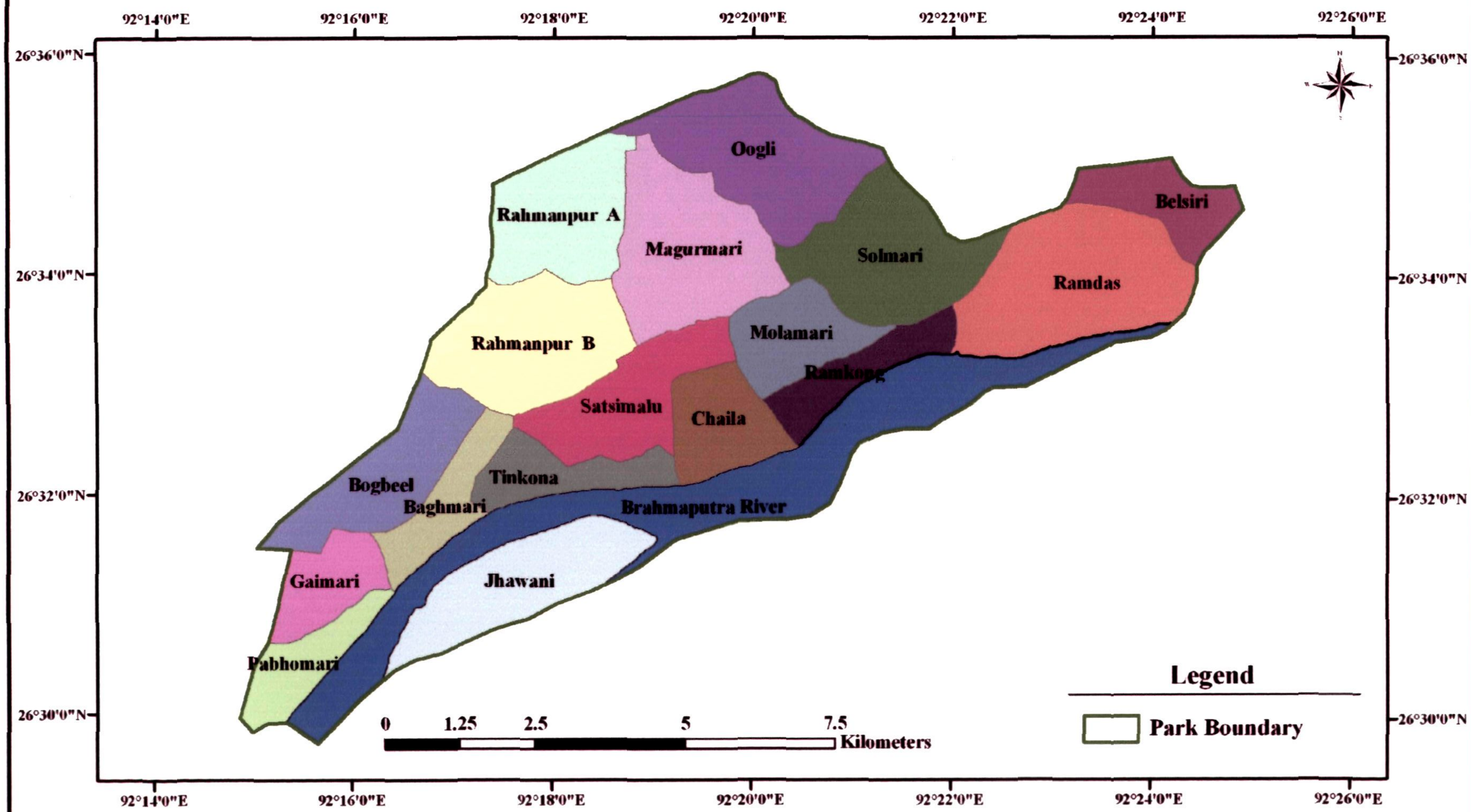


Fig. II a. Flow Chart for land cover change dynamics analysis

2.2 Data Source & Methodology for Habitat Utilization Pattern of Rhino

A direct method of monitoring the movement of the one-horned rhino was used (Laurie, 1978) to find out the seasonal variation of habitat utilization pattern of one-horned rhino in RG Orang NP. The tall grasses and dense woodland of RG Orang NP make observations exercises difficult particularly during monsoon season when much of the study area are flooded. Rhinos were observed on foot, on elephant backs, on field vehicles and from watch towers of RG Orang NP. The visibility of rhinos changes in different seasons depending on the height of the grasses and the frequency of the rhinos wallowed in open swamps. First of all, the entire study area was divided in to certain equisized blocks based on different habitat types, camp locations and availability of other resources like trained elephants (Map No. 9). A continuous ground survey for twelve months, considering five days in each month, was conducted with the help of trained elephants provided by the state forest department, Govt. of Assam. The survey was done in all the seasons of the year 2008-2009 i.e. pre-monsoon (Mar-May), monsoon (June-Sept), retreating monsoon (Oct-Nov) and winter (Dec–Feb) to get the accurate data of habitat utilization pattern of one horned rhino in RG Orang NP. A map was prepared prior to entering the park for collection of primary data, showing the survey blocks and was distributed to all block members to reduce the chance of overlapping of same block during the survey period. Altogether, eighteen blocks were prepared based on habitat pattern, camps location and availability

Blocks of Rajiv Gandhi Orang National Park



Source: RG Orang NP authority

Map No. 9

of other resources like trained elephants. The survey was carried out in each of the blocks at the same Indian Standard Time (IST) i.e. 6:00 AM and was use to complete at the same IST i.e. 10:00 AM to reduce the percentage of error. A data sheet was prepared (Appendix I b) where date of survey, habitat pattern, vegetation species, number of rhino count and number of dung piles count were recorded systematically. Finally, all these block wise primary data were entered into GIS domain to plot the data and get the map of seasonal variation of habitat utilization pattern of one horned rhino in RG Orang NP. The 64 rhinos of RG Orang NP were came in to notice for 183 times throughout the year long survey in RG Orang NP in different habitat types.Chi-square goodness of fit statistical analysis was carried out to understand the significance of habitat utilization pattern of rhino in Orang NP.

2.3 Data Source & Methodology for Habitat Suitability Analysis for Rhino

A wildlife habitat provides the necesssray combination of climate, sub-strate and vegetation that each animal species require. Within a habitat, the functional area that an animal occupies is referred to as its niche. Throughout evolution process, various species of animals adapted to various combinations of physical factors and vegetation.The adaptation of each species suits to a particular habitat and rules out to its use of other places. The number and type of animals that can be supported in a habitat are determnined by the amount and distribution of food, shelter, and water in relation to the mobility of the animal. By determining the food, shelter and water charecteristics of a particular area, general inference can be drawn about the ability of that area to meet the habitat requirement of different willife species (Lillesand, *et.al.* 2004). Habitat suitability modelling is a key way of defining an ideal habitat range of a species with the help of geo-spatial technology (Remote Sensing, GIS and GPS). The model is expected to assist the park managers to adopt adpative management to provide maximum suitable habitats to rhino. A year-long field survey was conducted in RG Orang NP from September 2008 to September 2009 to understand the habitat utilization pattern of rhino in different seasons of a year. GPS locations of the direct evidences like sighting and indirect evidences like dung piles, foot print of rhino was taken and plotted over the boundary layer of the park, which was digitized from the map available with state forest department of Assam. A habitat suitability model for one horned rhino was prepared based upon the field observation of rhino and its habitat relationship. A co-relation regression method was used to understand the relationship between rhino and their habitat. Based upon this extensive observation on rhino and its relations with habitat types, some habitat parameters were identified for rhino like cover type, slope, water availability, location of human settlement, distance from roads and their impacts on rhinoceros. The habitat parameters were discussed elaborately in the chapter VI of this thesis. Based upon all these parameters, a habitat suitability model for rhino was prepared for RG Orang NP using Arc GIS 9.3 software. Spatial analysis tools like, buffer, erase, select, intersect; union, etc were used to prepare the habitat suitability model for rhino in RG Orang NP.

The figure II b. shows the detail methodology of the rhino habitat suitability modeling and rhino habitat utilization pattern in RG Orang NP.

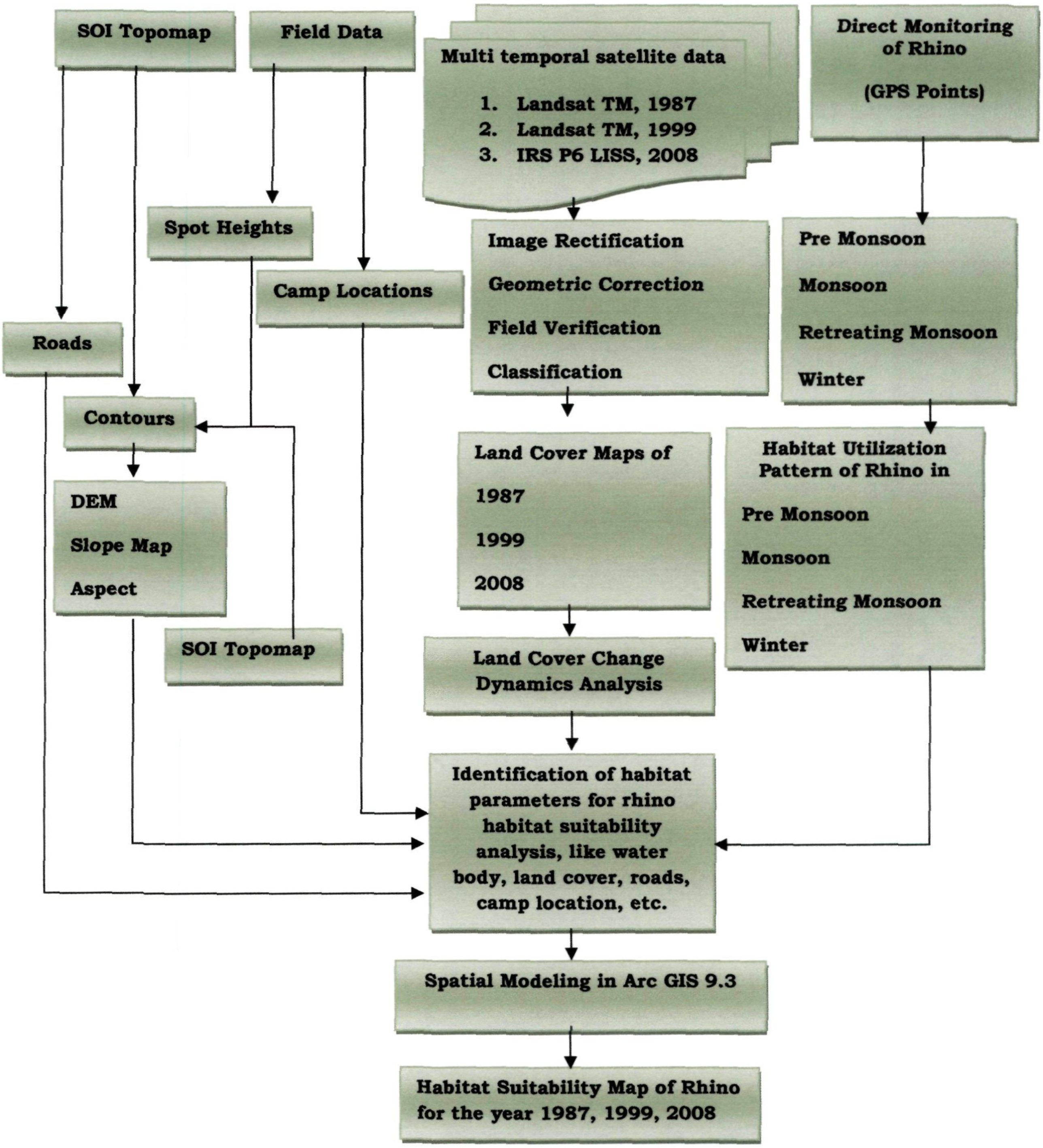


Fig. II. b) - General methodology of the study

2.3 Use of Remote Sensing and GIS Techniques:

Recent developments in the field of remote sensing and GIS have enhanced its application in various studies related to the environment and natural resources both in space and time domain. Remote sensing has an advantage over the conventional method of mapping and data collection because it has unique capability to provide timely, repetitive and synoptic coverage over large areas, over various spatial scales (Thapa 2004). GIS has the capability to integrate multiple sources of spatial and non spatial data into single platform and it has the capability to edit, manipulate and analyze the spatial and non spatial information.

The use of remote sensing and imagery to assess changes in forest cover is of great interest to forest conservationist. Such analyses can be used to estimate deforestation rates and patterns, which can be of value in identifying conservation priorities and potential sites for forest restoration. In addition, analysis of changes in forest cover can be used to infer changes over time in the availability of habitat for forest dwelling species. Typically, satellite imagery is used to evaluate changes in forest cover by producing classified maps that illustrate the distribution of different change classes, such as forest to non-forest, forest unchanged, non-forest to forest and non-forest unchanged (Horning, 2004).

Any assessment of forest cover change must carefully consider the type of change classes that are to be mapped (Newton, 2008). For example, what are the possible land-cover types that might have replaced forest? Is it possible that some land cover types have reverted to forest through a process of succession, and if so, how the succession of vegetation types be classified? *Have natural forest been replaced by plantation forests, and if so, are their* spectral characteristics likely to differ? It is always important to select images that adequately cover the period of interest, and that provide information at an appropriate spatial and spectral resolution to allow the detection of significant changes in forest cover.

During the past two decades, GIS has grown from a specialist technique with only a small number of practitioners to become one of the most important tools in environmental science and management (Newton, 2008). Use of GIS in forest ecology and conservation is now very widespread. Forest managers use GIS to manage and display inventory data, and as a basis for management planning and monitoring. GIS can be defined simply as a tool for the collection, integration, processing, and analysis of spatial data (DeMers 2005). A common feature of GIS is the ability to present data in different layers, which can be overlaid on top of one another. Implementation of GIS requires appropriate software and computer hardware on which to run it. At present numerous open sources and commercial GIS softwares are available in the market with different functionality, which have the capability to integrate and manage spatial and non-spatial information in to GIS domain. GIS also have the capability to do spatial modelling. Spatial modelling is a process of describing real world spatial objects so that these objects as perceived by the user can be represented in a form or notation which the user understand and use (Burrough, *et al.* 1995). The spatial models have different *descriptive models for different levels of complexity of perception of the real* world.

In this research habitat suitability modelling was done for Greater One-horned Rhino (*Rhinoceros unicornis*) using GIS tools to assess the suitability pattern of rhino habitat in RG Orang NP. A habitat suitability model was developed based upon field observation of rhino and their relations with the different environmental parameters like, food, cover, water and disturbance. Different habitat parameters layers like habitat type, water source, road network, human settlements, etc. were generated in GIS environment using multiple data source like ground based survey (GPS points), topographical sheets and satellite imageries. The output of the model was the habitat suitability map for rhino in RG Orang NP with their area coverage information in statistical form.

Remote sensing and GIS tools were extensively used in this research to analyse the land cover change dynamics pattern, seasonal variation of habitat utilization pattern of rhino and also to assess the suitability pattern of rhino habitat in RG Orang NP. A complete GIS based database on rhino habitat of RG Orang NP was also generated through this research which will be useful for further study on rhino and its habitat.

2.4 Organisation of the Manuscript:

The contents of the research work are organised and classified in the following eight major chapters.

The first chapter elucidates the research design and begins with a background of the research which is followed by a short description on Greater One-horned Rhino and its population in different protected areas of the world and also in RG Orang NP. Objective of the research, description of the study area in term of location, aerial extent and various physical aspect like physiography, slope, aspect, etc and assumption and research questions are included in this chapter. An overview of the literature on the topic of research has been discussed in this chapter.

The second chapter discusses about the datasets and methodology used for the research. Database and methodology used for the land cover change dynamics analysis in RG Orang NP is followed by the database and methodology used for the assessment of seasonal variation of habitat utilization pattern of rhino. Finally, database and methodology used for the rhino habitat suitability modelling and assessment has been discussed. A brief discussion on use of remote sensing and GIS in the research has also been discussed in this chapter.

The third chapter deals with the land use / land cover change in RG Orang NP and its impact on the rhino habitat of the park. The current land cover types of RG Orang NP and their spatial dimensions are discussed in this chapter. The historical land cover pattern and their areal extension of RG Orang NP are also discussed in this chapter. Finally, land cover change in RG Orang NP from 1987 to 2008 and the driving factors for the changes are discussed in this chapter. Soil erosion and depositional changes in the park from 1987 to 2008 are also discussed in this chapter. A brief discussion on the impact of land cover change on rhino habitat of RG Orang NP is presented in this chapter.

The seasonal variation of rhino habitat utilization pattern in RG Orang NP is discussed in the fourth chapter of this thesis. The habitat utilization patterns of rhino in pre-monsoon, monsoon, retreating monsoon and winter in RG Orang NP is presented in this chapter.

The fifth chapter deal with the spatial distribution of rhino habitat in RG Orang NP presenting block wise habitat distribution and their area coverage. The 18 blocks of RG Orang NP and their habitat pattern is discussed in detail.

In the sixth chapter the rhino habitat suitability pattern in RG Orang NP is discussed. Habitat suitability modelling for rhino and habitat parameters used for the suitability modelling are illustrated using regression analysis of rhino and its relation with the habitat parameters.

The seventh chapter illustrates the conservation and management of rhino habitat in RG Orang NP focussing some techniques.

Finally the entire research is summarised and concluded in the eighth chapter.

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CHAPTER - III

Chapter III

Land Use/Land Cover change and its impact on Rhino Habitat

3.1 Introduction:

Information on land use / land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban-industrial, environmental studies, economic production, etc.(Chopra *et al.* 1997). Currently, with the growing population pressure, changing human population-land ratio and increasing land degradation, the need for optimum utilization of land assumes much greater relevance. Anthropogenic changes in land use and land cover are being increasingly recognized as critical factor of influencing global change (Nagendra *et al.* 2004). While land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface, while land use is often shaped by human, socio-economic and political influence on the land (Nagendra *et al.* 2003). Change detection of land use/land cover is the process of identifying differences in the state of the object or phenomenon by observing it at different times. Essentially, it includes the ability to quantify changes using multi-temporal data sets. To understand the recent changes in the Earth System, the scientific community needs quantitative, spatially – explicit data on how land cover has change by human use or through natural process over a period of time. Measurements of past rates and spatial patterns of land cover changes can be derived from- a) maps and indirect evidences on past rates and spatial patterns of land cover, for the historical period, b) palaeo record for a more distance past and c) remote sensing based data for the recent past (Nagraja *et al*, 2003). Remote sensing, integrated with Geographic Information System (GIS), provides an effective tool for analysis of land-use and land cover changes at a macro, meso and micro level which could potentially enhance management of critical habitats for wildlife. The geospatial technology that combines the technology of remote sensing and GIS holds the potential for timely and cost effective assessment of natural resources. The techniques have been used extensively in the tropics for generating valuable information on forest cover, vegetation type and land use changes (Forman, 1995).

In this chapter remotely sensed satellite imageries and GIS techniques were used to analyze the present land cover pattern of RG Orang NP. This chapter also analyzed the land cover change dynamics and erosion and depositional scenario in RG Orang NP from 1987 to 2008 using historical and recent satellite imageries.

The entire land cover of RG Orang NP was categorized into nine land cover classes based upon field knowledge and collection of training sets of vegetation types. The nine classes are as follows:

i) Eastern Himalayan Moist Mixed Deciduous Forest (Dense)

ii) Eastern Himalayan Moist Mixed Deciduous Forest (Open)

iii) Dry Savannah Grassland

iv) Wet Alluvial Grassland

v) Seasonal Swamp Forest

vi) Degraded Grassland

vii) Water Body / River

viii) Moist Sandy Area

ix) Dry Sandy Area

3.2 Land Cover Status of RG Orang NP in 2008:

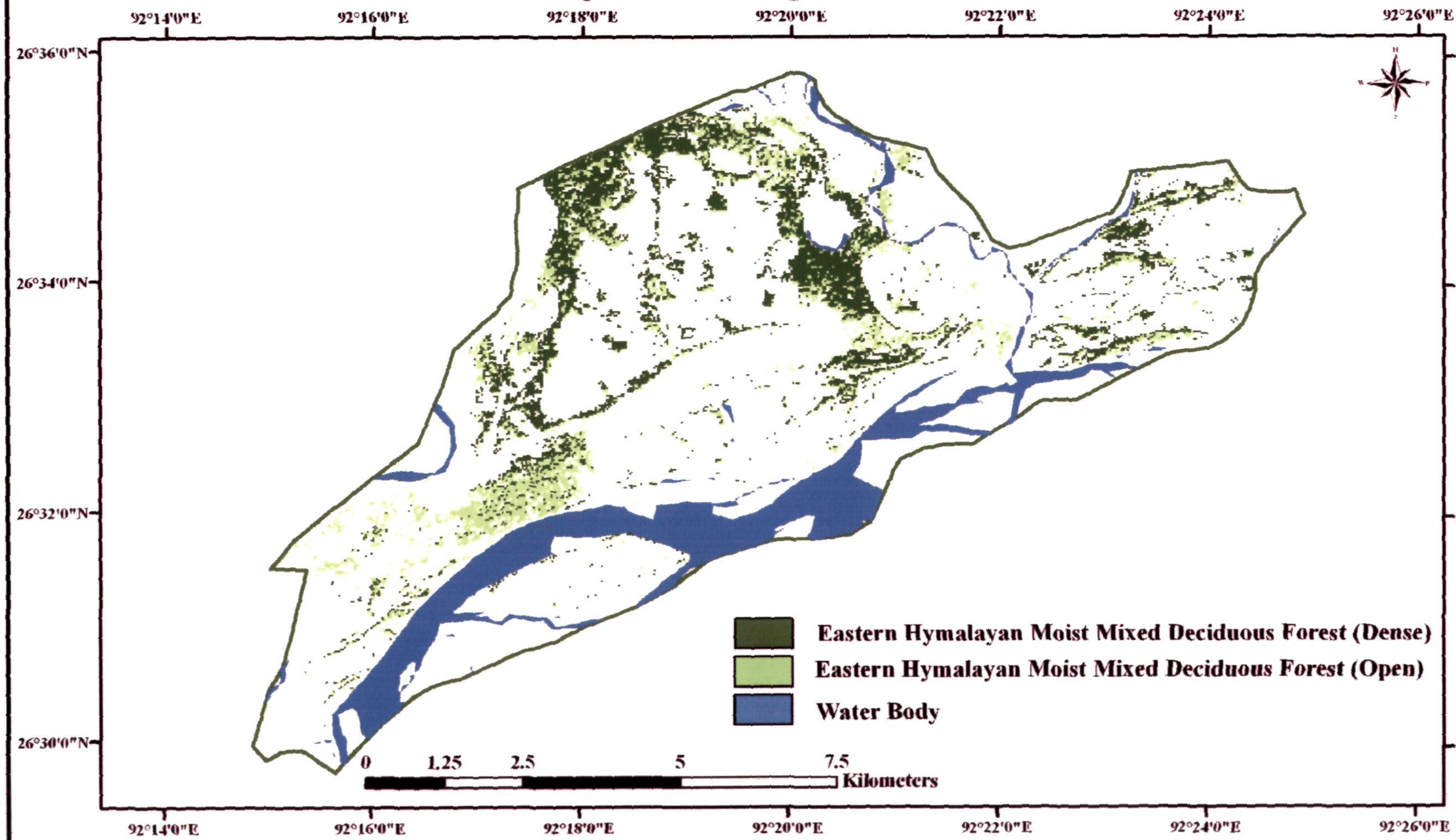
Satellite imagery of IRS P6 LISS III, 8^{th} November, 2008 was used to assess the land cover pattern of RG Orang NP.

The composition and distribution of land cover types of 2008 are as follows:

i) **Eastern Himalayan Moist Mixed Deciduous Forest (Dense and Open):**

This comprises of trees mostly belonging to moist deciduous type represented by *Bombax ceiba, Lagerstroemia flosreginae, Careya arborea, Terminalia bellerica and Gmelina arborea* and their distribution is mainly concentrated in the high altitude areas of the park. Map No. - 10 show the distribution of Eastern Himalayan Moist Mixed Deciduous Forest (Dense and Open) in RG Orang NP. This land cover type covers an area of 20.38 km^2 of RG Orang NP out of 78.8 km^2.

Distribution of Easter Himalayan Moist Mixed Deciduous Forest in Rajiv Gandhi Orang National Park



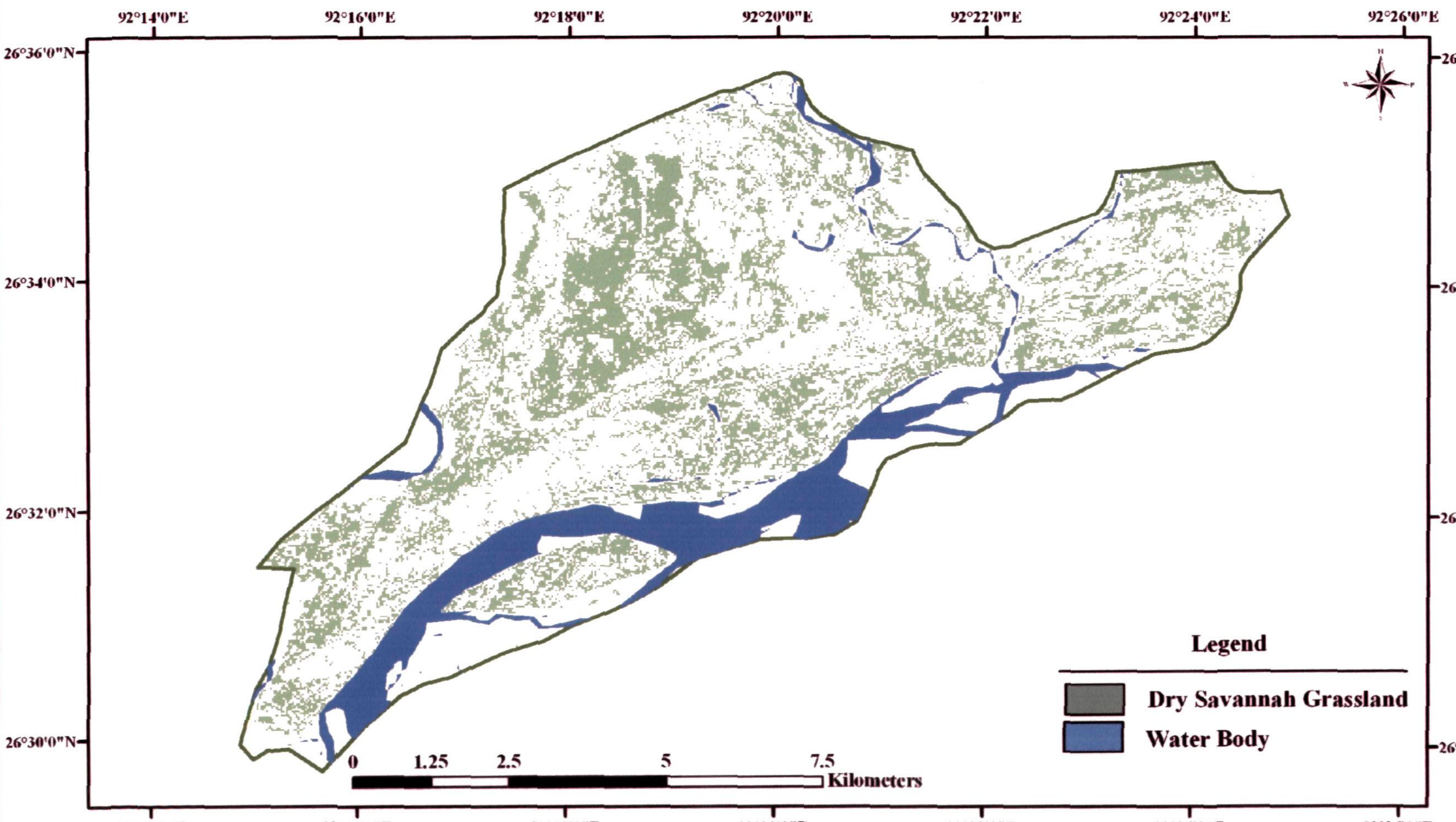
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 10

ii) **Dry Savannah Grassland:**

This type of grassland is dominated by grasses such as *Narenga porphyrocoma, Imperata cylindrica, Phragmites karka, Arundo donax, Saccharum spontaneum, Themeda arundinacea, etc.* This land cover type is mainly concentrated in the transitional zones of high and low lying areas of the park. Map No. - 11 shows the distribution of dry savannah grassland in RG Orang NP. This land cover type covers an area of 14.17 km^2 of the RG Orang NP.

Distribution of Dry Savannah Grassland



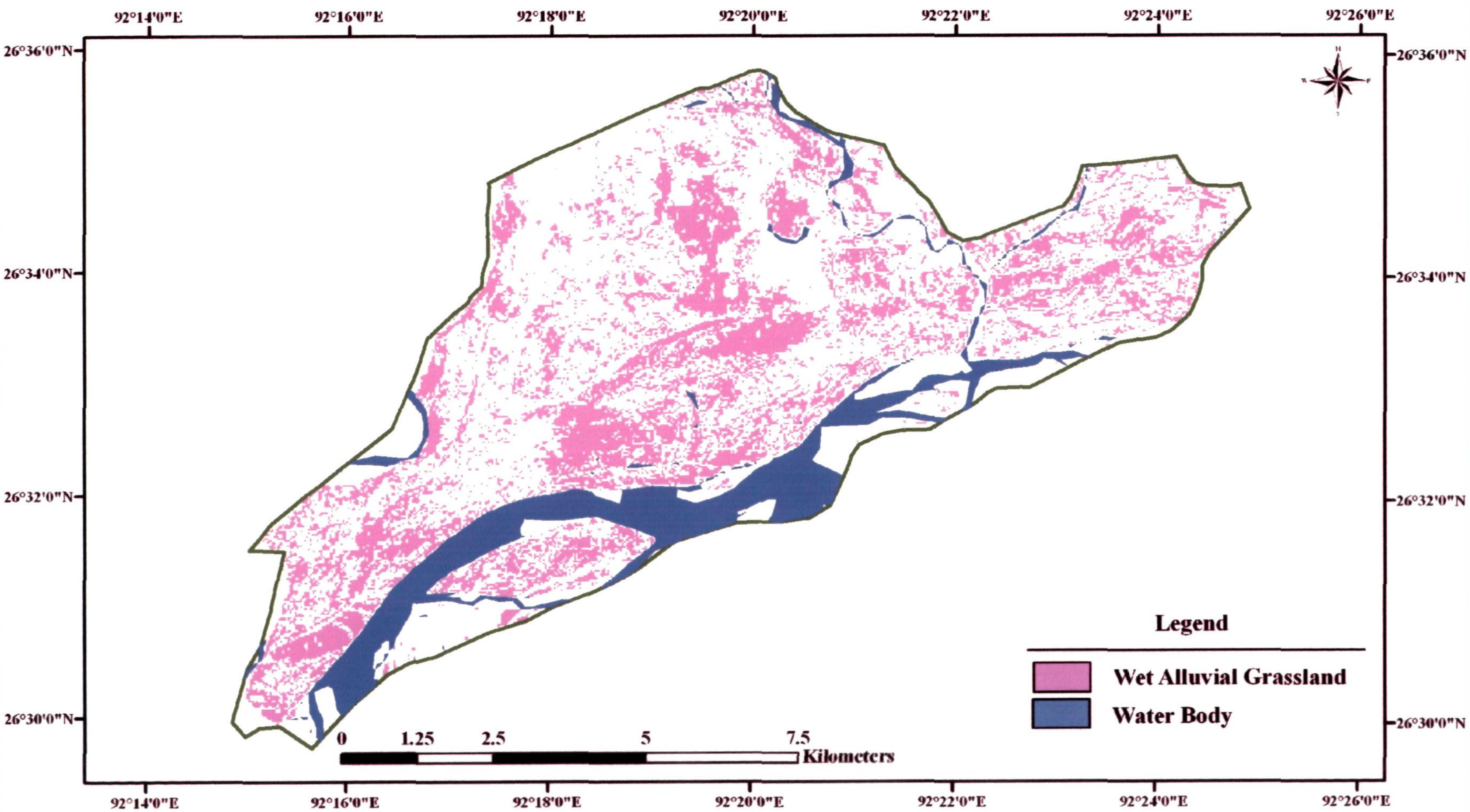
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 11

iii) **Wet Alluvial Grassland:**

The area under this category of land cover is 20.54 km^2. This land cover type is scattered all over the park area. Pure patches of grassland and presence of water characterize it during the rainy season. This wet alluvial grassland plays a critical role in rhinoceros habitat utilization pattern, as rhinoceros prefer to use this habitat throughout the year. This grassland type is mainly composed of *Alpinia allughas, Mikania scandens*, *Saccharum procerum*, *Pharagmites karka* etc. The distribution of wet alluvial grassland in RG Orang NP is shown in Map No. - 12.

Distribution of Wet Alluvial Grassland



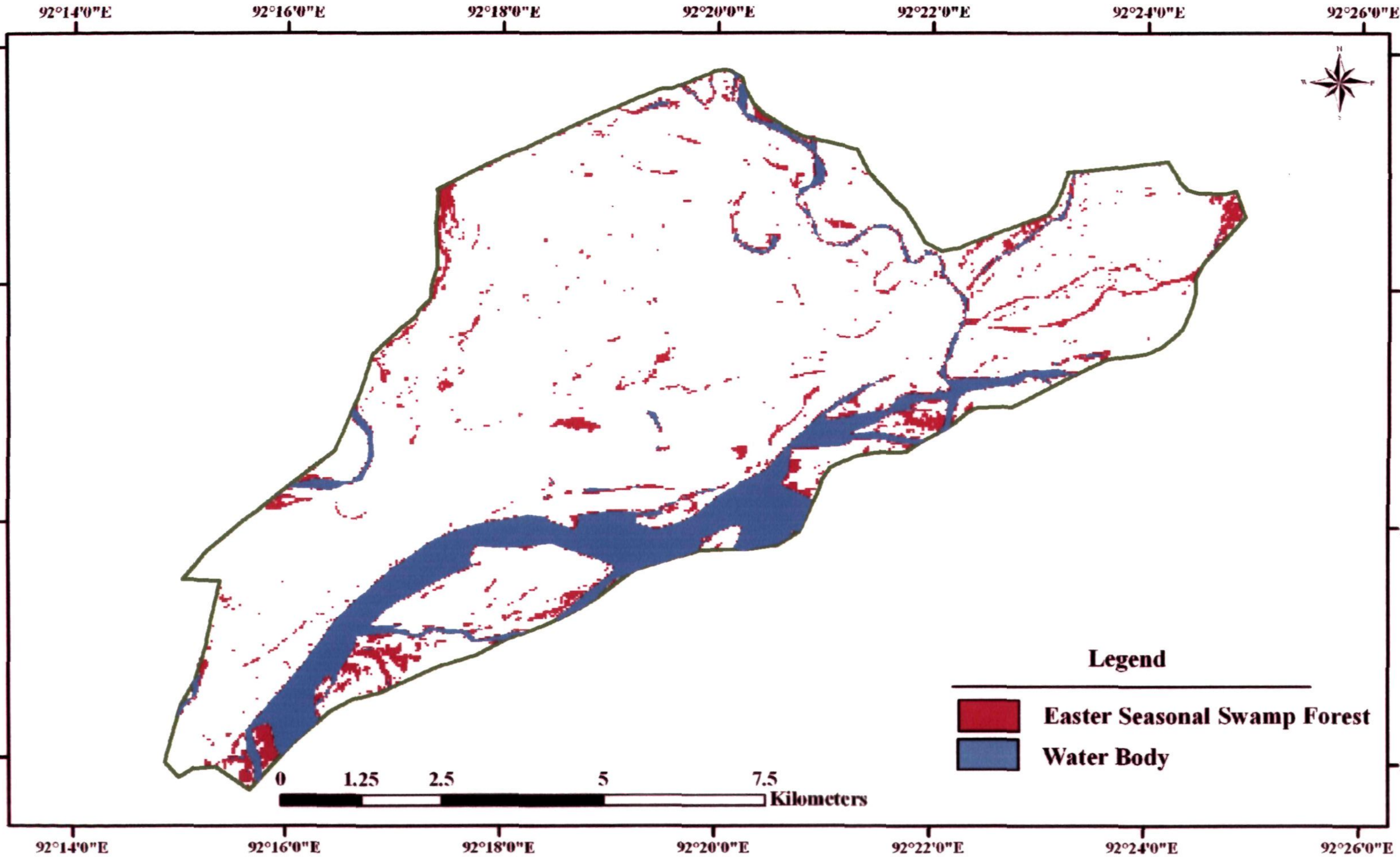
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 12

iv) **Eastern Seasonal Swamp Forest:**

This land cover type occupies an area of 1.36 km^2 in RG Orang NP. This type is mainly found along the river Brahmaputra, Dhansiri and Panchnoi and also in and around the wetlands of the park. This is mainly composed of *Barringtonia* type of vegetation. The distribution of Eastern Seasonal Swamp Forest in RG Orang NP is shown in the Map No. 13.

Distribution of Eastern Seasonal Swamp Forest



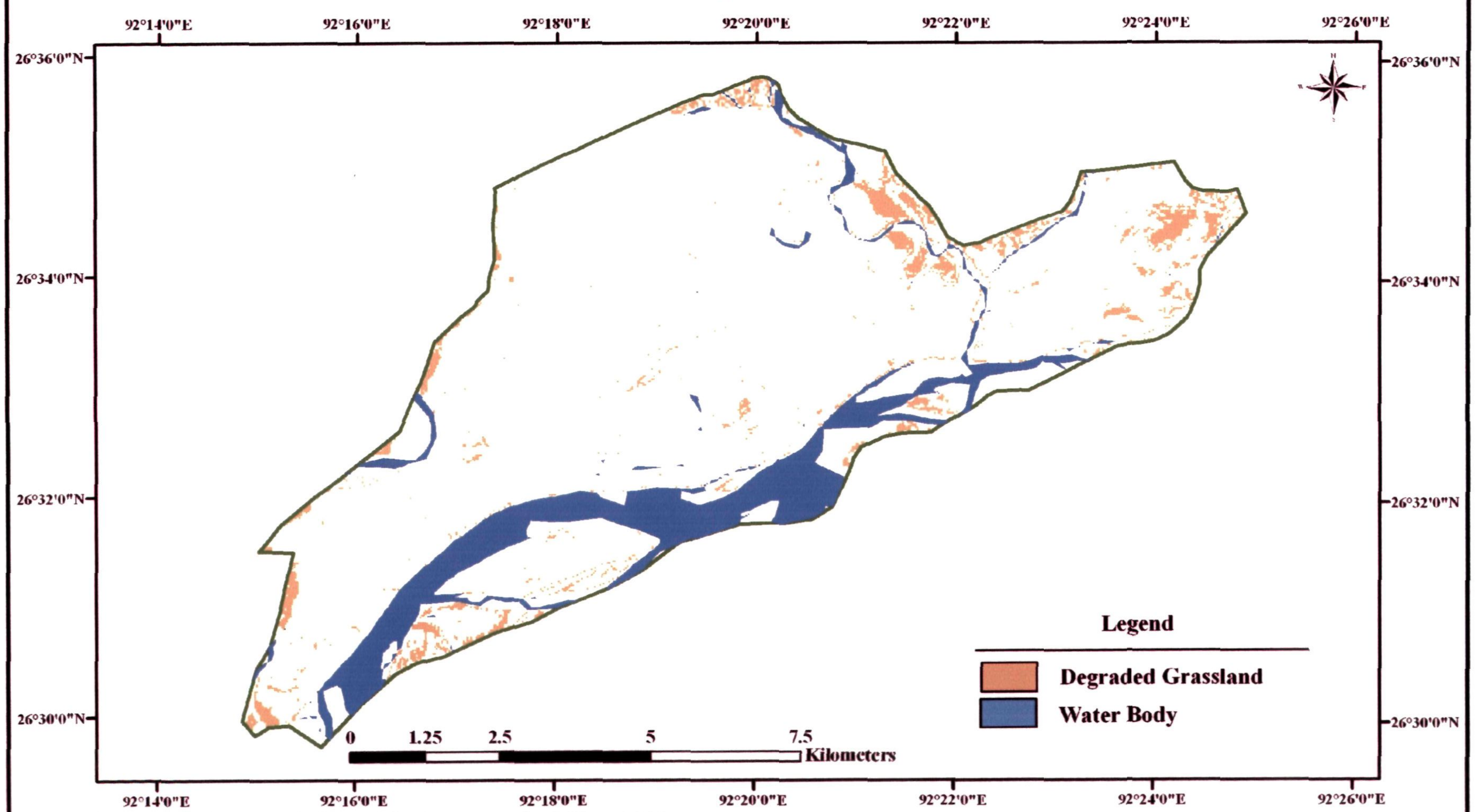
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 13

v) **Degraded Grassland:**

This type of grassland covers an area of 12 km^2 of RG Orang NP. These areas are mainly found near the easternmost and westernmost boundary of the park. The leading factor behind the formation of degraded grassland in RG Orang NP is the over grazing by the domestic cattle that comes from the fringe villages of the park. The impact of invasive species like *Mimosa invesa* is also a major factor in the formation degraded grassland in RG Orang NP. The distribution of the degraded grassland in RG Orang NP is shown in the Map No.- 14.

Distribution of Degraded Grassland



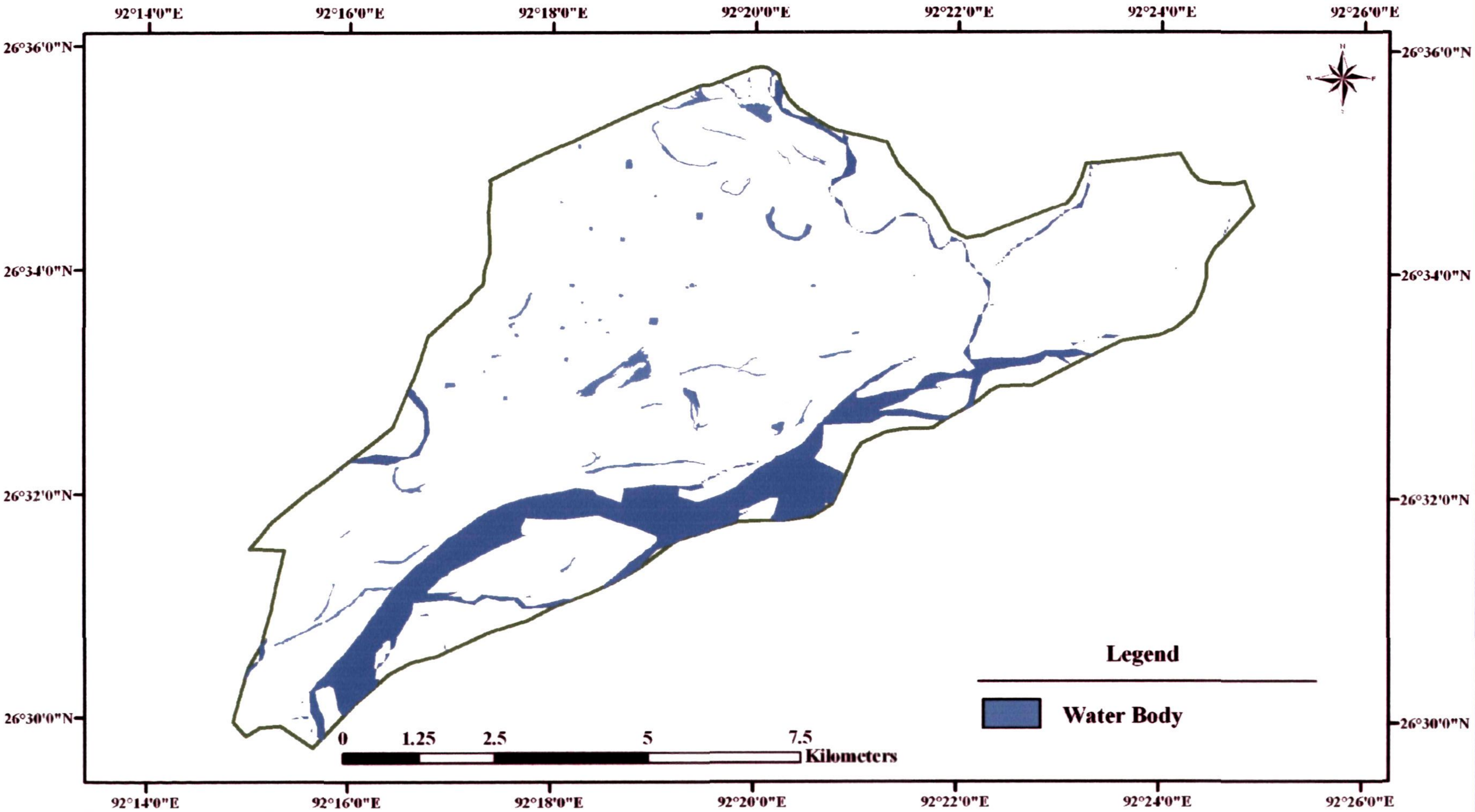
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 14

vi) **Water Body:**

The area under water bodies in RG Orang NP is 6.48 km^2. The mighty river Brahmaputra flows along the southern boundary of RG Orang NP which covers an area of 5.78 km^2 in the park. Besides this, there are several wetlands in the park, which are also recognized as good habitat for rhinoceros in the park. The distribution of water body in RG Orang NP is shown in the Map No. - 15.

Distribution of Water Body



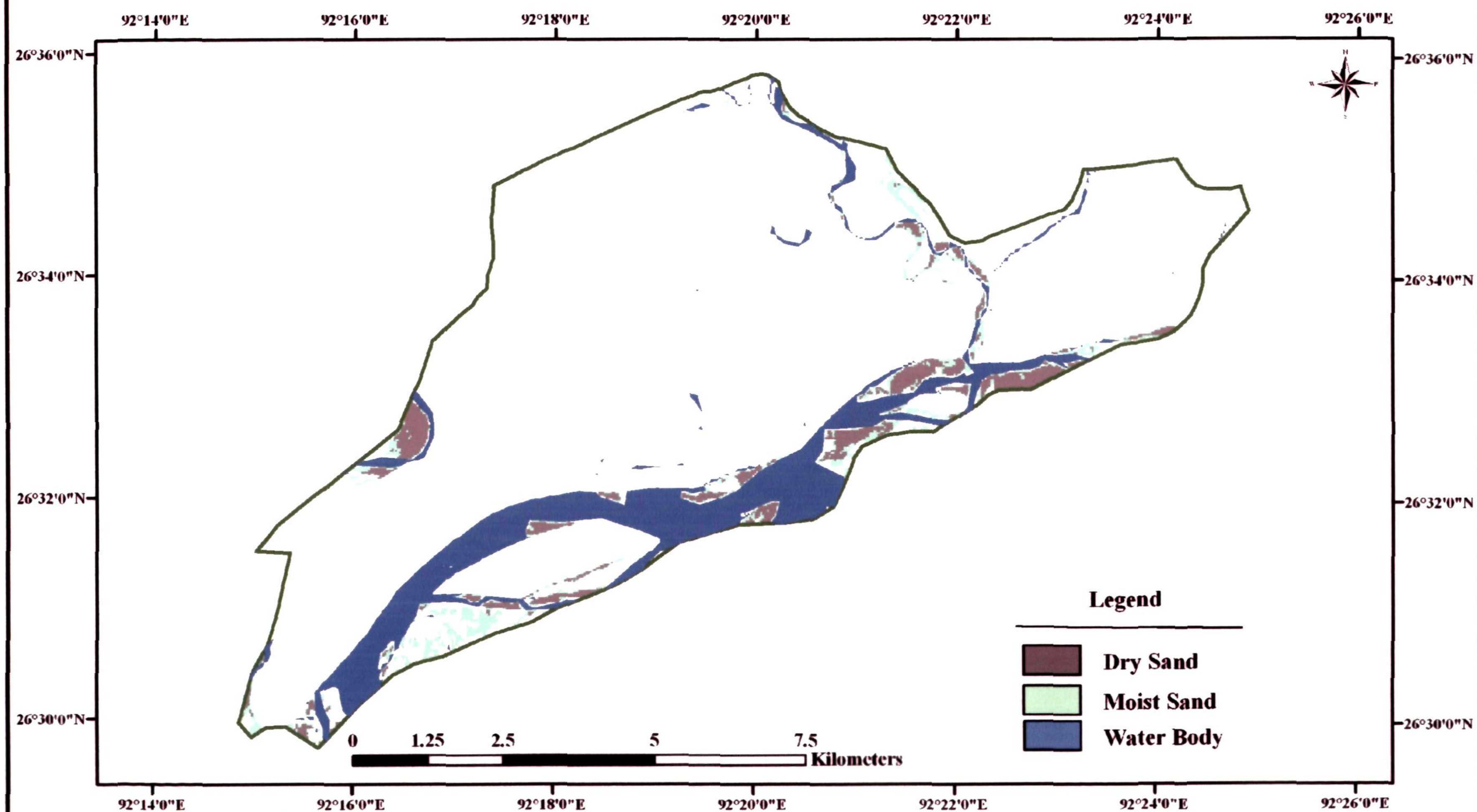
Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 15

vii) **Sandy Area (Dry and Moist):**

The area covered by sand in RG Orang NP is 3.87 km^2. River sand banks devoid of any vegetation are mainly concentrated around the dried river bed of Brahmaputra. The change in course of river Brahmaputra along with excessive siltation during the rainy season has resulted the expansion of such areas. The distribution of sandy area in RG Orang NP is shown in the Map No. 16.

Distribution of Dry Sand and Moist Sand



Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 16

The area covered by each of the land cover category in RG Orang NP is shown in the table III a.

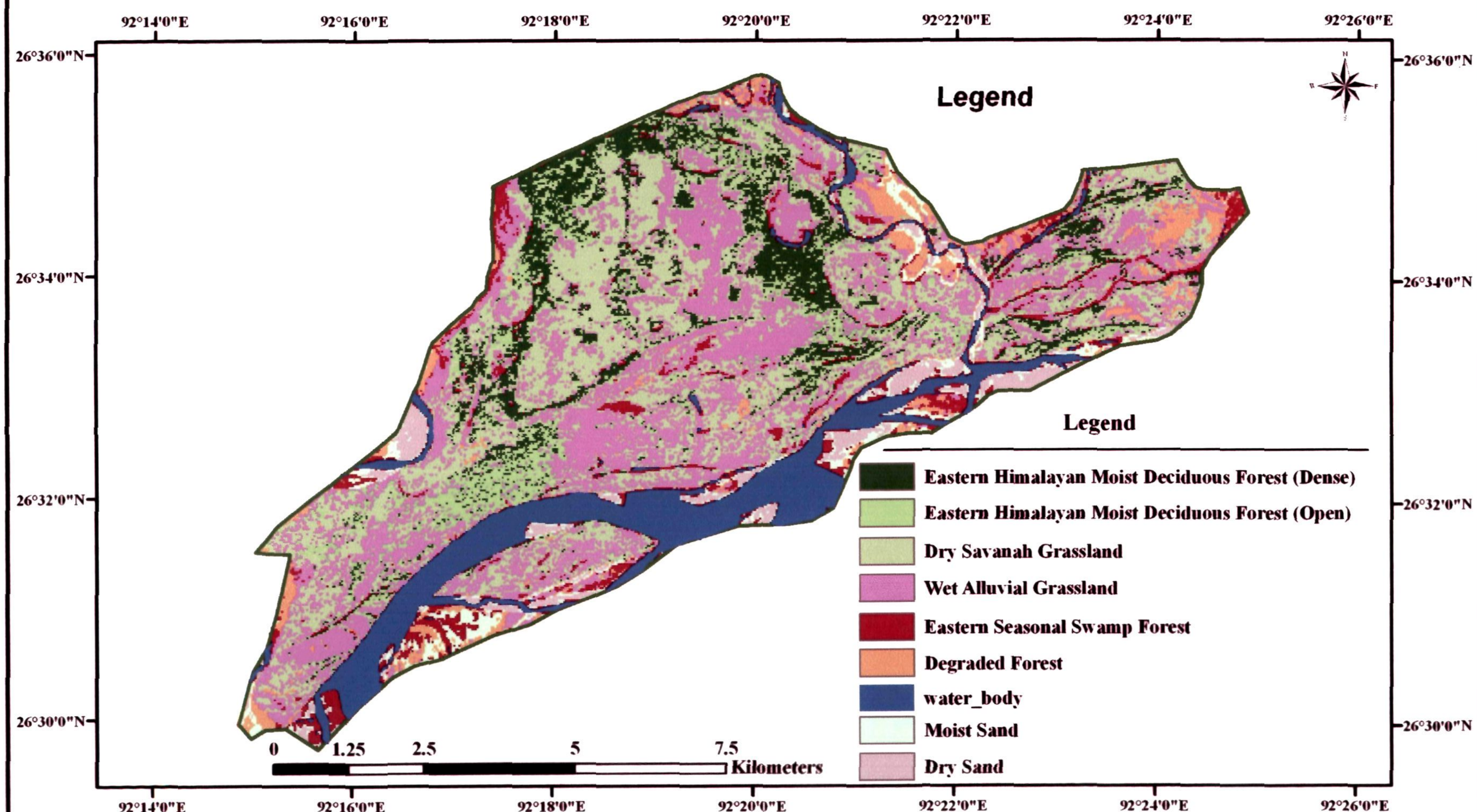
Table III a. – Land Cover Pattern of RG Orang NP in 2008

Land Cover Types	**Area in km²**	**% area covered**
Eastern Himalayan Mixed Moist Deciduous Forest (Dense)	9.84	12.48
Eastern Himalayan Mixed Moist Deciduous Forest (Open)	10.54	13.37
Dry Savannah Grassland	14.17	17.98
Wet Alluvial Grassland	20.54	26.06
Degraded Grassland	12	15.23
Eastern Seasonal Swamp Forest	1.36	1.72
Water Body	6.48	8.22
Moist Sand Area	1.02	1.29
Dry Sand Area	2.85	3.61

Source: IRS P6 LISS III Satellite Image of 8th Nov. 2008

The spatial distribution of above mentioned land cover categories in the RG Orang NP is shown in the Map No. - 17

Land Cover Pattern of Rajiv Gandhi Orang National Park, 2008.



Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008.

Map No. 17

The percentage of area covered by each land cover category is shown in the figure III a. The figure shows that the wet alluvial grassland covers the maximum area in RG Orang NP, covering an area of 26.06% of the total geographical area of the park. Dry savannah grassland covers an area of 17.98 % of the total geographical area of RG Orang NP. It indicates that RG Orang NP is mostly covered with grassland habitat (44.04%) and it provides the food and cover for survival of rhino in the park. The woodland (Easter Himalayan Mixed Moist Deciduous (Dense & Open) habitat covers 25.85% of the total geographical area of the park and these are mainly distributed in the upland areas of the park. Degraded grassland is covering a large area in the park, which is 15.23% of the total area of the park. Degraded grassland areas are mainly distributed along the eastern and westernmost boundaries of the park. Over grazing by the domestic cattle and impact of invasive species like *Mimosa invesa* are the main causes behind the expansion of degraded grassland in RG Orang NP. Water bodies in RG Orang NP are covering 8.22% of the total area of the park. Easter seasonal swamp forest covering 1.72% of the total area of the park and moist and dry sandy area covering 4.90% of the total area of the park.

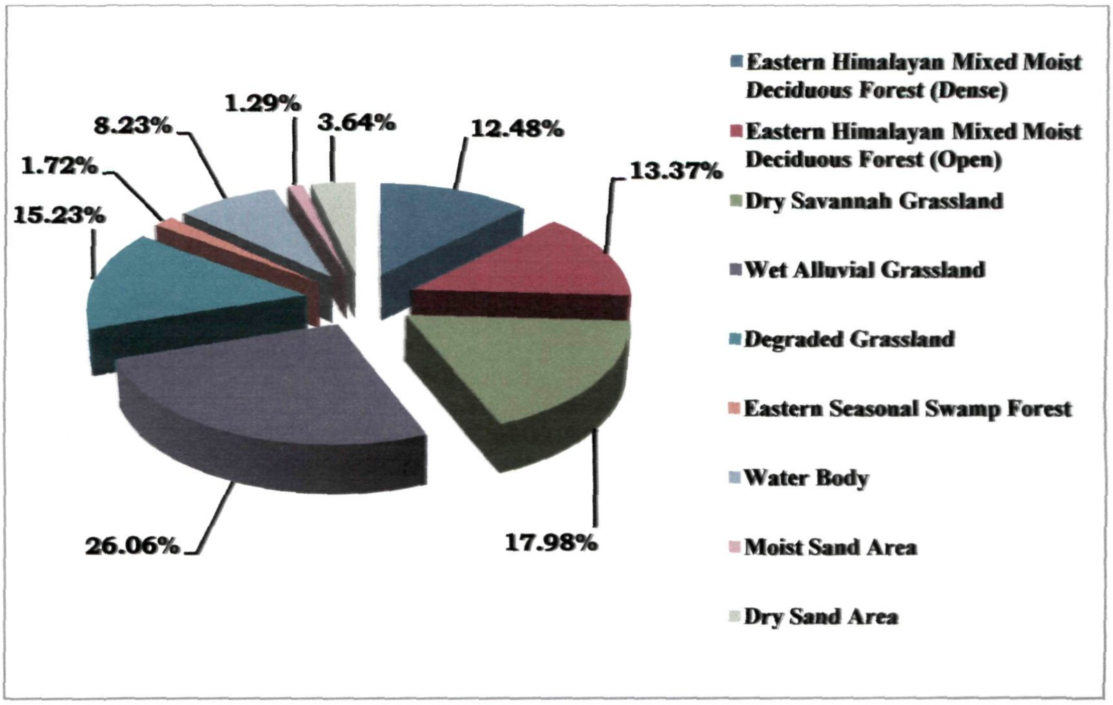


Fig. III a. Land cover pattern of RG Orang NP in 2008 (in %)

3.3 Land Cover Status of RG Orang NP in 1999:

Analysis and estimation of land cover pattern of RG Orang NP for the year 1999 was done using satellite imagery of Landsat TM, 19th December, 1999. Nine categories of land cover types were detected from the satellite imagery and those were classified accordingly. The nine land cover classes were similar to the 2008 land cover categories. The table III b. shows the land cover pattern of RG Orang NP and their respective area coverage as on 19th December, 1999.

Table III b. Land Cover Pattern of RG Orang NP in 1999

Land Cover Types	Area in km²	% of area covered
Eastern Himalayan Mixed Moist Deciduous Forest (Dense)	8.63	10.95
Eastern Himalayan Mixed Moist Deciduous Forest (Open)	10.58	13.42
Dry Savannah Grassland	12.41	15.74
Wet Alluvial Grassland	26.5	33.63
Degraded Grassland	10.35	13.13
Eastern Seasonal Swamp Forest	2.51	3.18
Water Body	3.13	3.97
Moist Sand Area	1.8	2.28
Dry Sand Area	2.89	3.68

Source: Landsat TM satellite imagery, 19th December, 1999.

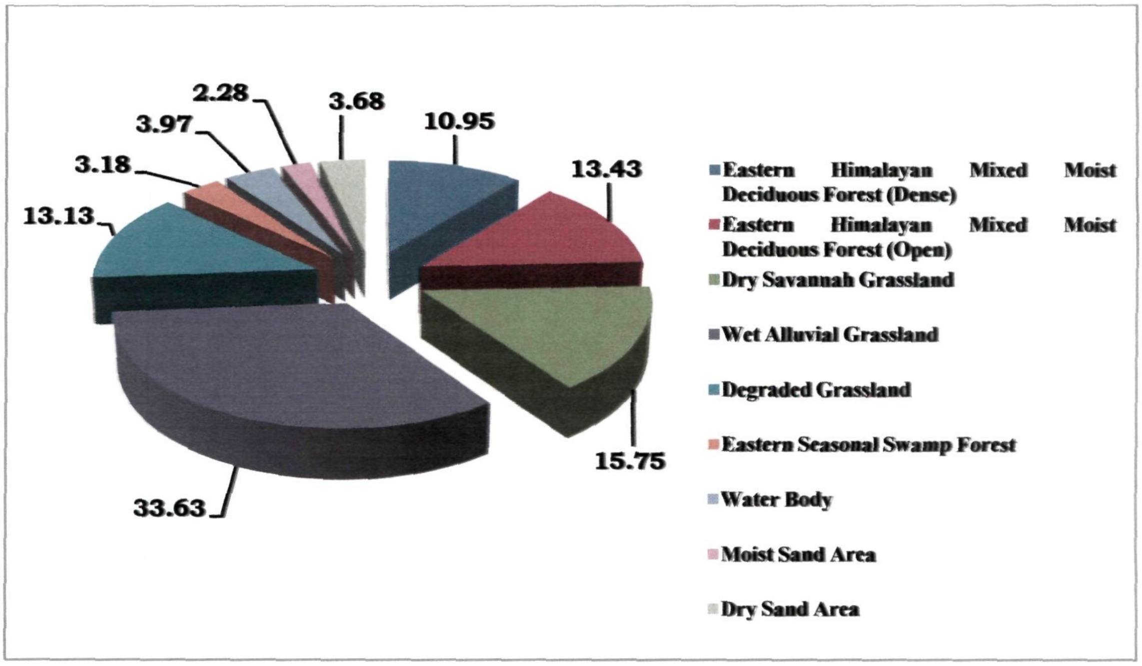
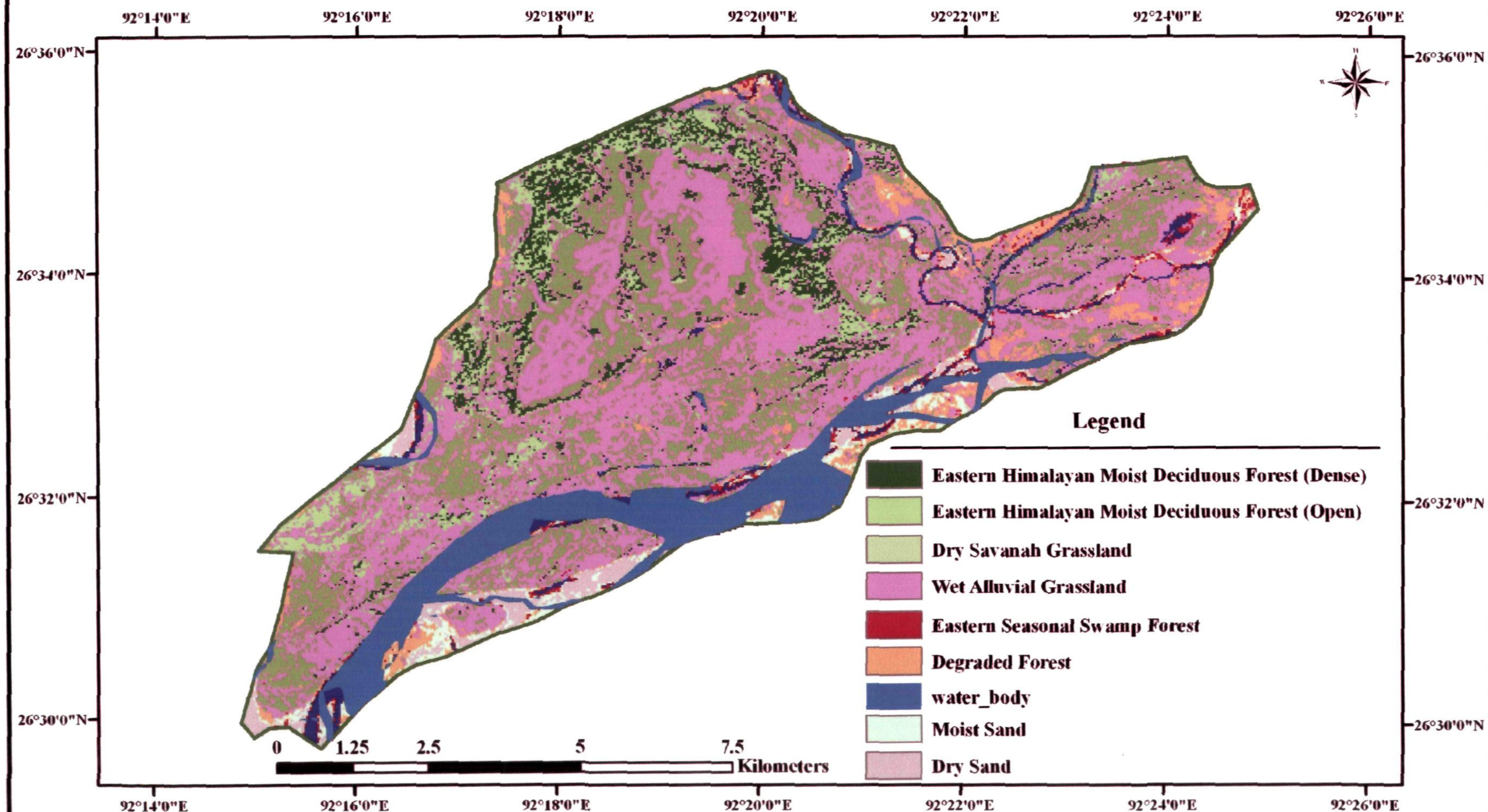


Fig. III b. Land cover pattern of RG Orang NP in 1999 (in %

Land Cover Pattern of Rajiv Gandhi Orang National Park, 1999.



Source: Landsat TM satellite imagery of 19th Dec. 1999.

Map No. 18

The Map No. - 18 show the land cover pattern of RG Orang NP in 1999. Wet alluvial grassland covered an extensive area in RG Orang NP in the year 1999. It covered 33.63% of the total area of the park. It indicates that the rhino habitat in RG Orang NP in 1999 was in quite good condition. Similarly the dry savannah grassland had covered 15.74% of the total area of the park. The total area covered by the grassland in RG Orang NP in the year 1999 was 49.37%. The woodland (Eastern Himalayan Mixed Moist Deciduous Forest Dense & Open) covered 24.38% of the total area of the RG Orang NP. Degraded grassland in 1999 covered 13.13% of the total area of the park. The eastern seasonal swamp forest covered 3.18% of the total area of the park and the moist and dry sandy areas covered 5.96% of the total geographical area of the RG Orang NP.

3.4 Land Cover Status of RG Orang NP in 1987:

Satellite imagery of Landsat TM, 26^{th} December, 1987 was used to assess the land cover pattern of RG Orang NP. The land cover pattern of RG Orang NP in 1987 was also categorised in to nine classes. The different land cover pattern and their respective area coverage of RG Orang NP in 1987 are shown in table III c. The Map No. - 19 shows the land cover pattern of RG Orang NP as on 26^{th} December, 1987.

Table III c. Land Cover Pattern of RG Orang NP in 1987

Land Cover Types	Area in km²	% of area covered
Eastern Himalayan Mixed Moist Deciduous Forest (Dense)	6.8	8.62
Eastern Himalayan Mixed Moist Deciduous Forest (Open)	7.6	9.64
Dry Savannah Grassland	6.88	8.73
Wet Alluvial Grassland	30.63	38.87
Degraded Grassland	6.86	8.71
Eastern Seasonal Swamp Forest	3.1	3.93
Water Body	5.76	7.31
Moist Sand Area	3.4	4.31
Dry Sand Area	7.05	8.94

Source:Landsat TM Satellite Imagery, 26th December, 1987.

The percentage of area covered by each land cover types in RG Orang in 1987 is shown in figure III c.

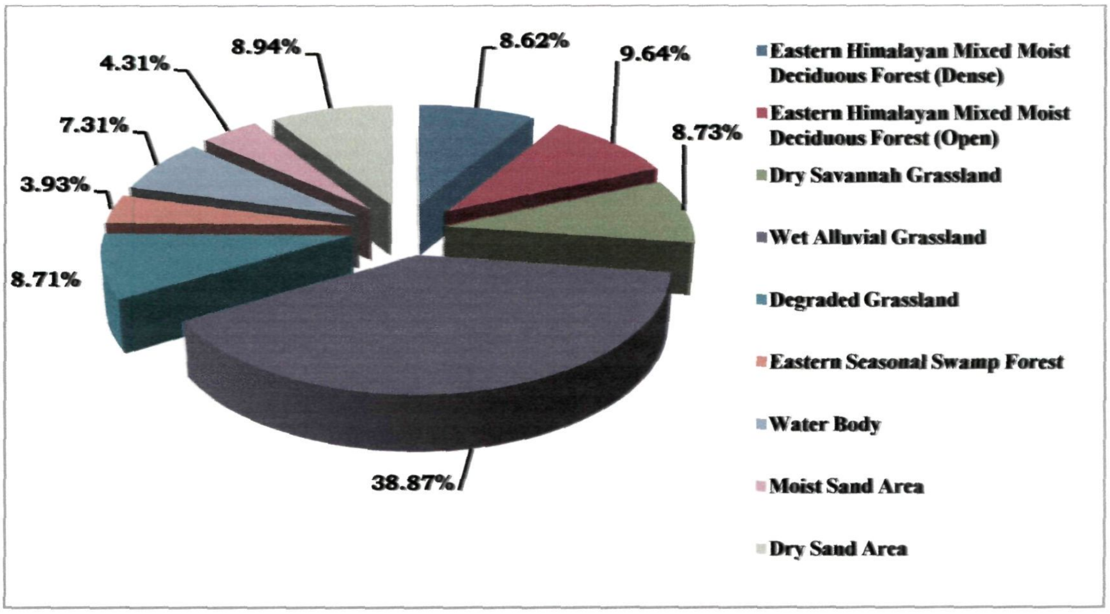
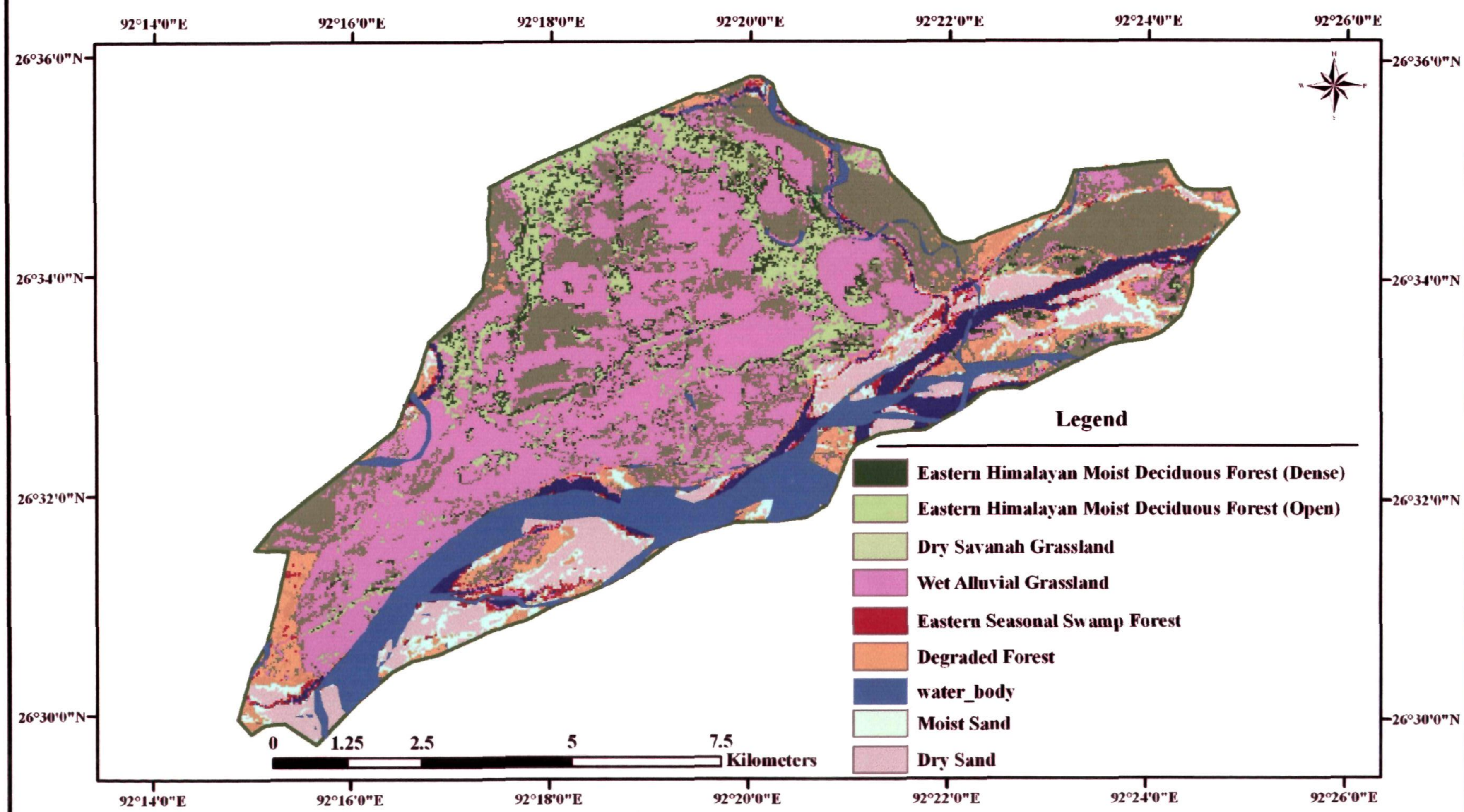


Fig. III c. Land Cover pattern of RG Orang Np in 1987 (in %)

Land Cover Pattern of Rajiv Gandhi Orang National Park, 1987.



Source: Landsat TM satellite imagery of 26th Dec. 1987.

Map No. 19

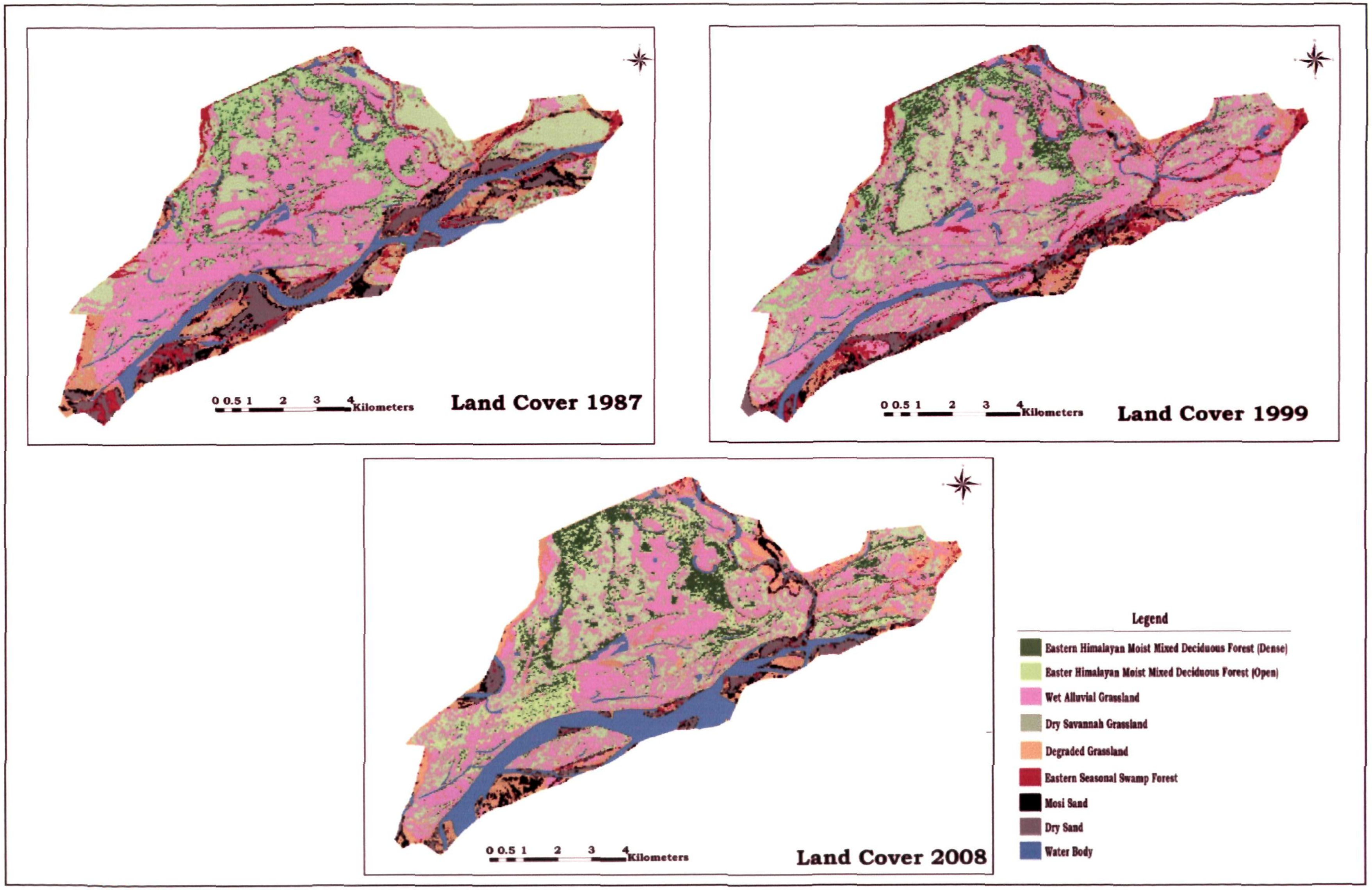
The result shows that the wet alluvial grassland was quite dominant in RG Orang NP in the year 1987. The percentage of area covered by wet alluvial grassland was 38.87%. Similarly dry savannah grassland covered 8.73% of the total area of the park. It shows that 47.6% area of RG Orang NP was covered by grassland in 1987. The woodland (Eastern Himalayan Mixed Moist Deciduous Forest- Dense & Open) covered 18.26% of the total area of the park in the year 1987. Degraded grassland covered 8.71% area of the park. The eastern seasonal swamp forest covered 3.93% of the total area of the park and the moist and dry sandy area covered 13.25% of the total geographical area of the park in the year 1987.

3.5 Land Cover Change in RG Orang NP:

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Timely and accurate change detection of earth's surface features are extremely important for understanding relationship and interactions between human and natural phenomena in order to promote better decision making (LU *et al.*2003). The real time land use/land cover information along with their spatial distribution is a pre-requisite for planning and formulation of policies and programs. Such computer updated knowledge of the forest lands and changes in land utilization from time to time are obligatory for habitat evaluation (Kamat, 1986, Roy, 1990). Analysis of the recent history and present patterns of forests offers a present day baseline for assessing future landscape patterns and their consequences (Zheng *et* *al.* 1997). In general, change detection involves the application of multi-temporal satellite imageries to quantitatively analyzed temporal effects of the phenomenon. Because of the advantage of repetitive data acquisition, its synoptic view, and digital format data are suitable for computer processing. Remotely senses data, such as Thematic Mapper (TM), IRS LISS III, Satellite Probatoire d'Observation de la Terre (SPOT), Radar and Advanced Very High Resolution Radiometer (AVHRR), have become the major data source for different change detection applications during the past decades (Lu, *et al.* 2003).

In this study analysis of land cover change dynamics in RG Orang NP, three datasets of satellite imageries were used pertaining to the year 1987, 1999 (Landsat TM) and 2008 (IRS P6 LISS III). A supervised classification technique has been used to prepare the land cover types of RG Orang NP from 1987 to 2008. Nine land cover types were identified from the images based on prior ground information as mentioned earlier. From the land cover change analysis of RG Orang NP it has been observed that Eastern Himalayan mixed moist deciduous forest (dense) has an increasing trend from 6.8 km^2 in the year 1987 to 8.63 km^2 in the year 1999 and it has increased up to 9.84 km^2 in the year 2008. The Eastern Himalayan moist deciduous forest (open) has also an increasing trend from 1987 to 2008. The area covered by Eastern Himalayan moist deciduous forest (open) in the year 1987 was 7.6 km^2 and it increased up to 10.54 km^2 in the year 2008. It is mainly due to the natural succession of woodland from Eastern Himalayan moist deciduous forest (open) to Eastern Himalayan moist deciduous forest (dense) from the year 1987 to 1999. However, from 1999 to 2008, a decreasing trend of Eastern Himalayan moist deciduous forest (open) is observed. There is a decrease of 0.04 km^2 area from 1999 to 2008 in case of Eastern Himalayan mixed moist deciduous forest (open). In case of dry savannah grassland, an increasing trend from 6.88 sq. km to 12.41 km^2 and up to 14.17 km^2 in the years of 1987, 1999 and 2008 respectively has been observed. This is mainly due to the natural succession of dry savannah grassland from wet alluvial grassland. In case of wet alluvial grassland, a decreasing trend has been observed from 1987 to 2008 covering areas of 30.63 km^2 to 20.54 km^2 respectively. Figure III d. shows the trend of dry savannah grassland and also the wet alluvial grassland form 1987 to 2008. This decrease of wet alluvial grassland in the park is mainly due to the impact of the invasive species named as *Mimosa invisa*. Mimosa is a native of tropical American species and was imported by tea gardeners from East Asia in the 1960s, as a nitrogen fixer prior to planting tea (Vattakkavan, et. al. 2005). The presence of *Mimosa invesa* is a major threat to the Orang NP. *Mimosa invesa* scrambles vigorously over other plants, forming dense tangled thickets up to 2 m. high. It is commonly seen in roadsides and moist places (Waterhouse, 1994) In fact, it can invade the growth completely, competing with other plants and smothering herbaceous growth implies habitat degradation and loss of biodiversity (Vattakkavan, *et al.* 2005). RG Orang NP is one of the best examples of habitat degradation caused by *Mimosa invesa* in recent times. This tremendous change of wet alluvial grassland in RG Orang NP has a major impact on the habitat of large herbivores like one horned rhino. Rhinos prefer to use wet alluvial grassland as their prime habitat throughout the year because it provide sufficient amount of food and nutrition for their survival (Laurie, 1978). RG Orang NP is a prime habitat for rhino and this change in wet alluvial grassland is a serious concern for many rhino conservation agencies working in Assam. In case of degraded grassland there is an increasing trend from 6.86 km^2 in the year 1987 to 10.35 km^2 in the year 1999. Similarly, from 1999 to 2008 it has witnessed an increasing trend and reached up to 12 km^2 of area. The degraded grassland is mainly found in the eastern most and western most part of RG Orang NP. The degradation of grassland in those pockets of RG Orang NP are mainly due to the over grazing by cattle from the nearby villages. Another cause behind the increasing trend of degraded grassland is also the impact of *Mimosa invesa*. In case of seasonal swampy forest, it was found that it reduced from 3.1 km^2 in the year 1987 to 2.51 km^2 in the year 1999. It has also a decreasing trend from 1999 to 2008 covering an area of 1.36 km^2 The main cause behind the reduction of seasonal swamp forest in RG Orang NP is also the impact of *Mimosa invesa.* In case of water body, it was found that it reduced from 5.76 km^2 in the year 1987 to 3.13 km^2 in the year 1999. It is mainly due to the deposition by the river Brahmaputra in the south eastern part of the park. However, from 1999 to 2008 it increased up to 6.48 km^2, which is mainly due to erosion caused by river Brahmaputra, Dhansiri and Pachnoi. In case of river sand or sandy area there is a decreasing trend from the year 1987 to 2008. The area under sand in the year

1987 was 10.45 km^2, which reduced to 4.69 km^2 in the year 1999, and finally it reduced up to 3.87 km^2 in the year 2008. It indicates that the sandy areas were drastically decreased from the year 1987 to 2008. It is mainly due to the conversion of sandy area to grassland habitat in the eastern most part of RG Orang NP from 1999 to 2008. The Map No. 20 shows the land cover change dynamics pattern in RG Orang NP from 1987 to 2008.



Source: Satellite Imagery of Landsat TM & IRS P6 LISS III.

Map No. - 20

Table III d. Land Cover Change Dynamics in RG Orang NP from 1987 to 2008

Land Cover Class	1987	1999	2008	% of Total Area Cover			Net Change in %	
	Area in km²			1987	1999	2008	1987 - 1999	1999-2008
Eastern Himalayan Moist Mixed Deciduous Forest (Dense)	6.8	8.63	9.84	8.62	10.95	12.48	+ 2.33	+ 1.53
Eastern Himalayan Moist Mixed Deciduous Forest (Open)	7.6	10.58	10.54	9.64	13.42	13.37	+ 3.78	- 0.05
Dry Savannah Grassland	6.88	12.41	14.17	8.73	15.74	17.98	+ 7.01	+ 2.24
Wet Alluvial Grassland	30.63	26.5	20.54	38.87	33.63	26.07	- 5.24	- 7.56
Degraded Grassland	6.86	10.35	12	8.71	13.13	15.22	+ 4.42	+ 2.09
Eastern Seasonal Swamp Forest	3.1	2.51	1.36	3.93	3.18	1.72	- 0.75	- 1.46
Water Body	5.76	3.13	6.48	7.31	3.97	8.22	- 3.34	+ 4.25
Moist Sand Area	3.4	1.8	1.02	4.31	2.28	1.29	- 2.03	- 0.99
Dry Sand Area	7.05	2.89	2.85	8.94	3.66	3.61	- 5.28	- 0.05

Source: Satellite Imagery Landsat TM & IRS P6 LISS III of 1987, 1999, 2008.

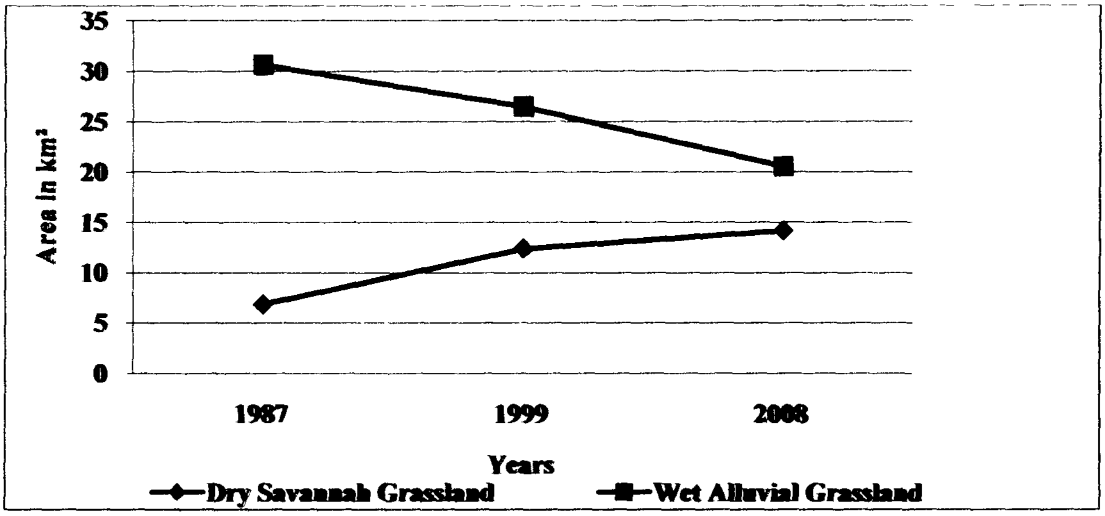
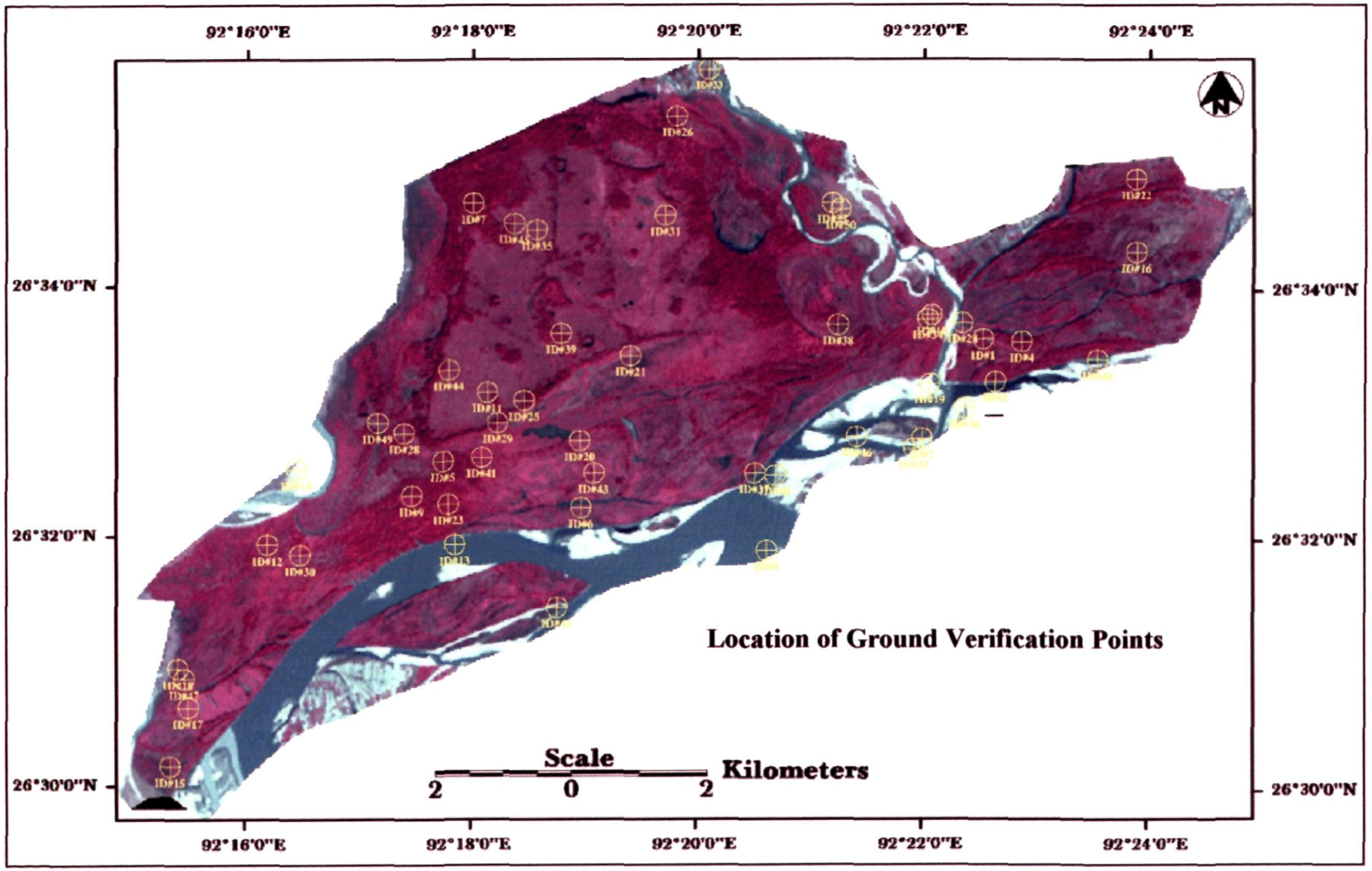


Fig. III d. Changes in Wet Alluvial and Dry Savannah Grassland in Orang NP from 1987 to 2008

3.6 Accuracy assessment of the land cover classification:

Accuracy assessment is very important for understanding the developed results and employing these results for decision-making (Lu, *et al.* 2003). The need for assessing the accuracy of a map generated from any remotely sensed data has become universally recognized as an integral project component. With the widespread application of geographic information system employing remotely sensed data as layers, the need for such an assessment has become even more critical. There are a number of reasons why this assessment is so important, including the need to perform self evaluation and to learn from the mistakes, the ability to compare method/algorithms analysts quantitatively and the desire to use the resulting maps/spatial information in some decision making process (Lunetta, *et al.* 2004). The accuracy assessment for change detection is particularly difficult due to problems in collecting reliable temporal field-based datasets. Therefore, much previous research on change detection cannot provide quantitative analysis of the research results. Although standard accuracy assessment techniques were mainly developed for single-date remotely sensed data, the error matrix-based accuracy assessment method is still valuable for evaluation of change detection results (Lu, *et al.* 2003). To check the classification accuracy of land cover types derived from the supervised classification, we used a reference template from the margining data. With fifty randomly selected samples on IRS P 6 LISS III imagery, overall accuracy, user's accuracy, producer's accuracy and Kappa statistics were derived. The kappa statistics incorporated the off diagonal elements of the error matrices and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance (Lillesand, *et al.* 2004). Selecting random sample points with known classes on the IRS P6 LISS imagery (Map No. - 21) and then comparing with the land cover map obtained by supervised classification of IRS P 6 LISS III imagery an accuracy assessment report and kappa statistics was generated using ERDAS 9.0 software. The overall accuracy of the classification was 94 percent and the overall kappa (K^) statistics was 0.9099. The Kappa statistics is derived from the statistical equation:

$$K^{\wedge} = \frac{\text{Observed accuracy} - \text{chance agreement}}{1 - \text{chance agreement}}$$

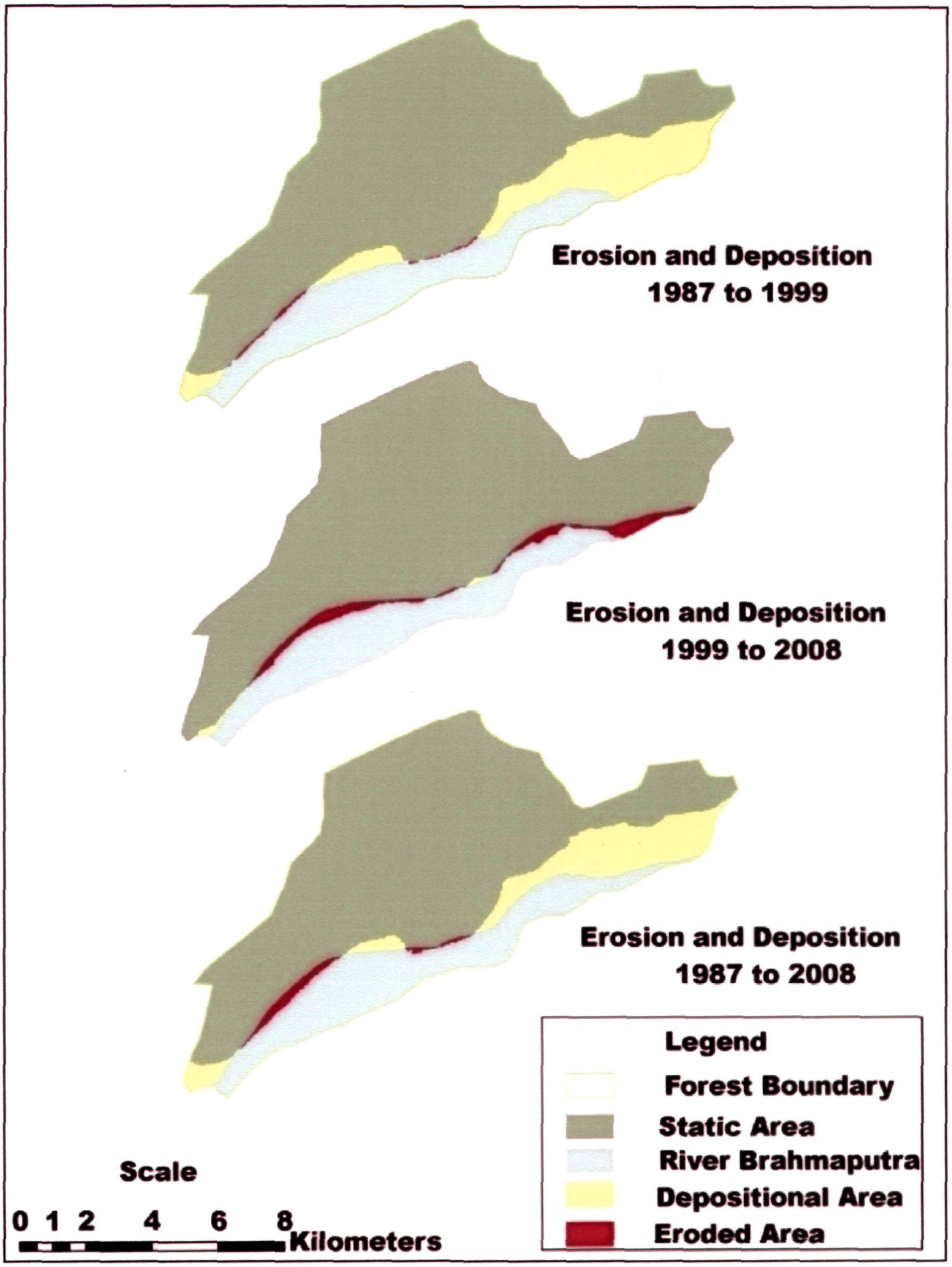


Source: GPS locations collected from field survey

Map No. - 21

3.6 Erosion and Silt Deposition in RG Orang NP:

The RG Orang NP is situated along the northern bank of river Brahmaputra. The park has a 20 km long river bank along its southern boundary. Here in this study an attempt was made to assess the erosion and depositional pattern of river Brahmaputra in RG Orang NP. Historical satellite imageries of 1987, 1999 and recent satellite imagery of 2008 were used to assess the erosion and depositional pattern in RG Orang NP. From the literature survey it was clear that from 1914 to 1975 erosion is much more prominent in RG Orang NP (Sharma, 2004, Kotoky, 2005,). But in this study we have observed an increasing trend of silt deposition in the park by the river Brahmaputra during the year 1987 to 2008. It was observed that from 1987 to 1999 only 0.23 km^2 was eroded in RG Orang NP whereas 9.48 km^2 was deposited during that period in the park. Similarly from 1999 to 2008 almost 2.54 km^2 was eroded in the park and 0.18 km^2 was deposited by the river Brahmaputra in the park during the same period. It shows that the depositional trend is more prominent during the period from 1987 to 1999 in comparison to 1999 to 2008. Map No. – 22 and table III e. shows the erosion and depositional trend by the river Brahmaputra along the river bank of RG Orang NP.



Source: Satellite Imagery of 1987, 1999, 2008

Map No. 22

Table III e. Erosion and depositional scenario in RG Orang NP

Erosion & Deposition Status	1987 to 1999	1999 to 2008	1987 to 2008
	Area in sq. km		
Eroded Area	0.23	2.54	0.94
Deposited Area	9.48	0.18	8
Static Area	55.96	62.68	55.24
River Brahmaputra	13.11	13.6	14.82

Source: Satellite imagery of 1987, 1999 & 2008

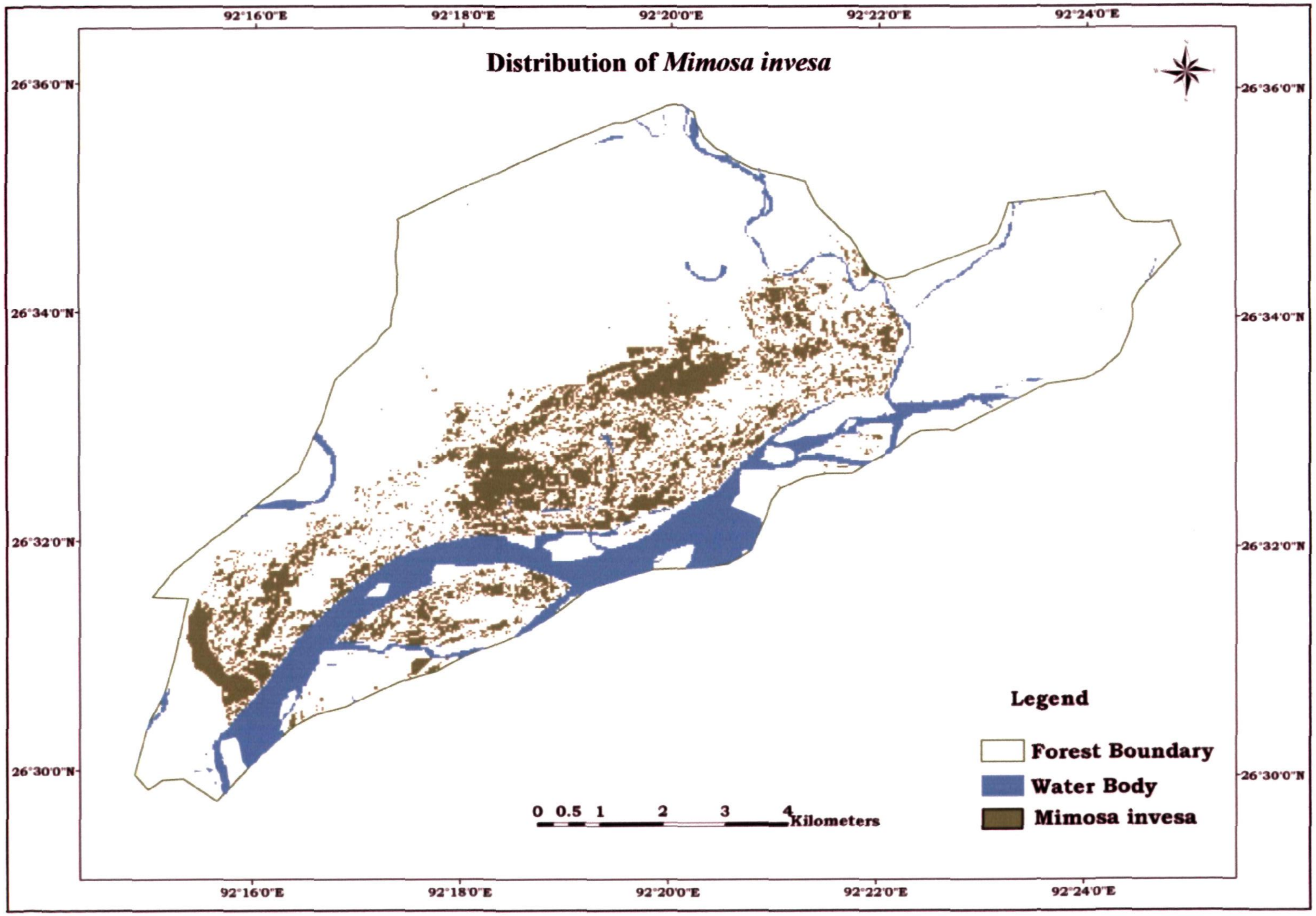
3.7 Factors Affecting the Land Cover Change:

There are four major factors which have directly or indirectly affecting the land cover change in RG Orang NP. The factors are as follows

a) **Impact of invasive species:**

The impact of invasive species on land cover change in RG Orang NP is recognized as a major factor. Human intervention in pristine ecosystem has helped some species cross ecological barriers and spread. Alien invasive species are recognized as the second largest threat to biological diversity (Singh 2001; IUCN, 2000).Recent developments in trade, travel and other fields have rendered every precaution taken, through customs quarantine practices. IUCN (2000) defines an alien invasive species as an alien species, which become established in natural and semi-natural ecosystem or habitat, as an agent of change, and threatens native biological diversity. The RG

Orang NP is infested with a invasive species named as *Mimosa invesa.* It is a straggler that chokes that native grassland habitat in the park and has established itself mainly in small patches. It produces minute seed profusely, which are easily spread across the park during the rains. The weed was reported to be spreading rapidly across wild habitat, hampering access to food and other resources and the movement of wildlife. In RG Orang NP the wet alluvial grassland habitat, which is essential for survival of rhino is gradually decreasing in size mainly due to the impact of the invasive species composed with *Mimosa invesa.* The total area covered by *Mimosa invesa* in RG Orang NP is 11.23 km^2 The wet alluvial grassland is gradually converted to dry savannah grassland and degraded grassland in the park. The distribution of Mimosa invesa in RG Orang NP is shown in the Map No. 23

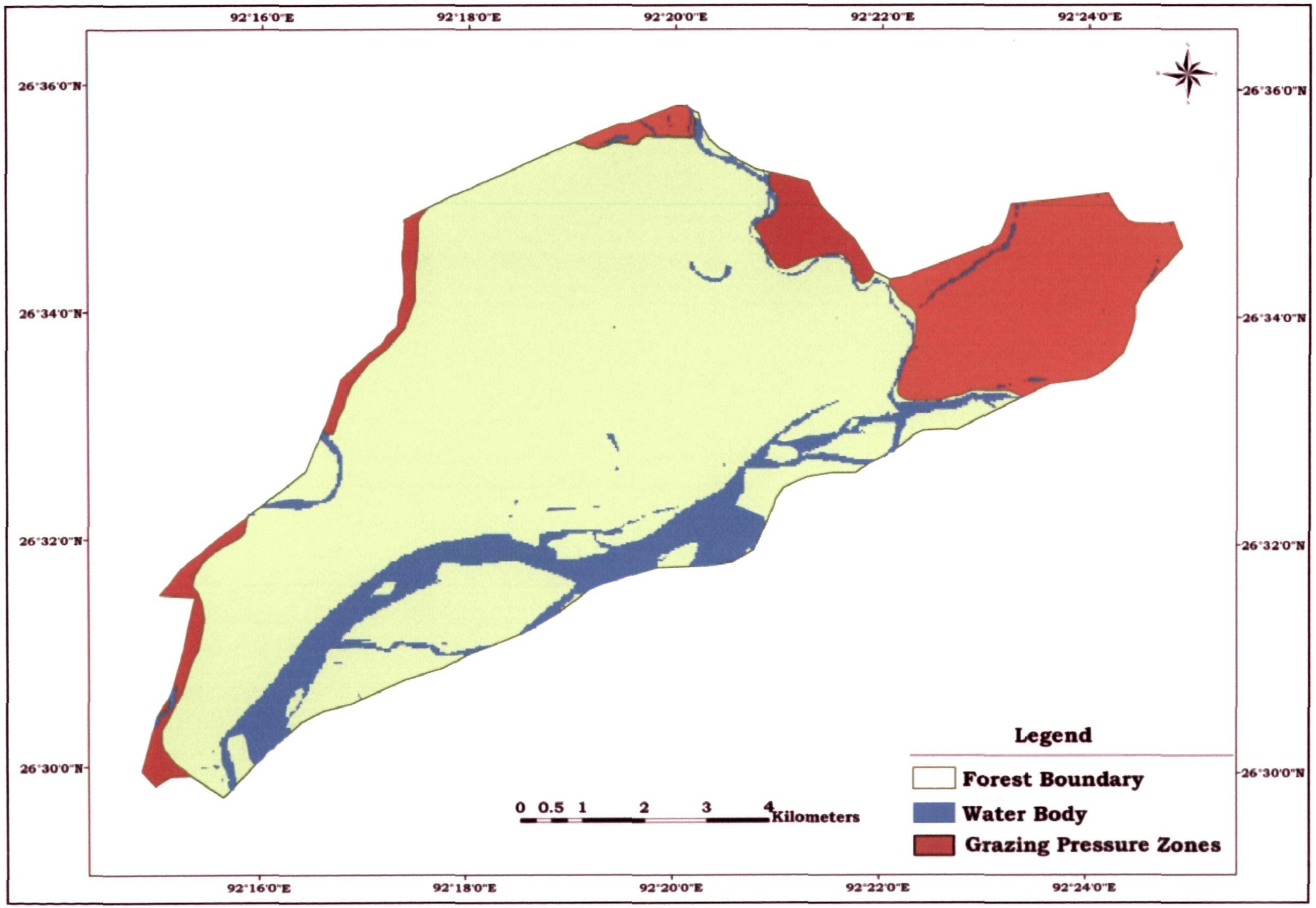


Source: IRS P6 LISS III Satellite Imagery of 8th Nov. 2008 and GPS locations collected from field

Map No. - 23

b) Grazing pressure:

The grazing pressure from nearby villages of RG Orang NP is also a major factor of land cover change in the park. The main livelihood of the community living on the periphery of RG Orang NP is crop-based agriculture and dairy farming, both of which depend on cattle. During the study period (September, 2008 to September, 2009) it was observed that on an average more than 1500 cattle enter the park every day. The pressure is more intense towards the eastern part and western most part of the park. This intense grazing pressure by domestic cattle inside the National Park leads to the increase of degraded grassland in the park. These also destroy the rhino habitat in the eastern and western part of the park. The Map No. 24 shows the grazing pressure zones inside the RG Orang NP



Source: Field data collected by researcher

Map No. - 24

c) Erosion and deposition in the park:

The impact of erosion and depositional activities by the river Brahmaputra and its tributaries i,e. Dhansir and Panchnoi has also lead to the land cover change in the RG Orang NP. It was mentioned earlier that from 1987 to 2008 total 8 km^2 area was newly deposited in the RG Orang NP. Deposition has led to formation of new habitat for rhino and other wild animals in the park. Depositional trend from 1987 to 2008 is more prominent compared to the erosion in the park. It was observed that only 0.96 km^2 area was eroded from 1987 to 2008 by the river Brahmaputra. The formation of new wildlife habitat in the RG Orang NP is shown in the Map No. 22

d) Annual flood in the park:

The RG Orang NP is a flood prone area located in the north bank of river Barmaputra (Kotoky, et. al. 2005). Almost every year the park experiences flood and most of its low lying areas are submerged during the flood period. The seasonal flood in RG Orang NP is a major factor for the changes of land cover pattern of the park. The running water during the monsoon season or flood season carries the seeds of *mimosa invesa* and spread it in all the low lying areas of the park (Vattakkavan, et. al. 2005). This process has encouraged the growth of *mimosa invesa* in the park and its impact on land cover change is already discussed. The annual flood in RG Orang NP is also encouraged the siltation of the wetlands. The debris carried by the river during the flood is deposited in the wetlands which ultimately raised the bed of the wetlands. This process has reduced the water body in the park from 1987 to 1999. This is the period when the depositional activity was more prominent in RG Orang NP. Due to heavy siltation during flood period wetlands are gradually reducing in RG Orang NP. Wetlands are used by rhino for wallowing purpose, to maintain their body temperature. This gradual reduction of wetlands in the park has badly affected the rhino habitat of RG Orang NP.

3.8 Impact of Land Cover Change on Rhino Habitat:

This study reveals that there is a tremendous change of rhino habitat in RG Orang NP from 1987 to 2008. This rhino habitat changes in RG Orang NP were the result of non-implementation of habitat management/manipulation activities on time that are pre-requisite for supporting viable population of flagship animal like the Indian rhino. Similarly the rapid spread of invasive species like *Mimosa invesa* is also responsible for this land cover change in the park. From the study it is found that there is a tremendous change in wet alluvial grassland habitat in the park. The area covered by wet alluvial grassland was drastically reduced from 38.87% to 26.07% from 1987 to 2008 where as dry savannah grassland was substantial increased from 8.73% to

17.98% from 1987 to 2008. Rhinos prefer to use wet alluvial grassland habitat as their prime habitat throughout the year because it provide sufficient amount of food and nutrition for their survival (Laurie, 1978). This change in wet alluvial grassland is mainly due to the impact of three important factors. These are : a) natural succession of dry savannah grassland from wet alluvial grassland, b) natural growth of woodland and c) conversion of wet alluvial grassland to degraded grassland due to the impact of invasive species i.e. *Mimosa invesa* and grazing pressure from the nearby villages of the park. RG Orang NP is a prime habitat of rhino and this change in wet alluvial grassland will have tremendous impact on the survival of the large herbivores in near future. Immediate actions should be taken to manage the rhino habitat of RG Orang NP for conservation of rhino for long run.

3.9 Discussion:

The study shows that there are tremendous changes in land cover pattern in RG Orang NP. These changes in the park are mainly due to the natural factors as well as human impact over the park. The natural factors which contribute in the land cover changes in RG Orang NP are erosion and depositional process by river Brahmaputra and its tributaries, natural succession process of the forest cover and impact of invasive species i.e. *Mimosa invesa*. The human induced factors are over grazing by domestic cattle from the nearby villages of the park and improper management of the grassland habitat by the park managers.

With changing habitat in RG Orang NP, scientific measures are needed to increase the quality of rhinos feeding on habitat within the park through careful manipulation of the habitat and preventing livestock grazing inside the park. Immediate attention is required to intensify the management practices of wet alluvial grassland with sustainable habitat interventions, so that the desired species composition is attained. Scientific measurements should be taken to maintain the wet alluvial grassland like patch burning, suitable cover during the time of re-growth of wet alluvial grassland. Similarly, an artificial water holding mechanism within the park during winter season is crucial to keep wet alluvial grassland available during dry season. Manual uprooting should be done in RG Orang NP to control the invasive species like *Mimosa invesa*. Uprooting needs to be done by October or middle of November every year before the seeds set in. A second removal should be done in the month of April to remove the germinating seedlings and saplings. Similarly, to reduce the degradation of grassland in the park proper protection in the boundary should be taken immediately so that cattle from the nearby villages could not come inside the park.

Finally it is found that geo-spatial technology is quite useful for understanding the wildlife habitat evaluation and habitat quality assessment. It is also recommended that regular monitoring of wildlife habitat in other protected areas of Assam should be done using geo-spatial tool for proper protection and conservation of wildlife including Indian rhino.

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CHAPTER - IV

Chapter IV

Seasonal variation of habitat utilization pattern of Rhino

4.1 Introduction:

The individuals or groups of wild animals never use the entire habitat homogenously, but utilizes selective zones of the habitat. This habitat selection could be determined by the availability of food resources, mate distribution as well as safety from predators (Fjellstad & Steinheim, 1996). There are species-specific variations of habitat use pattern owing to distinct food choice of individual species, which may or may not be available in each habitat patches and home range area (Bell, 1971). The differences of food choice lead to a variation of habitat utilization pattern in different species. It is widely applicable among herbivorous animals. The seasonal variation of food availability, such as burning of grasslands and annual flood affects the variation of habitat utilization pattern of herbivores animals (Lahan, *et al.* 1973, Debroy, 1986). The differences in age and sex ratios of animals were calculated to determine the habitat use types (Hazarika, 2007). The study of the species-specific habitat selection and its utilization pattern are important to draw a comprehensive conservation strategy of the species (Dinerstein, *et al.* 1991, Jnawali, *et al.* 1991)

The studies on the habitat use and utilization pattern of Greater One-horned Rhinos were conducted by Laurie (1978, 82), Rookmaaker (1982) and Dinerstein & Price (1991) in Terai grassland ecosystem of Chitwan National Park and Royal Bardia Wildlife Sanctuary in Nepal. However, very little information is available regarding the study of habitat utilization pattern of Indian Rhino in the Brahmaputra floodplain habitat (Hazarika, et. al. 2006). This present chapter try to analyse the seasonal variation of habitat utilization patter of Indian rhino in RG Orang NP. The prime aim of this study was to find out the habitat preferences of rhino in different seasons of a year in RG Orang NP.

4.2 Habitat utilization pattern of rhino in 2008/09:

During the study period from September, 2008 to September, 2009 rhino was sighted 183 times in RG Orang NP in different habitats. The total rhino population of RG Orang NP is 64 as per 2009 census conducted by Department of Environment and Forest, Govt of Assam. These 64 rhinos were sighted 183 times in different habitats of the park throughout the year long survey. Study revealed that, the Indian rhino use maximum 59.56% of wet alluvial grassland habitats, followed by 24.59% dry savannah grassland, 13.11% woodland habitat and only 2.74% of wetlands habitat in RG Orang NP during the study period from September, 2008 to September, 2009. During the study period out of 183 rhinos, 109 rhinos were sighted in wet alluvial grassland habitat, followed by 45 rhinos were found in dry savannah grassland, 29 rhinos were found in woodland and wetland habitat. The Indian rhinos were never sighted in other habitats like sandy areas, degraded grasslands or in seasonal swamp forests during the study period. But hoof marks were seen in these habitats. The figure IV a. shows the habitat utilization pattern of rhino in RG Orang NP for the year 2008-09. This indicates that during the study period from September, 2008 to September 2009 rhinos of RG Orang NP used maximum wet alluvial grassland, followed by dry savannah grassland, woodland and wetlands. It seems that rhinos prefer mostly wet alluvial grassland in RG Orang NP in all the seasons of the year. It is also evident from some recent study on rhino habitat utilization pattern and also in ecology and behavioural study of one horned rhino that rhino prefers mostly wet alluvial grassland (Steinheim, *et al.* 2005; Deka, *et al.* 2002; Laurie, 1979). The chi square goodness of fit analysis also shows that irrespective of seasons, significantly highest number of rhinos were found in wet alluvial grassland (**χ^2 = 134.09, df= 4, $p<0.01$**).

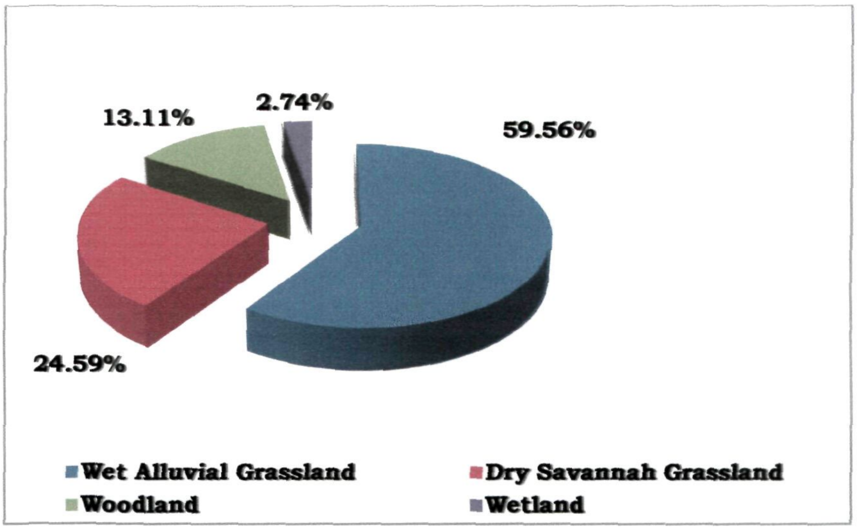


Fig. IV a. Habitat utilization pattern of rhino in RG Orang NP in the year 2008/2009 (Data in % basis)

In case of block wise habitat utilization pattern of rhino in RG Orang NP, highest number of rhino was sighted in Satsimalu Block. Out of total 183 rhino sighted, 51 rhinos were sighted in Satsimalu block of RG Orang NP throughout the year long survey from September, 2008 to September, 2009. This indicates that rhinos prefer Satsimalu block most in comparison to other blocks of the park. The main cause behind this is the availability of food plant for rhino i.e. wet alluvial grassland and water body for wallowing in this block. The table IV a. shows the block wise sighting of rhino in RG Orang NP in the year 2008-2009.

Table IV a. Block wise rhino sighting in RG Orang in the year 2008 – 2009.

Blocks	No of rhino sighting
Baghmari	14
Belsiri	0
Boogbeel	7
Chaila	9
Gaimari	10
Jhawani	0
Magurmari	11
Moalamari	19
Oogli	10
Pabhomari	6
Rahmanpur_A	2
Rahmanpur_B	18
Ramdas	0
Ramkong	6
Satsimalu	51
Solmar	8
Tinkona	12
Brahmaputra_River	0

Source: Field Data

The table IV a. indicates that rhino prefer mostly Satsimalu block of RG Orang NP as the habitat of the block is mainly composed with wet alluvial grassland. It also seems that rhino sighting was more in those blocks where wet alluvial grassland was also more. There is a positive correlation between rhino sighting and wet alluvial grassland (**R = 0.582**). The figure IV b. shows the correlation between these two variables i.e. block wise percentage of wet alluvial grassland and number of rhino sighting. Here percentage of wet alluvial grassland was considered as independent variable and number of rhino sighting was considered as dependent variable.

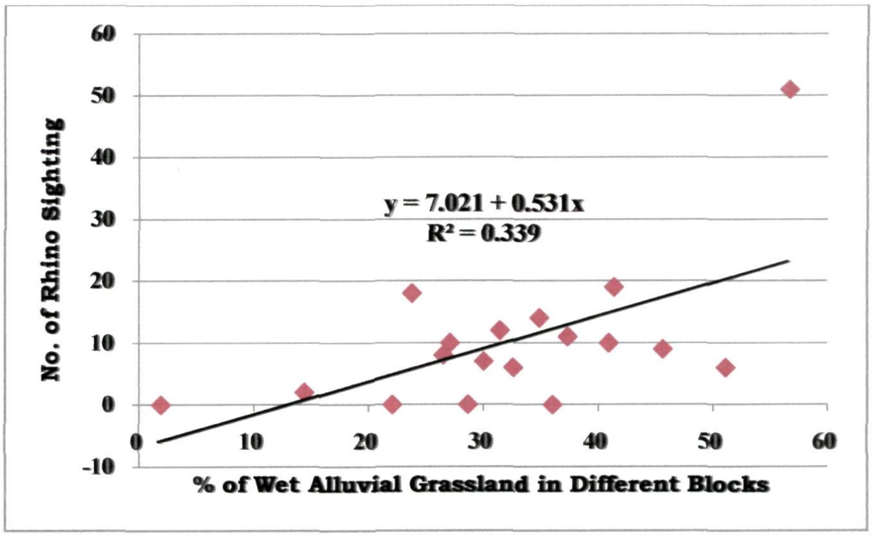


Fig. IV b. Correlation between wet alluvial grassland and rhino sighting.

4.3 Seasonal variation of habitat utilization pattern:

The seasonal variation of food availability, burning of grasslands and annual flood affects the variation of habitat utilization pattern of herbivores animals (Lahan, *et al.* 1973, Debroy, 1986). Rhino is a mega herbivore and its habitat utilization pattern is also changes depending upon availability of food, cover and water in different seasons of a year. To understand the seasonal variation of rhino habitat utilization pattern in RG Orang NP, rhinos were monitored throughout the year from September 2008 to September 2009. The entire year was categorized in to four seasons like Pre-monsoon season (March to May), Monsoon (June to August), Retreating Monsoon season (September to November) and Winter season (December to February). Rhinos were monitored in all the seasons using trained elephants, available with the park authority of RG Orang NP. The chi-square goodness of fit analysis has been done to understand the habitat utilization pattern of rhino in RG Orang NP. The widely used chi-square statistics was introduces by Karl Pearson in the year surrounding 1900 (Zar, 2007). Chi-square is a statistical measure used in the context of sampling analysis for comparing a variance to a theoretical variance. As a non-parametric test it can be used to determine if categorical data shows dependency or the two classifications are independent. It can also be used to make comparison between theoretical populations and actual data when categories are used (Kothari, 2009). The result of the chi-square goodness of fit analysis shows that there were significant association between habitat types and seasons in distribution of rhinos in RG Orang NP (**χ^2 = 16.97, df =9, p<0.05**) in the year 2008-2009. It also indicates that rhinos were scattered in the park according to seasons and habitat; i.e., they were sighted in certain habitats in certain seasons. Similarly irrespective of seasons, significantly high number of rhinos were found in wet alluvial grasslands (**χ^2 = 134.09, df =4, p<0.01**) in the year 2008-2009. It reveals that rhino prefers wet alluvial grasslands in RG Orang NP, which is also evident from recent research works on one-horned rhino in Nepal and India (Steinheim, *et al.* 2005, Deka, *et al.* 2002) and also in ecology and behaviour study of one horned rhino (Laurie, 1979). The season wise rhino habitat utilization pattern in RG Orang NP in the year 2008 – 2009 is discussed below.

4.3.1 Pre-monsoon Season (March – May):

The study shows that, the rhinos of RG Orang NP used 61.84% of wet alluvial grasslands, followed by 22.36% of dry savannah grasslands, 15.60% of woodland and 0.20% of wetland habitat in pre-monsoon season. Here in pre monsoon season significantly highest number of rhinos were found in wet alluvial grassland habitat (**$\chi^2 = 63.05$, df = 3, $p<0.01$**). The figure IV c. shows the habitat utilization pattern of rhino during pre-monsoon season. Similarly Map No. 25 shows the rhino sighting locations in RG Orang NP during pre-monsoon season.

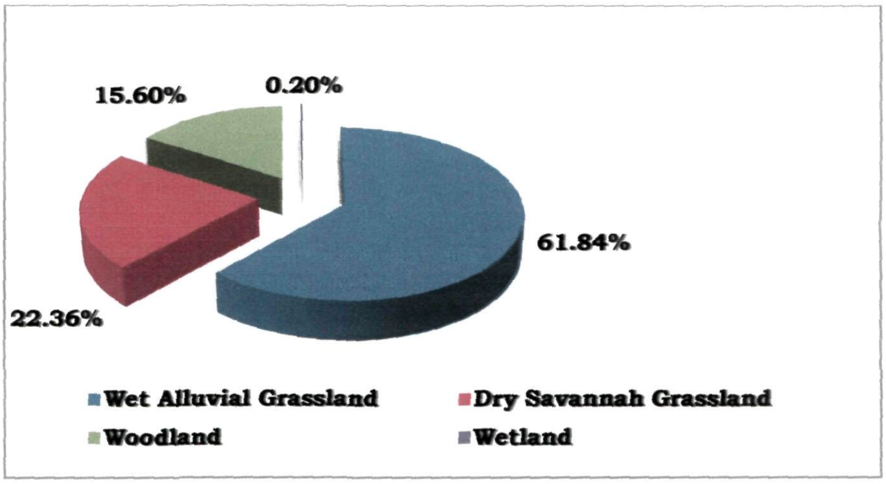
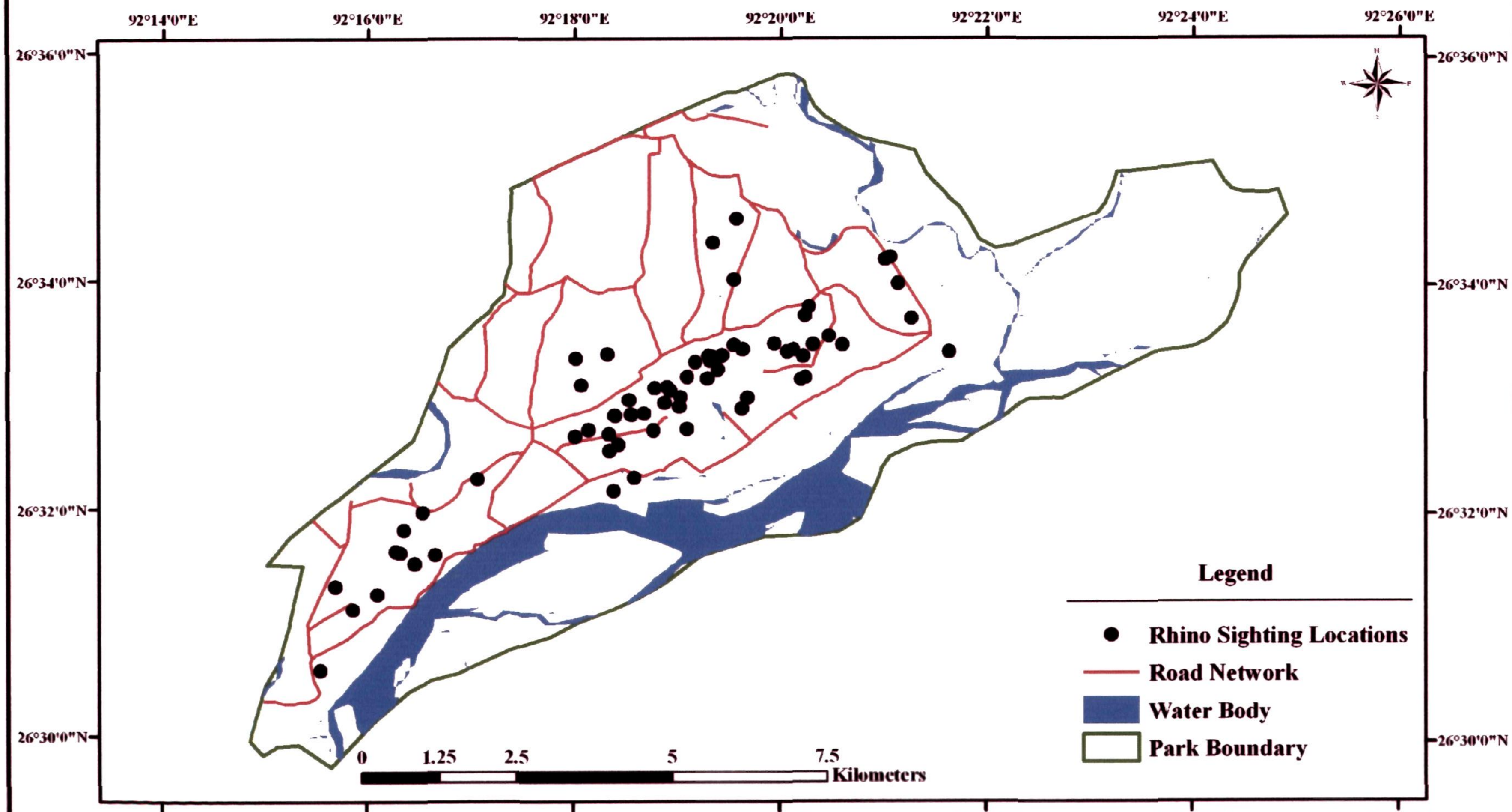


Fig. IV c. Habitat utilization pattern of rhino in RG Orang NP during pre-monsoon season (Data in % basis)

The figure IV c. indicates that in pre monsoon season rhino prefers mostly wet alluvial grassland in RG Orang NP.

Rhino Sighting Locations in Pre-monsoon Season



Source: Prepared by researcher based on field data.

Map No. 25

4.3.2 Monsoon Season (June – August):

The study shows that during monsoon season rhinos used 48.71% of wet alluvial grasslands, followed by 35.89% of dry savannah grasslands, 12.82% of woodland and 2.58% of wetland habitat in RG Orang NP. During the monsoon season significantly highest number of rhinos were sighted in wet alluvial grasslands (**$\chi^2 = 20.79$, df = 3, $p<0.01$**). The figure IV d. shows the habitat utilization pattern of rhino in RG Orang NP during monsoon season. Similarly the Map No. 26 shows the sighted location of rhino during monsoon season in RG Orang NP.

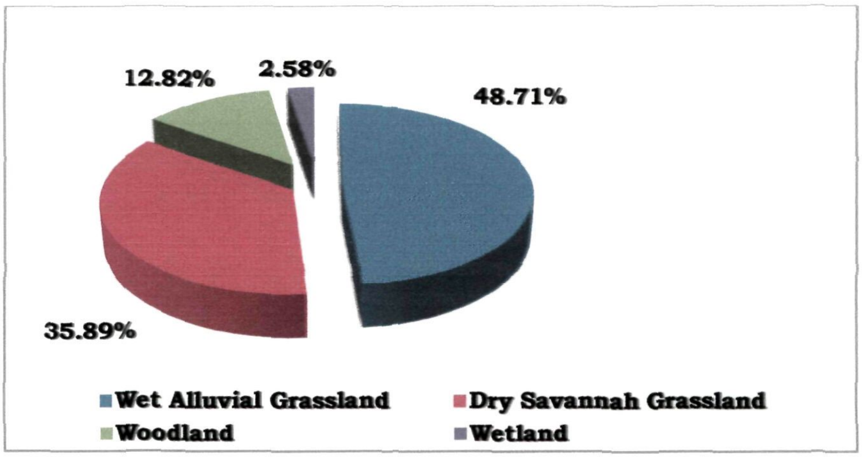
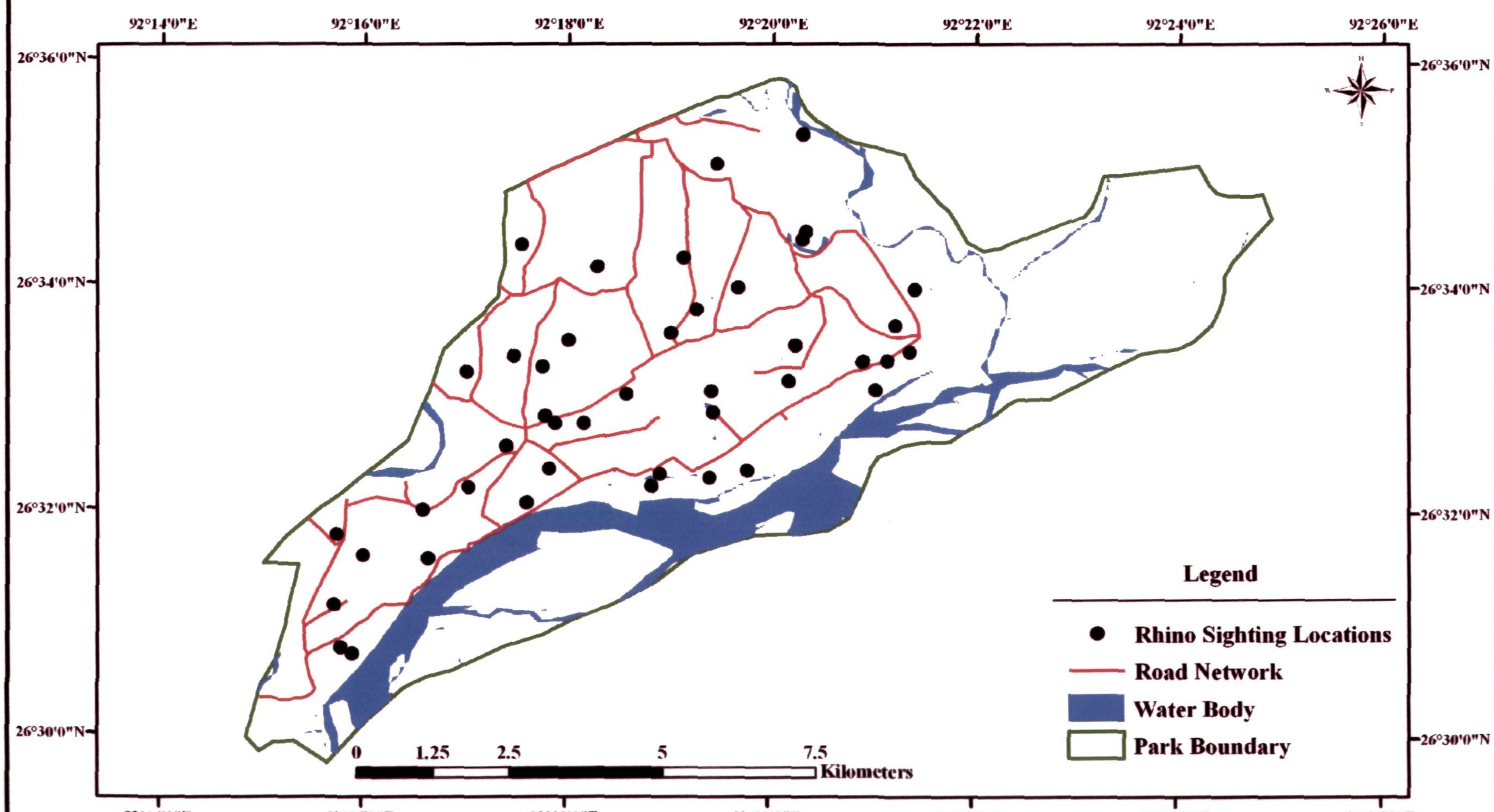


Fig. IV. d. Habitat utilization pattern of rhino in RG Orang NP during monsoon season (Data in % basis)

From the study it becomes evident that during monsoon season also rhinos prefer mostly wet alluvial grassland in RG Orang NP.

Rhino Sighting Locations in Monsoon Season



Source: Prepared by researcher based on field data.

Map No. 26

4.3.3 Re-treating monsoon Season (September – November):

Findings show that during retreating monsoon season rhinos have used 65.62% of wet alluvial grassland followed by 21.87% dry savannah grassland, 12.50% woodland and 0.01% of wetland habitat in RG Orang NP. In retreating monsoon season also significantly highest number of rhinos were sighted in wet alluvial grasslands (**χ^2 = 31.20, df = 3, p<0.01**). The figure IV e. shows the habitat utilization pattern of rhino in RG Orang NP during retreating monsoon season in the year 2008-2009. Similarly the Map No. - 27 shows the spatial distribution of rhino in RG Orang NP during retreating monsoon season.

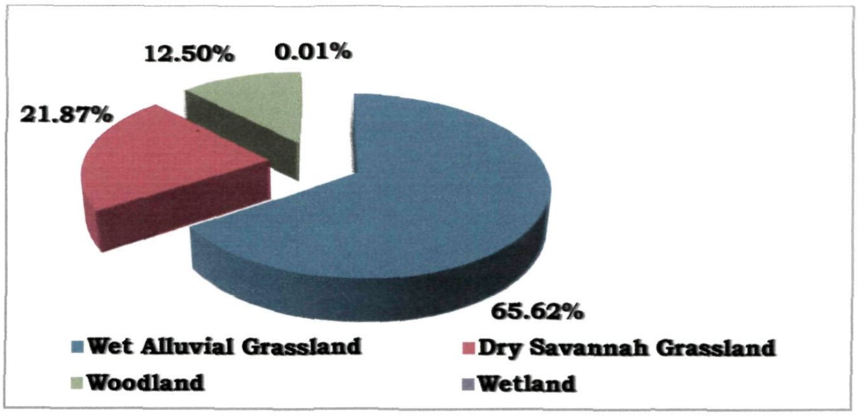
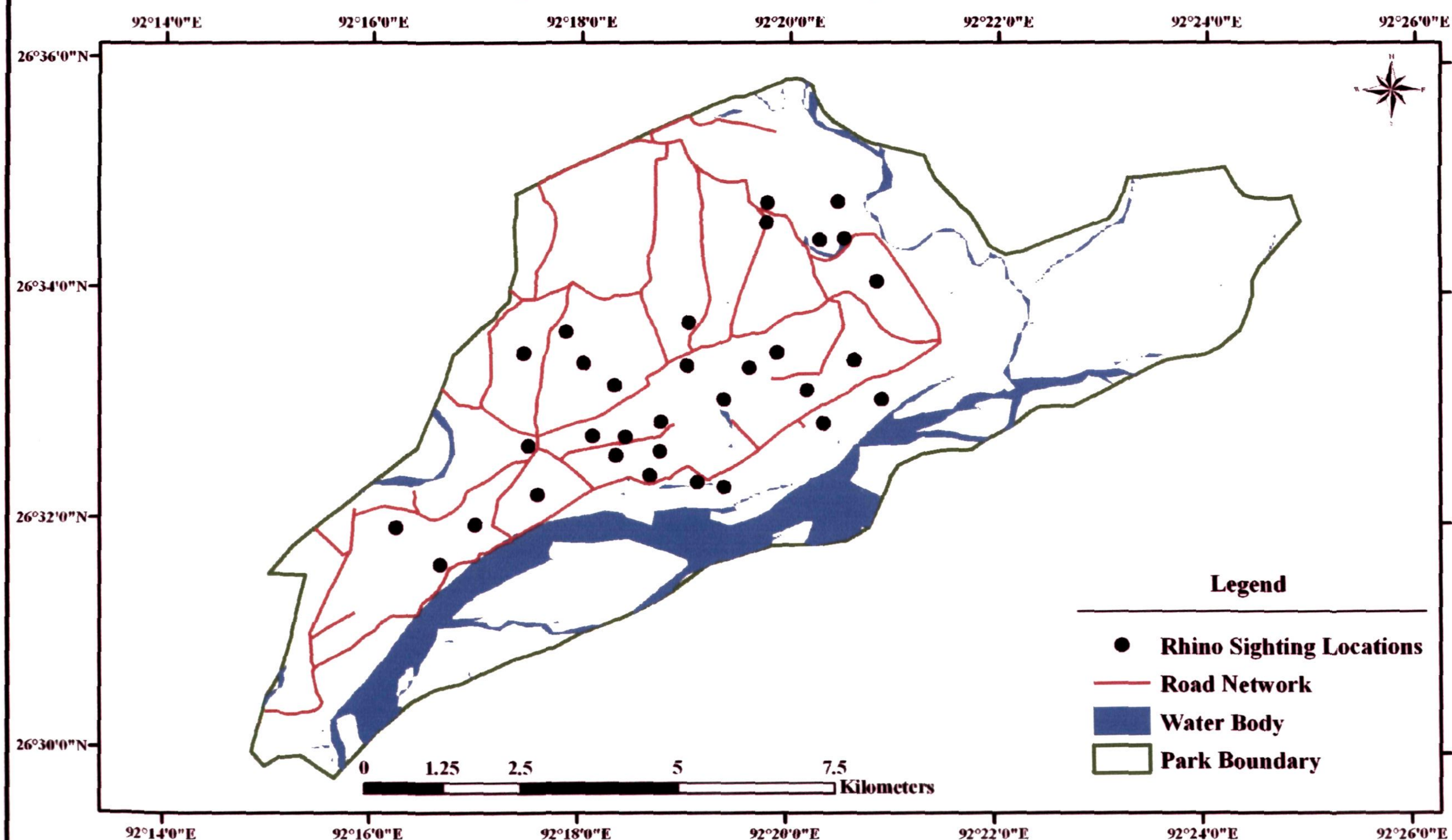


Fig. IV e. Habitat utilization pattern of rhino in RG Orang NP during re-treating monsoon season(Data in % basis)

In retreating monsoon also it seems that rhinos use mostly wet alluvial grassland in RG Orang NP.

Rhino Sighting Locations in Retreating-monsoon Season



Source: Prepared by researcher based on field data.

Map No. 27

4.3.4 Winter Season (December – February):

In winter season the result shows that rhino used 61.11% of wet alluvial grassland followed by 19.44% dry savannah grassland, 11.12% woodland and 8.33% wetland habitat in RG Orang NP. In winter season significantly highest number of rhino was sighted in wet alluvial grassland area (**$\chi^2 = 26.06$, df = 3, $p<0.01$**). The figure IV f. shows the habitat utilization pattern of rhino in RG Orang NP during winter season of the year 2008-2009. Map No. - 28 show the spatial distribution of the rhino during winter season in RG Orang NP.

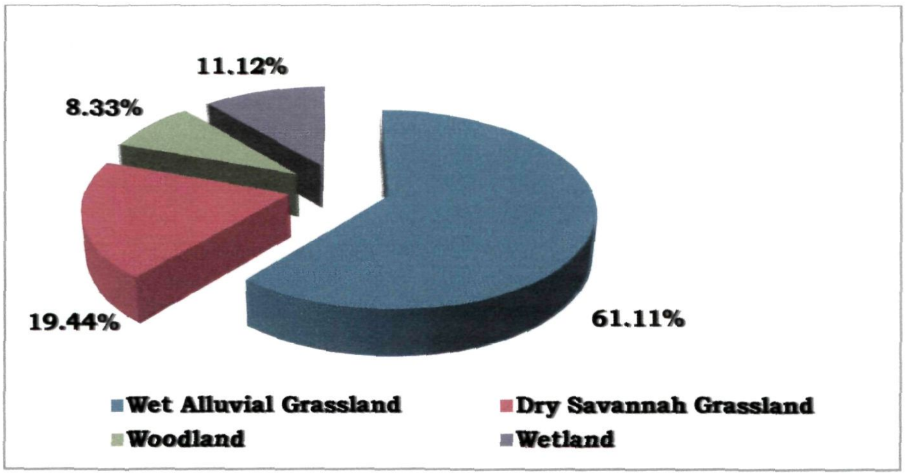
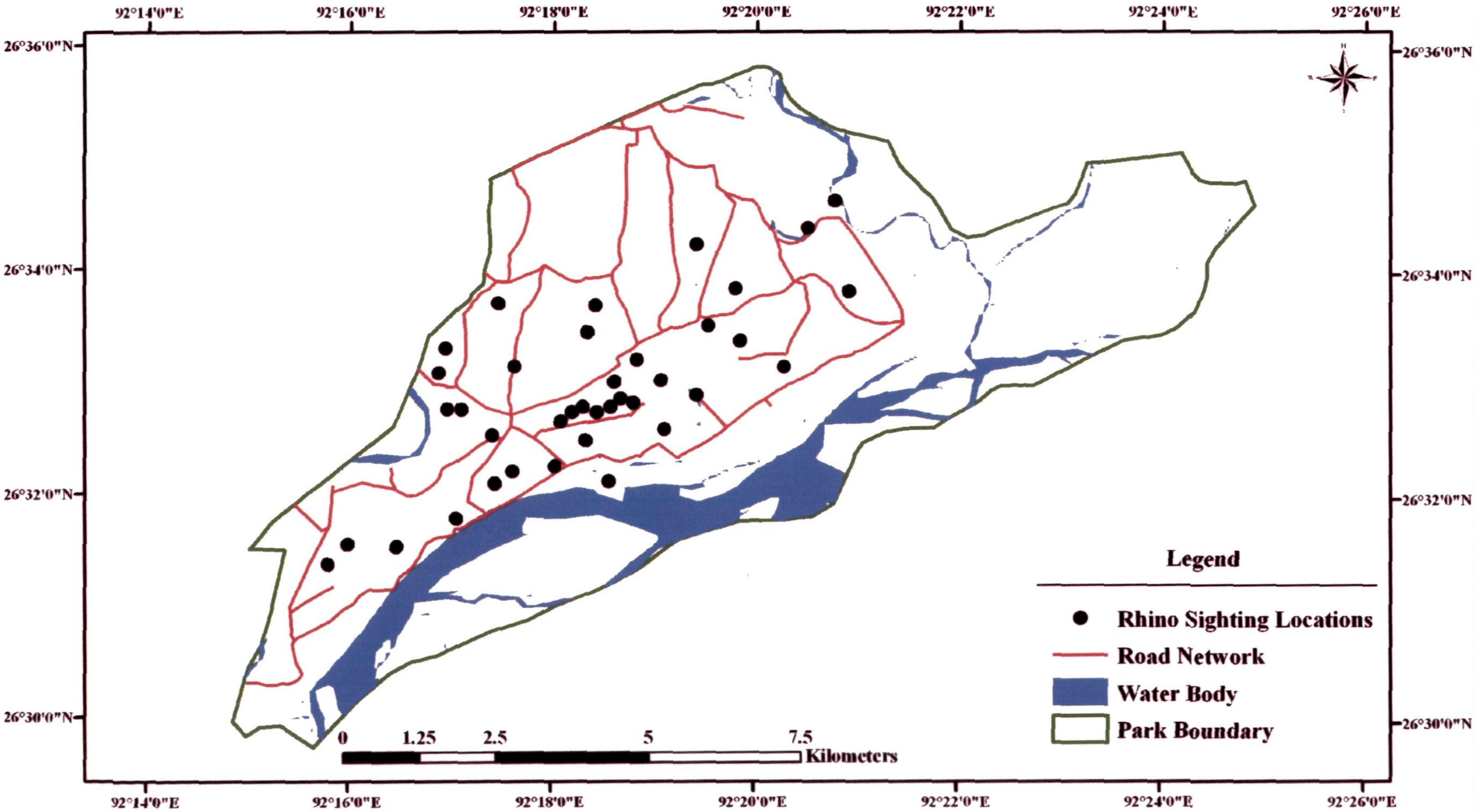


Fig. IV f. Habitat utilization pattern of rhino in RG Orang NP during winter season (Data in % basis)

In winter season also it seems that rhinos prefer mostly wet alluvial grassland in RG Orang NP.

Rhino Sighting Locations in Winter Season



Source: Prepared by researcher based on field data.

Map No. 28

The above discussion shows that in all the seasons of the year 2008 – 2009, rhinos prefer mostly wet alluvial grassland in RG Orang NP. The reason for this is the wet alluvial grassland provides sufficient food and cover to rhino in all the seasons of a year. The rhino prefers wet alluvial grass species for forage and it is also used by the rhino for wallowing. Wallowing is a prominent activity of Greater one horned rhino and they prefer low lying areas with mud and water. Usually rhinos selected wallows with a water pool. The rhino probably wallow to cool off and to get rid of ectoparasites (Pal, 1982, 1986). Wet alluvial grassland provides all these necessary requirements to rhino and because of this rhino prefers mostly wet alluvial grassland. Study shows that rhino used wet alluvial grassland most during retreating monsoon season (September to November). During that period 65.62% of wet alluvial grassland was used by rhino in RG Orang NP. During pre-monsoon season (March to May) 61.84% of wet alluvial grassland was used by rhino in the park, similarly during winter season also 61.11% wet alluvial grassland was used by rhino in RG Orang. But during monsoon season it was seen that wet alluvial grassland was less utilized by rhinos n RG Orang NP. During that season only 48.71% of wet alluvial grassland was used by the rhinos of RG Orang NP. It is mainly due to the impact of flood during that season. During the monsoon season most of the low lying areas of RG Orang NP were submerged due to flood and in that season rhinos prefer to stay in high elevation areas, where dry savannah grassland is prominent. In case of dry savannah grassland it was observed that rhino used this habitat highest in the monsoon season (35.89%) followed by pre-monsoon season (22.36%), retreating monsoon season (21.87%) and finally in winter season (19.44%). It indicates that rhinos prefer dry savannah grassland in monsoon season in RG Orang NP. In case of woodland habitat it was observed that rhinos used this habitat most in the pre-monsoon season (15.60%), followed by monsoon season (12.82%), retreating monsoon season (12.50%) and finally in winter season (11.12%). In case of wetland habitat the rhino used this habitat most in winter season (8.33%) in RG Orang NP, followed by monsoon season (2.58%), pre-monsoon season (0.20%) and finally in retreating monsoon season (0.01%). Rhinos prefer wetland habitat in winter season because during winter season most of the area of RG Orang NP is generally dried up due to low rainfall and because of this they prefer wetland habitat for wallowing purpose.

4.4 Block wise habitat utilization patter of rhino in different seasons:

In RG Orang NP, there are 18 blocks, which were demarcated by the park authority for management and conservation of wildlife and their habitat. During the field survey period from September 2008 to September 2009 it was observed that the distribution of rhinos was different in different blocks in different seasons. It seems that rhinos prefer some particular blocks in particular season. The table IV b. shows the number of rhino sighting in different block in different block in different seasons.

Table: IV b. Block wise habitat utilization pattern of rhino in different seasons in RG Orang NP

Blocks	Pre Monsoon	Monsoon	Retreating Monsoon	Winter
Baghmari	4	3	3	4
Belsiri	0	0	0	0
Boogbeel	2	2	1	2
Chaila	2	4	2	1
Gaimari	3	2	3	2
Jhawani	0	0	0	0
Magurmari	3	4	2	2
Moalamari	11	3	3	2
Oogli	0	4	4	2
Pabhomari	1	2	2	1
Rahmanpur_A	0	2	0	0
Rahmanpur_B	3	5	4	6
Ramdas	0	0	0	0
Ramkong	1	3	2	0
Satsimalu	26	4	8	13
Solmar	4	2	1	1
Tinkona	2	4	2	4
Brahmaputra_River	0	0	0	0

Source: Field Data.

The table – IV b. shows that rhino prefer some particular blocks in RG Orang NP in some particular seasons. This variation of habitat utilization pattern of rhino is mainly due to the availability of habitat requirements like food, cover and water. During pre-monsoon season highest rhino was sighted in Satsimalu block. There were as many as 26 rhinos were sighted in this block in pre-monsoon season. It seems that in pre-monsoon season rhino prefers mostly Satsimalu block of RG Orang NP. The main causal factor behind this is the availability of wet alluvial grassland and small wetlands in Satsimalu block. During pre-monsoon season Satsimalu block provide all the requirements for the survival of rhino i.e. food, cover and water and because of this rhino prefer to use this block more in comparison to other blocks of the park. Similarly, during winter season also rhino sighting was highest in Satsimalu block. Total 13 rhinos were sighted in this block during winter season. It is also mainly due to the availability of water holes in this block during winter which was used by the rhino for wallowing purpose. Similarly in Maolamari block rhino sighting was more during pre-monsoon season. Total 11 rhinos were sighted in Maolamari block during pre-monsoon season. But in other seasons of the year rhinos were sighted almost equally in Maolamari block. This indicates that habitat utilization pattern of rhino in RG Orang NP changes with the availability of habitat requirements in different blocks in different seasons of a year. The figure IV g. shows the graphical representation of block wise habitat utilization pattern of rhino in RG Orang NP during 2008 – 2009 periods.

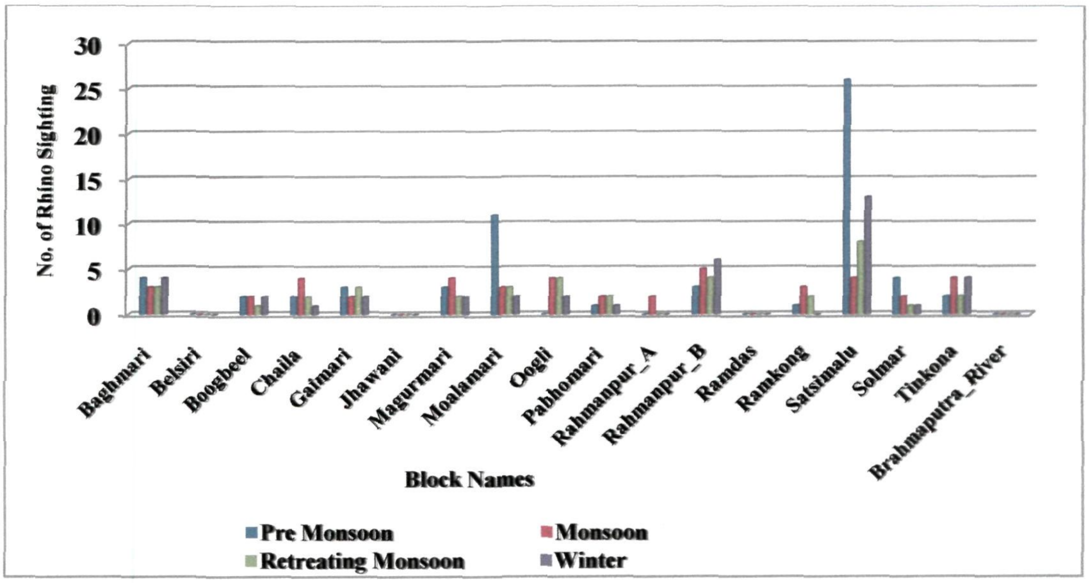


Fig. IV g. Block wise habitat utilization pattern of rhino in different seasons

4.5 Discussion:

From the above analysis it is clear that in all seasons significantly highest number of rhinos were sighted in wet alluvial grasslands in RG Orang NP during 2008-2009 (**χ^2 = 134.09, df = 4, p<0.01**). It indicates that rhino prefers mostly wet alluvial grasslands in all seasons of a year (59.56%). It is evident from the present study that, the Indian rhino in RG Orang NP prefers wet alluvial grasslands throughout the year. This habitat selection of Indian rhino is not because of food availability, but also positive selection of foraging ground. Since, most of the rhinos prefer fodder, which are available in the wet habitat (marshy land) of the study area. There are many reasons which lead to selection of wet alluvial grassland habitat by rhino. Firstly, grass types of the wet alluvial grassland habitat are relatively soft than the dry savannah grasslands. Secondly, the Indian rhinos forage on marshy habitats where they confront fewer disturbances from annoying flies. Thirdly, the body temperature is regulated by water content available in the marshy habitat while grazing, standing and wallowing in waterlogged areas. Again the edible grasses are available in wet alluvial grasslands and marshy habitats in all seasons. The tall grasses become mature during late October then soft grasses becomes coarse, hard and unpalatable, hence, the Indian rhino seldom use dry savannah grasses after October. Ghose, (1991), reported this type of grazing situation on unpalatable grasses of dry grassland from October onwards until sprouting stage of new grass in his study. It is also come to know that during monsoon season rhino utilized wet alluvial grassland comparatively less than the other seasons of the year and it is mainly due to the impact of seasonal flood in the low lying areas of the park. This study also shows that the habitat utilization pattern of rhino changes in blocks with the changing of seasons. This indicates that rhinos prefer some specific habitat blocks in specific season. Finally, this study shows that the habitat utilization pattern of rhino is dependent upon the availability of the habitat requirements like food, cover and water, which are required for the survival of the species. This study also shows that in different seasons of a year the habitat utilization pattern of rhino is also different.

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CHAPTER - V

Chapter V

Spatial Distribution of Rhino Habitat

5.1 Introduction:

With the exponential growth of human population and consequent demand on natural resources, the earth is being transformed from large expanses of natural vegetation to a patchwork of natural, modified and man-made ecosystems. Faced with such reduction, fragmentation or complete disappearance of their specific habitat, many wildlife species have suffered reduction in their numbers or range, or have become extinct. The hunting, fishing, collection or poaching may be classified as direct negative effect, and they indirectly detrimental to wildlife habitat. The alteration and loss of habitat is considered greatest threat to the richness of life on earth (Meffe *et al.* 1994). Mapping of different wildlife habitat type and their distribution is always an interesting topic of discussion for the ecologist and biodiversity conservationist. Assessment of distribution or status of particular habitat types often forms an important part of any conservation related work (Newton, 2008). Particular species of conservation concern may be associated with particular types of habitat and estimation of the extent and distribution of potential habitat for such species may therefore form an important part of conservation planning. Habitat assessment of a particular species of conservation concern is always an important before developing any conservation strategy. Habitat evaluation is the first step towards meaningful wildlife conservation and management (Kushuwaha *et al.* 2004). Evaluation of wildlife habitats based on ecological principle is well established in USA in connection with environmental impact assessment, where the aim has been to ensure appropriate consideration to wildlife in the development planning process. At the same time, there has been considerable pressure for the use of standardized procedures for habitat evaluation, both for economic as well as ecological reasons among various organizations and professionals. This pressure for standardization is one of the reason why the Habitat Evaluation Procedure (HEP) was developed (initially by US Fish and Wildlife Service) to use in the evaluation of water and related land resources development projects (US Fish and Wildlife Service, 1981).

The geospatial technology, including remote sensing and GIS, holds the potential for timely and cost-effective assessment of natural resources. Remotely sensed data provides synoptic, frequent, real-time assessment, monitoring and management of large areas. Earlier studies suggest a significant role for geospatial technology in wildlife conservation and management. Remote sensing data have been used for habitat evaluation of *sambar* and *muntjak* by Kushwaha *et al.* (2004). Hazarika (2005) used

Landsat and IRS satellite imagery for the habitat assessment for rhino in Kaziranga National Park of Assam. Kafley *et al.* (2009) have used Landsat TM data for the habitat evalution of rhino in Chitwan National Park of Nepal. Thapa (2005) have used Landsat data and GIS techniques for evaluation of rhino habitat in Chitwan National Park. Habitats of rhino, wild buffalo, swamp deer, hog deer, Asian elephant, have been evaluated using high resolution space photographs and Landsat multispectral data.

In this chapter rhino habitat evaluation of RG Orang NP was done using IRS P 6 LISS III multispectral satellite imagery of 8th November 2008. A micro level habitat evaluation approach was adopted using as many as 18 blocks, demarcated and generated by the RG Orang NP authority for conservation and management of rhino habitat. Block wise distribution of rhino habitat and their area coverage was assessed using the satellite image with proper ground verification.

5.2. Rhino habitat of RG Orang NP:

In RG Orang NP nine habitat types are recognized based upon ground observation and collected training sets. These were collected from the field using GPS device. The nine habitat types were already discussed in detail in chapter III. In this chapter block wise habitat pattern and their spatial distribution is discussed in detail.

5.3 Block wise distribution of rhino habitat:

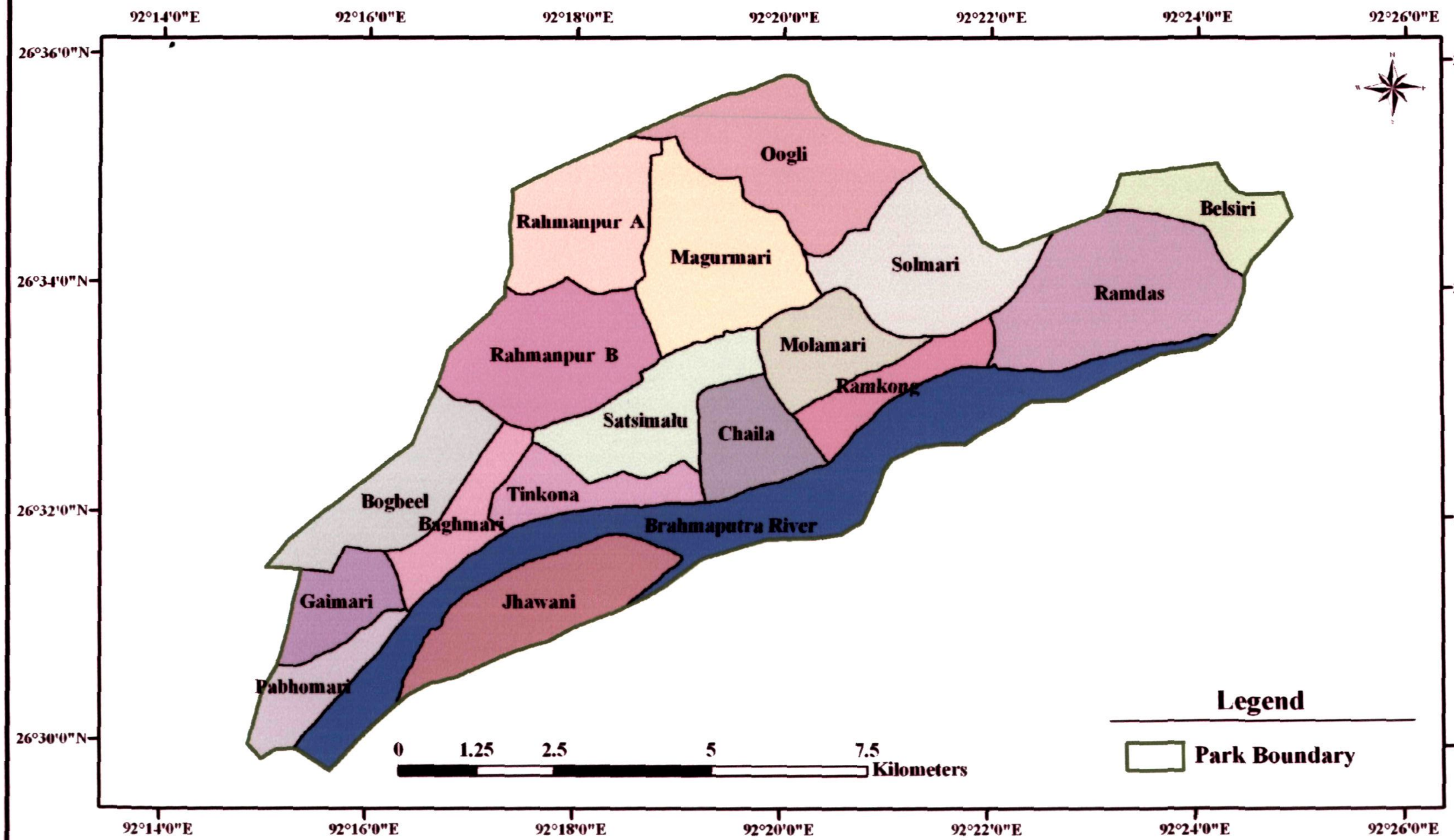
The RG Orang NP is one of the prime rhino habitats of Assam covering an area of 78.8 km^2 (Talukdar *et al.* 2007). The park authority has divided the park in to 18 blocks, which are used for monitoring of wild animals including rhino and also for habitat management practices. These block areas are created based on habitat characteristics, location of anti poaching camps and also using trained elephants. The Map No. 29 shows the location of these blocks in the RG Orang NP. The details of the blocks and their respective percentage area coverage are shown in the table –V a. and figure V a.

Table: V a. Area covered by each block in RG Orang NP

Sl. No.	Blocks	Area in km²	% of area cover
1	Baghmari Block	2.36	2.99
2	Belsiri Block	2.34	2.96
3	Boogbeel Block	4.29	5.44
4	Chaila Block	2.87	3.64
5	Gaimari Block	2.37	3
6	Jhawani Block	4.94	6.27
7	Magurmari Block	6.35	8.06
8	Moalamari Block	3.02	3.83
9	Oogli Block	6.24	7.92
10	Pabhomari Block	2.22	2.82
11	Rahmanpur_A Block	4.78	6.07
12	Rahmanpur_B Block	5.94	7.53
13	Ramdas Block	7.49	9.50
14	Ramkong Block	2.33	2.96
15	Satsimalu Block	4.32	5.48
16	Solmar Block	5.68	7.22
17	Tinkona Block	2.45	3.13
18	Brahmaputra_River Block	8.81	11.18

Source: RG Orang NP authority

Blocks of Rajiv Gandhi Orang National Park



Source: RG Orang NP authority

Map No. 29

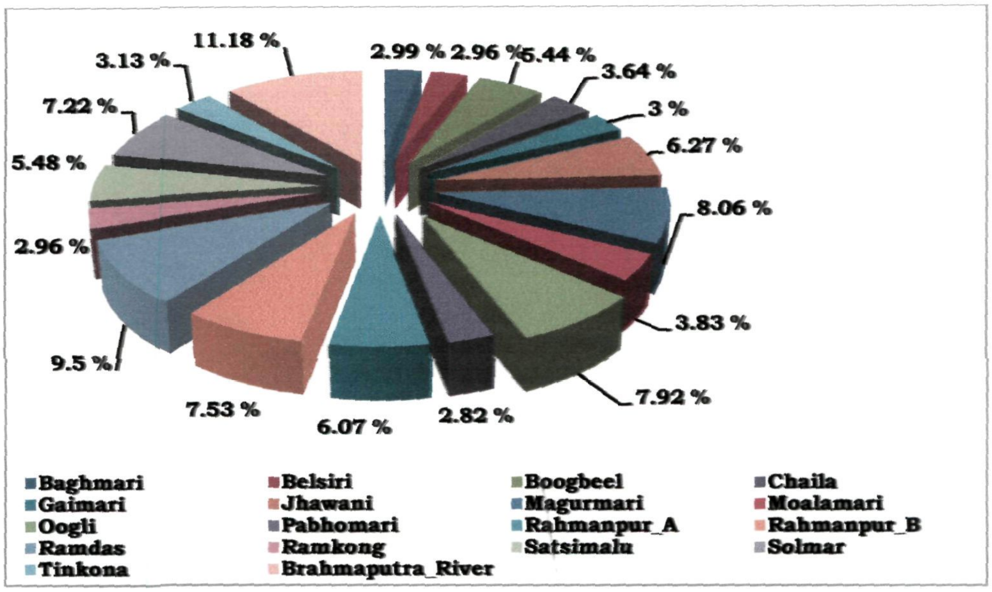


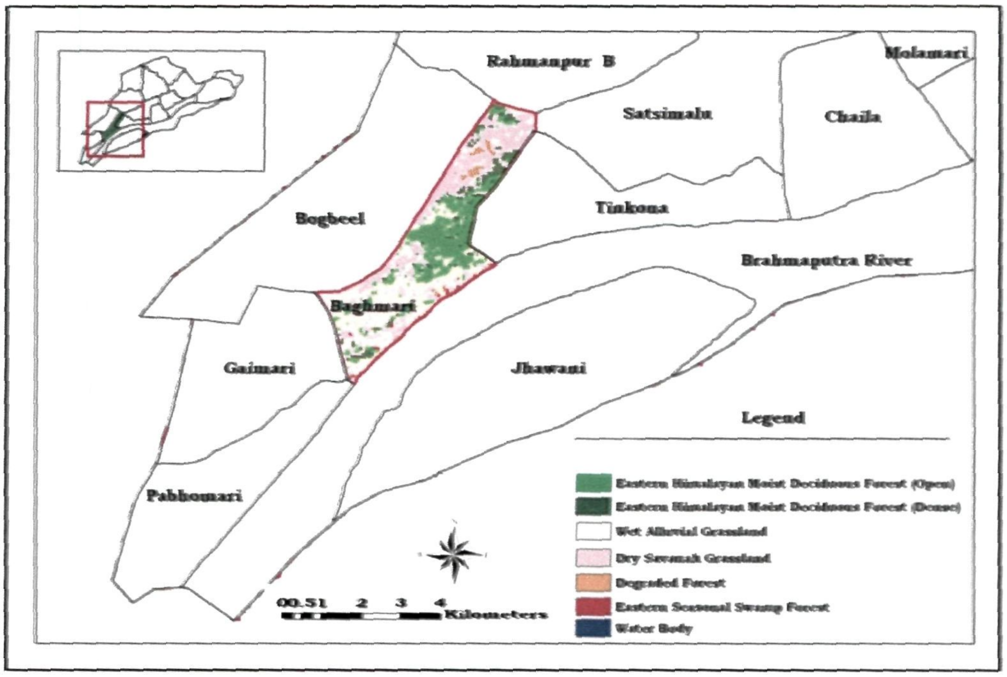
Fig. V a. Percentage of area covers by each block of RG Orang NP

The table V a. shows that the biggest block in RG Orang NP is the Brahmaputra block covering 8.81 km^2, which is 11.18% of the total geographical area of the park. Similarly Pabhomari block is the smallest block in the park with an area of 2.22 km^2 which is 2.82% of the total geographical area of the park.

The individual habitat characteristics and their spatial distribution in each block are discussed below in detail:

5.3. i Baghmari Block:

Baghmari block of RG Orang NP covers an area of 236 hectares (Map No. 30). The habitat of Baghmari block is consist of eastern Himalayan moist deciduous forest (Dense), eastern Himalayan moist deciduous forest (Open), wet alluvial grassland, dry savannah grassland, degraded grassland, eastern seasonal swamp forest and water body. Wet alluvial grassland is prominent in this block covering an area of 82.26 hectares which is 34.86 % of the total geographic area of the block. The dry savannah grassland covers an area of 70.2 hectares which is 29.74 % of the block. The Eastern Himalayan Moist Deciduous Forest (open) covers an area of 53.1 hectares which is 22.5% of the total area of the block. The table – V b. and figure V b. shows habitat types of Baghmari block with their respective areal coverage.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 30

Table: V b. Habitat pattern of Baghmari Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	18.54	7.86
Eastern Himalayan Moist Deciduous Forest (Open)	53.1	22.52
Wet Alluvial Grassland	82.26	34.88
Dry Savanah Grassland	70.2	29.77
Degraded Grassland	4.95	2.09
Eastern Seasonal Swamp Forest	2.34	0.99
Water Body	4.41	1.89

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

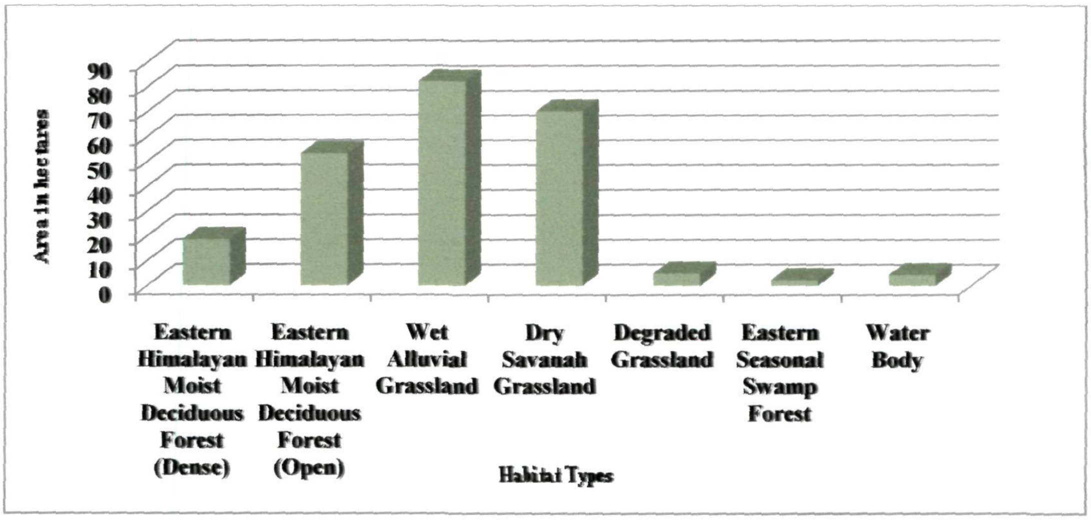
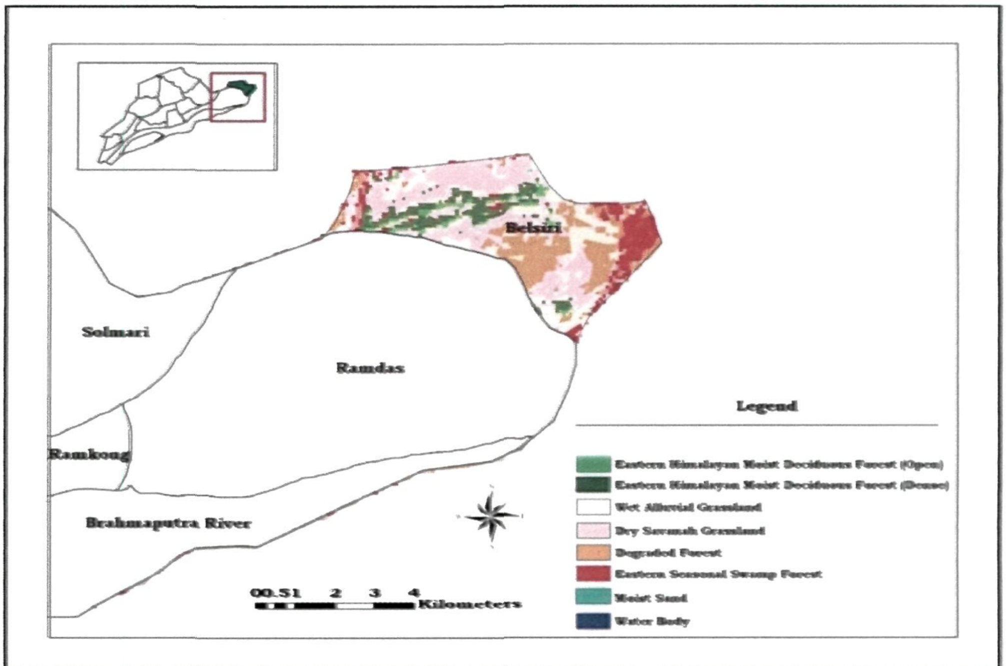


Fig. V b. Habitat pattern of Baghmari Block

5.3. ii Belsiri Block:

Belsiri block of RG Orang NP is located in the western most part of the park (Map No. 31). The total area of this block is 258.8 hectares. The habitat types available in this block are eastern Himalayan moist deciduous forest (Dense), eastern Himalayan moist deciduous forest (Open), wet alluvial grassland, dry savannah grassland, degraded grassland, eastern seasonal swamp forest, moist sand and water body. Result shows that dry savannah grassland is more prominent in this block covering an area of 84.42 hectares, which is 32.63 % of the total geographical area of the block, followed by the wet alluvial grassland covering an area of 57.06 hectares (22.05%), degraded grassland covers an area of 52.47 hectares (20.28%). The eastern Himalayan moist deciduous forest (Dense and Open) covers an area of 35.1 hectares which is 13.56 % of the total area of the block. The table – V c. and figure V c. shows the habitat types and their respective area cover in Belsiri block.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 31

Table: V c. Habitat pattern of Belsiri Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	24.39	9.42
Eastern Himalayan Moist Deciduous Forest (Open)	10.71	4.14
Wet Alluvial Grassland	57.06	22.05
Dry Savanah Grassland	84.42	32.63
Degraded Grassland	52.47	20.28
Eastern Seasonal Swamp Forest	25.2	9.74
Moist Sand	0.81	0.31
Water Body	3.69	1.43

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

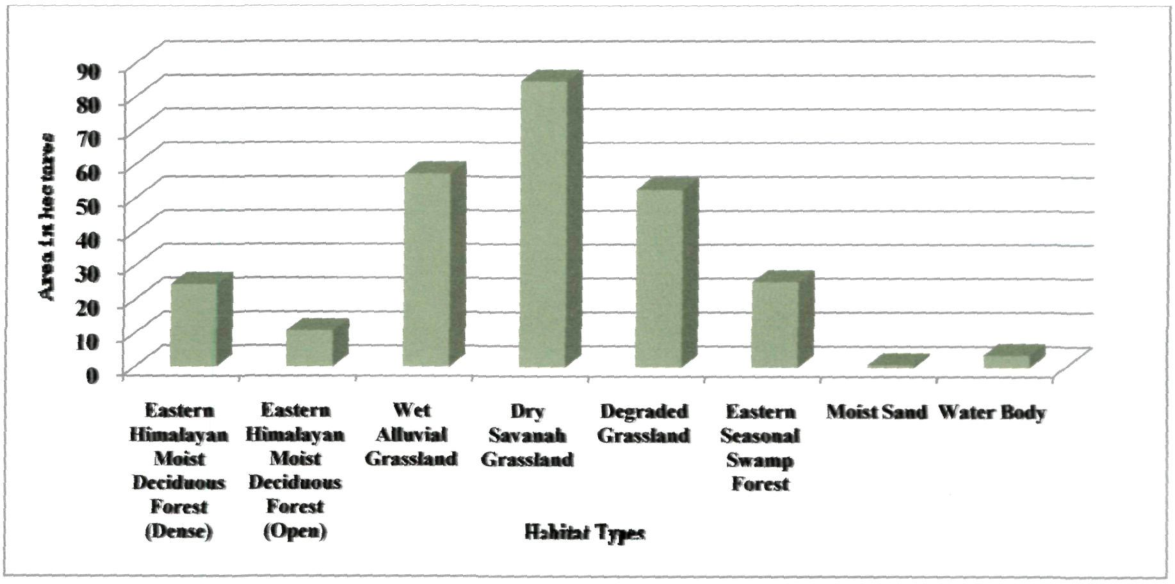
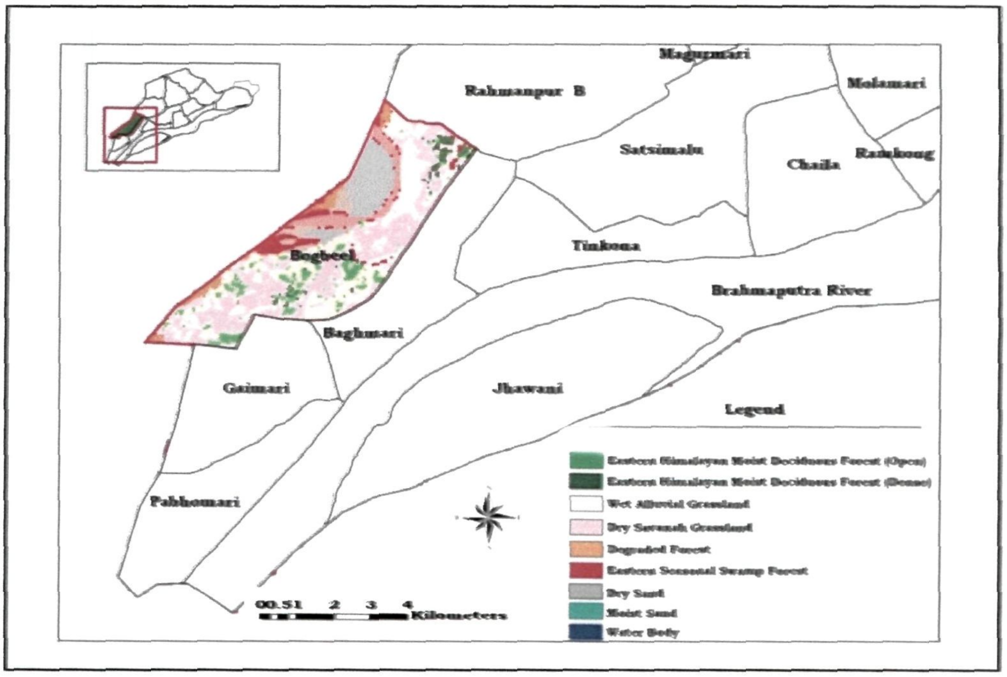


Fig. V c. Habitat pattern of Belsiri Block

5.3. iii Bogbeel Block:

The Bogbeel block is located in the eastern most part of the RG Orang NP (Map No. 32). The total area of this block is 429 hectares. Here in this block dry savannah grassland covers a large area of 140.49 hectares (32.75%), followed by wet alluvial grassland with an area cover of 128.79 hectares (30.02%). The rest of the habitat covers an area of 159.42 hectares (37.16%) of the block. The different habitat types available in Bogbeel block is shown in the table – V d. and figure – V d.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 32

Table: V d. Habitat pattern of Bogbeel Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	11.43	2.66
Eastern Himalayan Moist Deciduous Forest (Open)	30.78	7.17
Wet Alluvial Grassland	128.79	30.02
Dry Savanah Grassland	140.49	32.75
Degraded Grassland	18.36	4.28
Eastern Seasonal Swamp Forest	19.53	4.55
Moist Sand	16.65	3.88
Dry Sand	40.05	9.36
Water Body	22.86	5.33

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

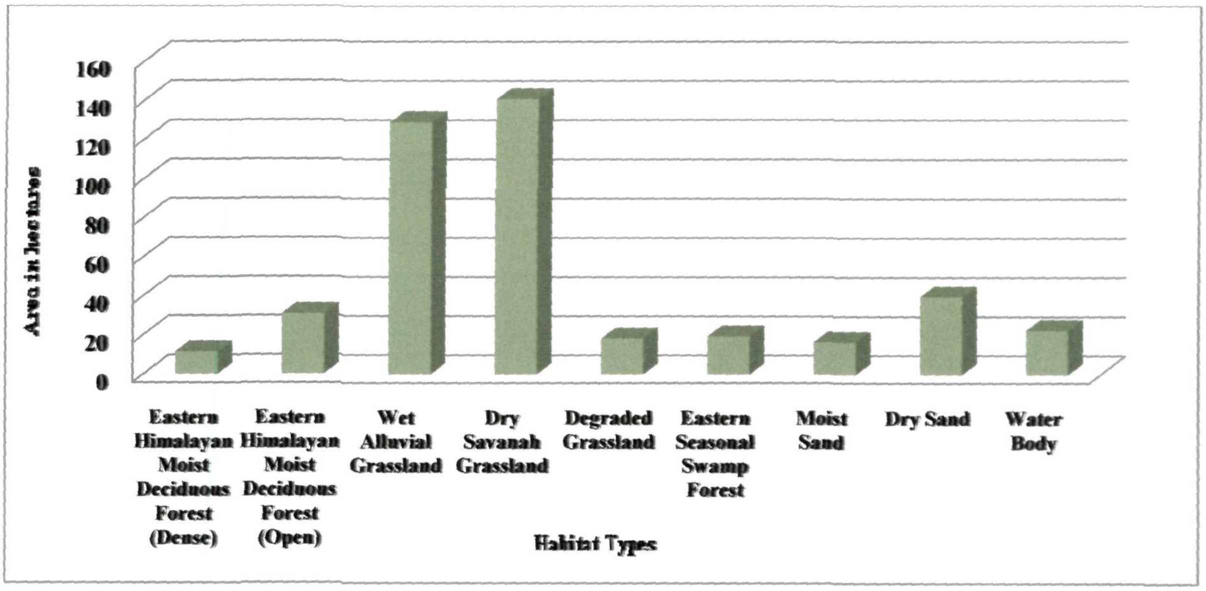
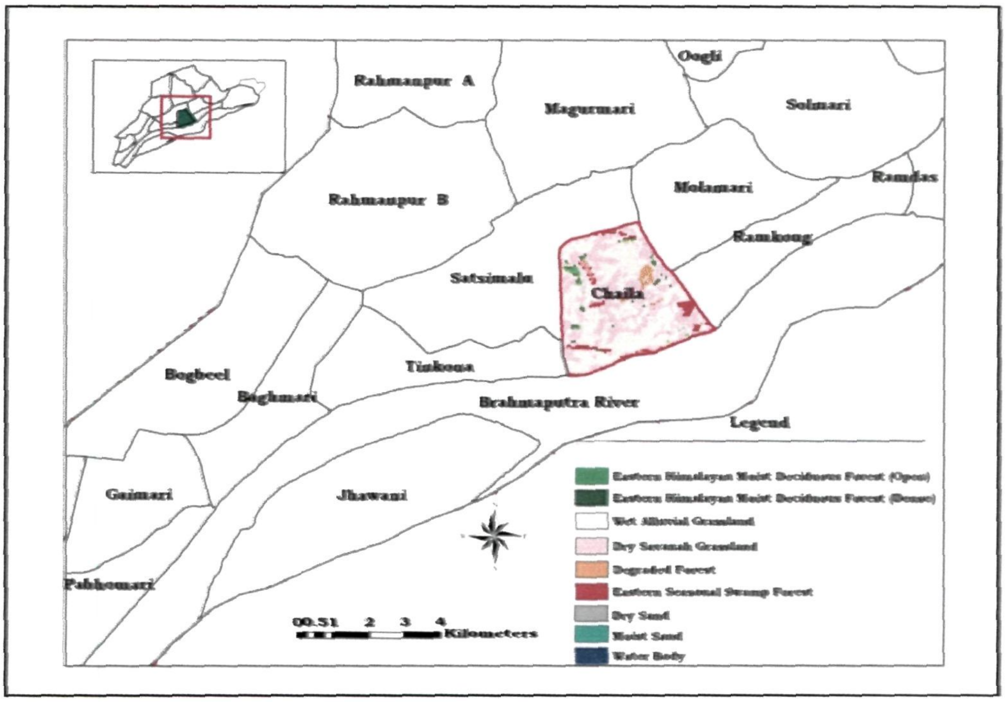


Fig. V d. Habitat pattern of Bogbeel Block

5.3. iv Chaila Block:

The Chaila block is located in the southern most part of the RG Orang NP (Map No. 33). The total area of the block is 287 hectares. Wet alluvial grassland is more prominent in this block covering an area of 131.13 hectares which is 45.69% of the total geographical area of the block. Dry savannah grassland covers an area of 119.61 hectares, which is 41.67% of the total area of the block. In this block eastern seasonal swamp forest is also covers an area of 13.59 hectares area. The habitat types of Chiala block and their respective area coverage is shown in the table – V e. and figure – V e.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 33

Table: V e. Habitat pattern of Chaila Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	4.95	1.72
Eastern Himalayan Moist Deciduous Forest (Open)	4.23	1.47
Wet Alluvial Grassland	131.13	45.63
Dry Savanah Grassland	119.61	41.62
Degraded Grassland	6.93	2.41
Eastern Seasonal Swamp Forest	13.59	4.73
Moist Sand	0.99	0.35
Dry Sand	0.27	0.09
Water Body	5.67	1.98

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

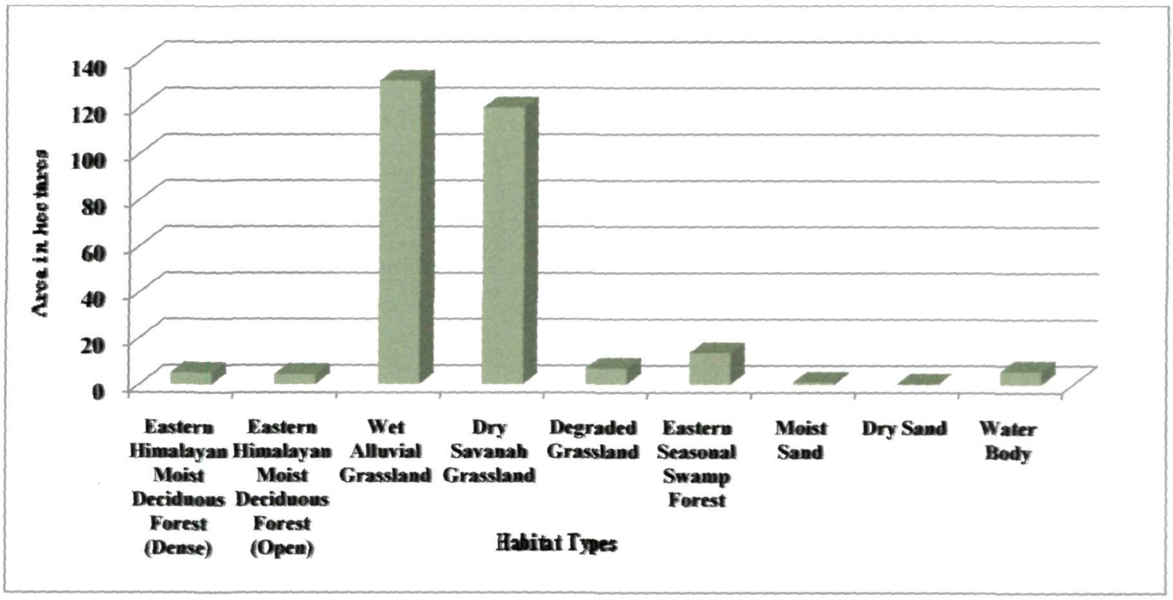
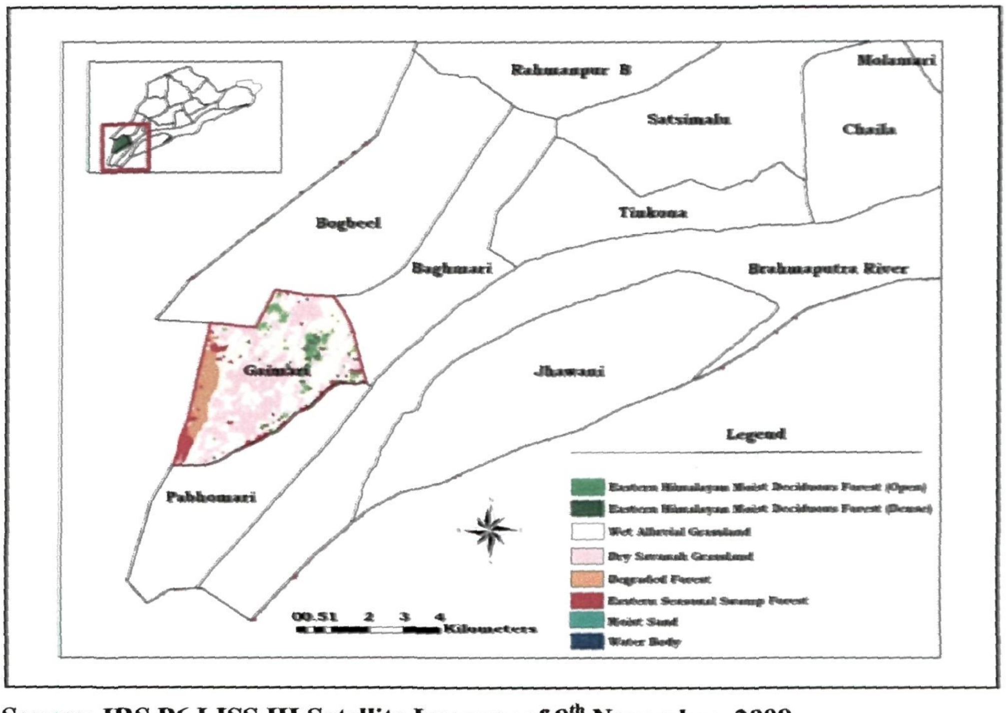


Fig. V e. Habitat pattern of Chiala Block

5.3. v Gaimari Block:

The Gaimari block is located in the western most part of the RG Orang NP (Map No. 34). Total area of this block is 237 hectares. Wet alluvial grassland is more dominated in this block covering an area of 96.93 hectares, which is 40.90% of the total area of the block. Dry savannah grassland covers an area of 87.66 hectares, which is 36.99% of the total block area. Here in this block degraded grassland is prominent covering an area of 17.82 hectares, which is 7.56% of the total block area. The available habitat types of Gaimari block is shown in the table – V f. and figure – V f.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 34

Table: V f. Habitat pattern of Gaimari Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	9.09	3.84
Eastern Himalayan Moist Deciduous Forest (Open)	13.05	5.51
Wet Alluvial Grassland	96.93	40.90
Dry Savanah Grassland	87.66	36.99
Degraded Grassland	17.82	7.52
Eastern Seasonal Swamp Forest	10.71	4.52
Moist Sand	0.81	0.34
Water Body	0.9	0.38

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

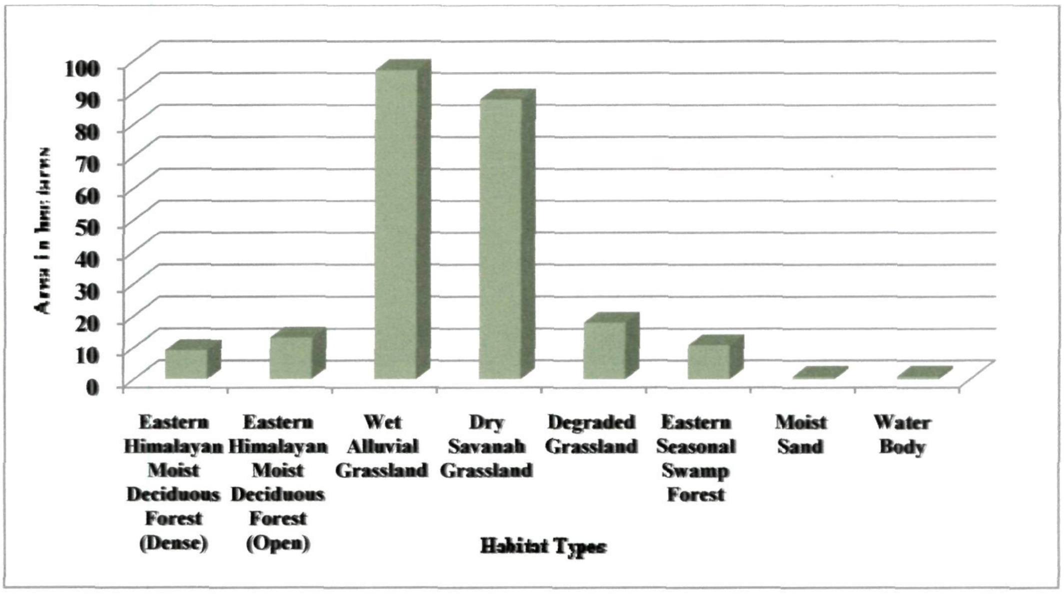
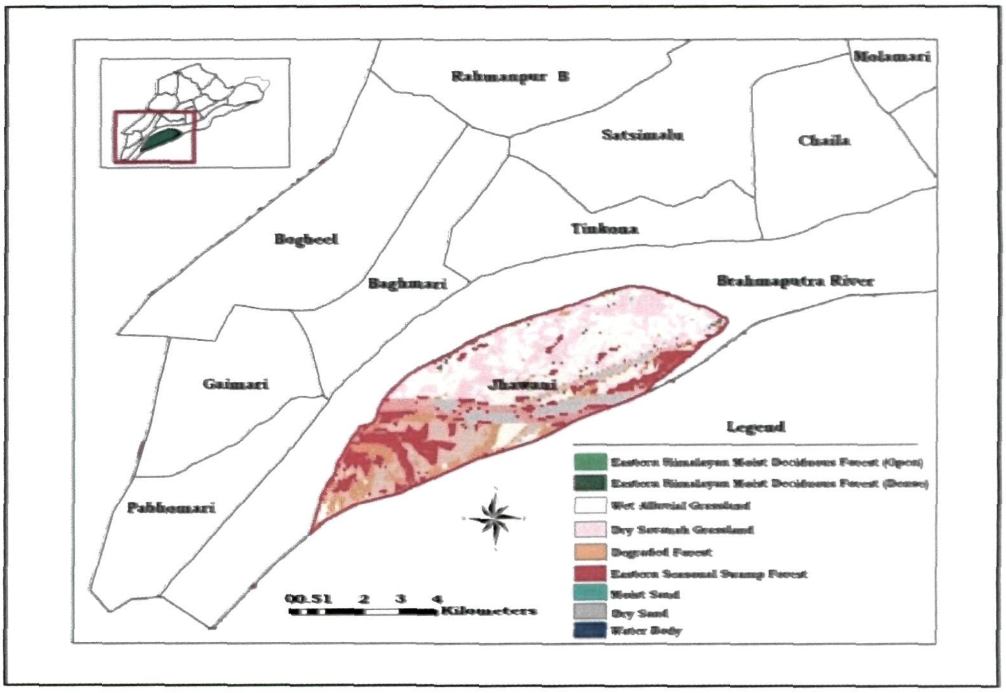


Fig. V f. Habitat pattern of Gaimari Block

5.3. vi Jhawani Block:

The Jhawani block of RG Orang NP is located in the southern most part of the park (Map No. 35). This block is actually a river island developed by depositional activities of the river Brahmaputra. This block covers an area of 494.19 hectares. Wet alluvial grassland is highest in this block covering an area of 140.94 hectares, which is 28.52% of the total area of the bock. Dry savannah grassland is covering an area of 102.87 hectares which is 20.81% of the total area of the block. Sandy area is quite prominent in this block covering an area of 95.32 hectares, which is 19.28% of the total area of the block. The habitat types and their area cover are shown in the table – V g. and figure – V g.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 35

Table: V g. Habitat pattern of Jhawani Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	5.76	1.16
Eastern Himalayan Moist Deciduous Forest (Open)	2.61	0.53
Wet Alluvial Grassland	140.94	28.65
Dry Savanah Grassland	102.87	20.64
Degraded Grassland	47.61	9.63
Eastern Seasonal Swamp Forest	67.32	13.56
Moist Sand	70.38	14.24
Dry Sand	24.93	5.05
Water Body	31.77	6.54

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

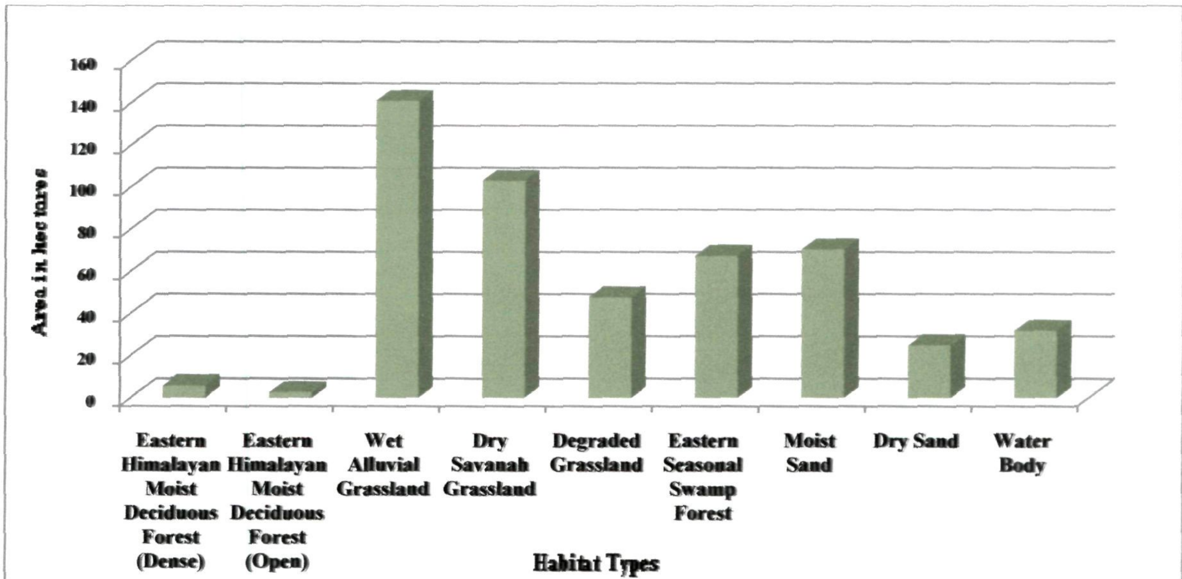
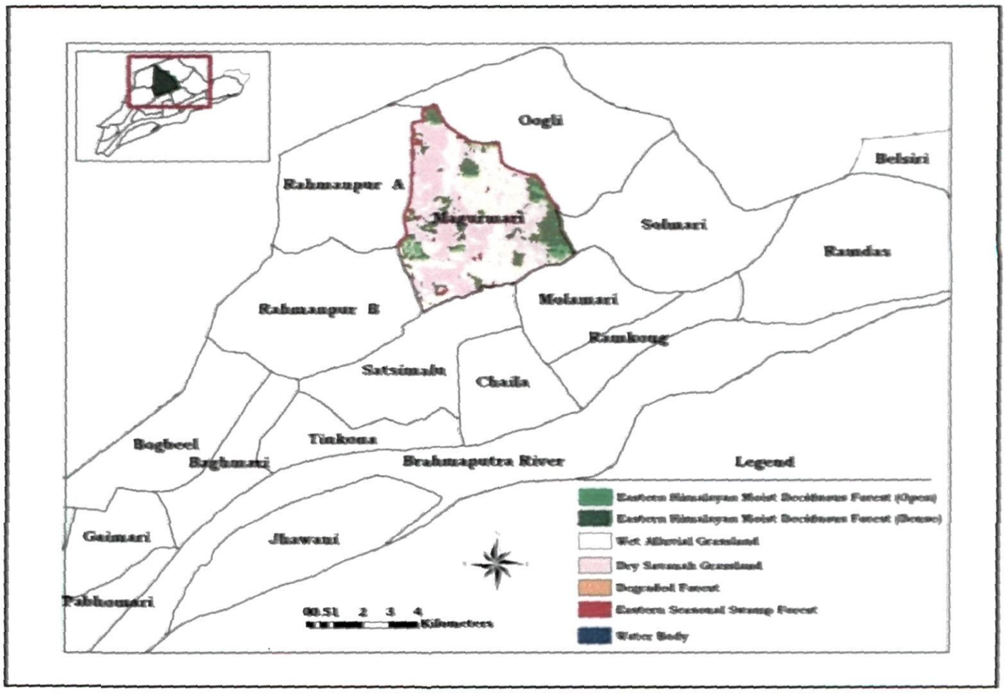


Fig. V g. Habitat pattern of Jhawani Block

5.3. vii Magurmari Block:

The Magurmari block is covering an area of 635.22 hectors in RG Orang NP. It is located in the centre of the park (Map No. 36). Dry savannah grassland is extensively cover an area of 252.18 hectors in this block, which is 39.70% of the total area of the block. Wet alluvial grassland in this block cover an area of 237.24 hectares, which is 37.35% of the total area of the block. Eastern Himalayan Moist Deciduous Forest (Dense) covers an area of 108.99 hectares in Magurmari block which is 17.16% of the total area of the block. The detail of the habitat types available in Magurmari block is shown in the table – V h. and figure – V h.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. – 36

Table: V h. Habitat pattern of Magurmari Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	108.99	17.16
Eastern Himalayan Moist Deciduous Forest (Open)	31.23	4.91
Wet Alluvial Grassland	237.24	37.33
Dry Savanah Grassland	252.18	39.74
Degraded Grassland	0.36	0.05
Eastern Seasonal Swamp Forest	5.13	0.8
Water Body	0.09	0.01

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

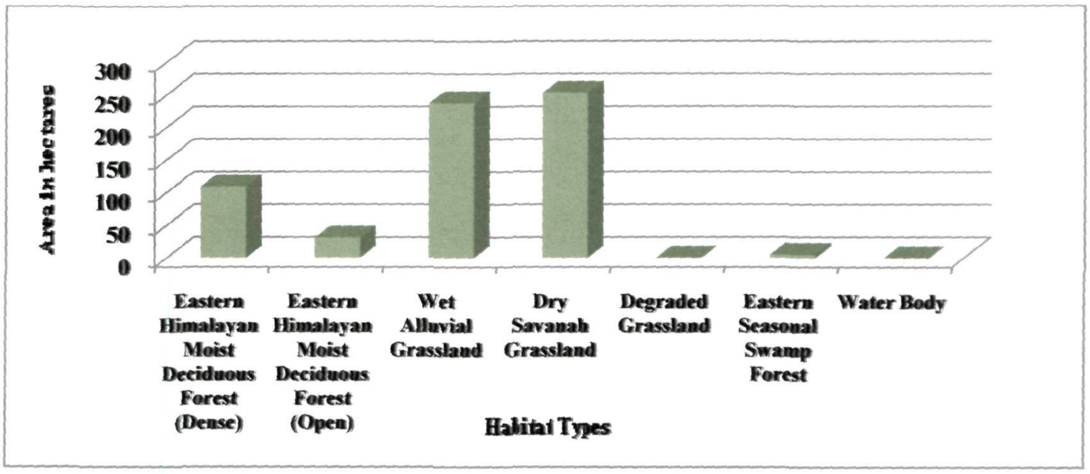
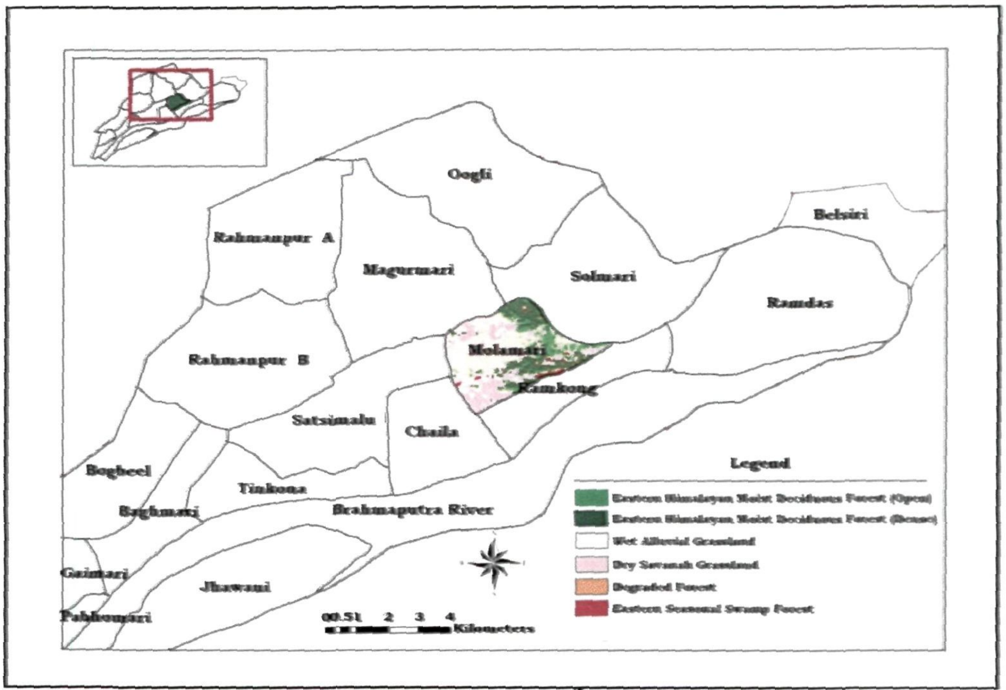


Fig. V h. Habitat pattern of Magurmari Block

5.3. viii Moalamari Block:

The Moalamari block of RG Orang NP is located in the south of Magurmari block (Map No. 37). This block covers an area 302.4 hectors. In this block wet alluvial grassland is prominent covering an area of 125.1

hectares, which is 41.37% of the total area of the block. Dry savannah grassland covers an area of 75.24 hectares in this block, which is 24.88% of the total area of the block. Eastern Himalayan Moist Deciduous Forest (Dense and Open) covers an area of 97.74 hectares in this block, which is 32.32% of the total area of the block. The detail of the habitat types and their area cover is shown in the table – V i. and figure – V i.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. – 37

Table: V i. Habitat pattern of Moalamari Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	60.39	19.97
Eastern Himalayan Moist Deciduous Forest (Open)	37.35	12.35
Wet Alluvial Grassland	125.1	41.37
Dry Savanah Grassland	75.24	24.88
Degraded Grassland	0.27	0.09
Eastern Seasonal Swamp Forest	4.05	1.34

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

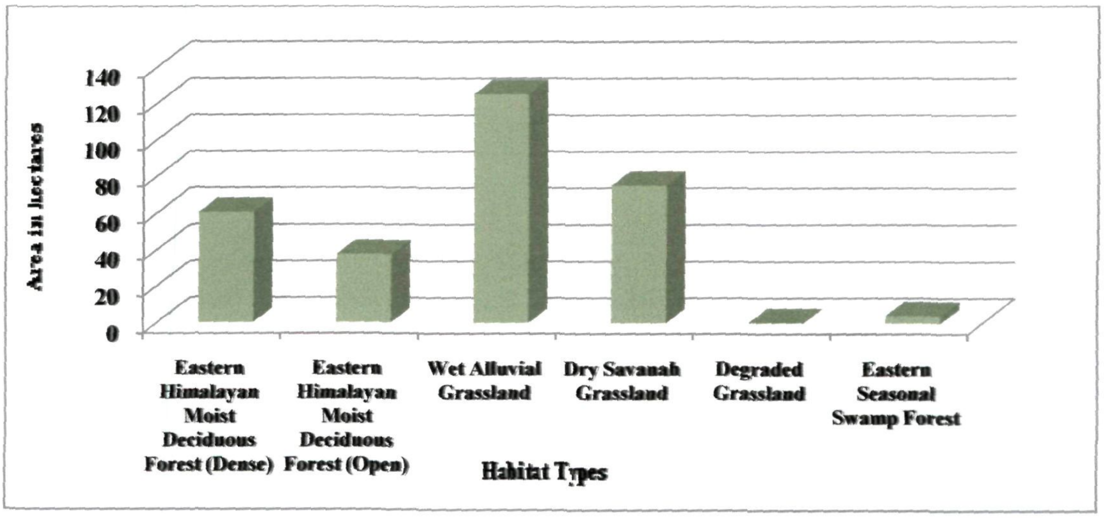
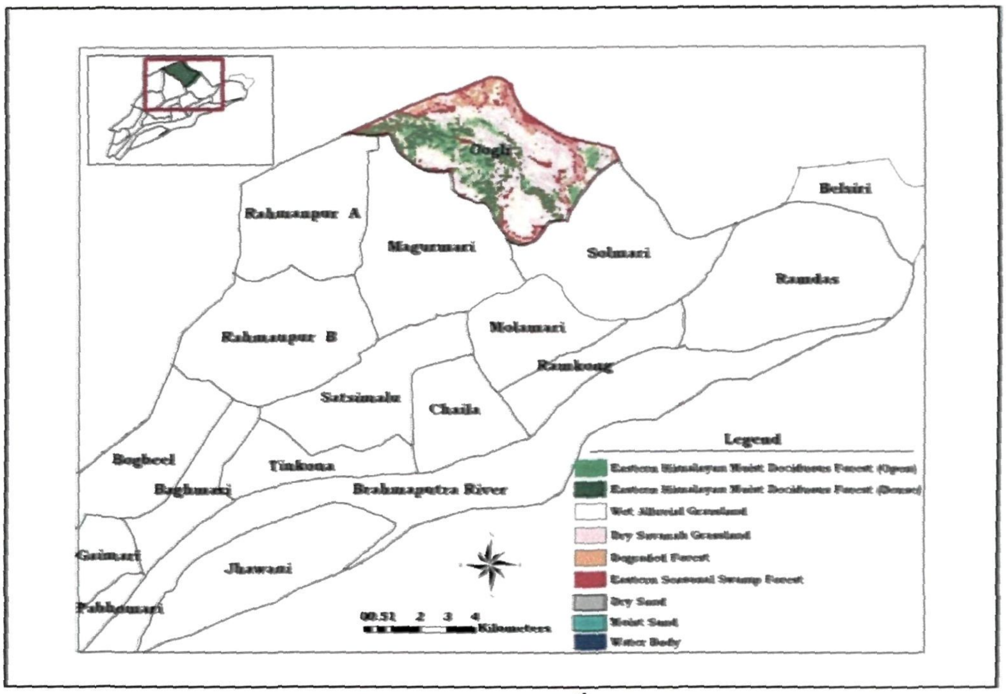


Fig. V i. Habitat pattern of Moalamari Block

5.3. ix Oogli Block:

The Oogli block is located in the north eastern part of the RG Orang NP (Map No. 38). The area covered by the Oogli block is 623.7 hectares. Here in this block wet alluvial grassland is prominent covering an area of 169.02

hectares, which is 27.09% of the total geographical area of the block. Dry savannah grassland covers an area of 135.72 hectares in this block which is 21.76% of the total area of the block. The eastern Himalayan moist deciduous forest (Dense and Open) covers an area of 195.39 hectares, which is 31.31% of the total area of the block. The detail of the habitat types and their area cove of Oogli block is shown in the table – V j. and figure –V j.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 38

Table: V j. Habitat pattern of Oogli Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	119.61	19.18
Eastern Himalayan Moist Deciduous Forest (Open)	75.78	12.15
Wet Alluvial Grassland	169.02	27.09
Dry Savanah Grassland	135.72	21.76
Degraded Grassland	29.43	4.71
Eastern Seasonal Swamp Forest	46.98	7.53
Moist Sand	8.73	1.4
Dry Sand	1.62	0.28
Water Body	36.81	5.9

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

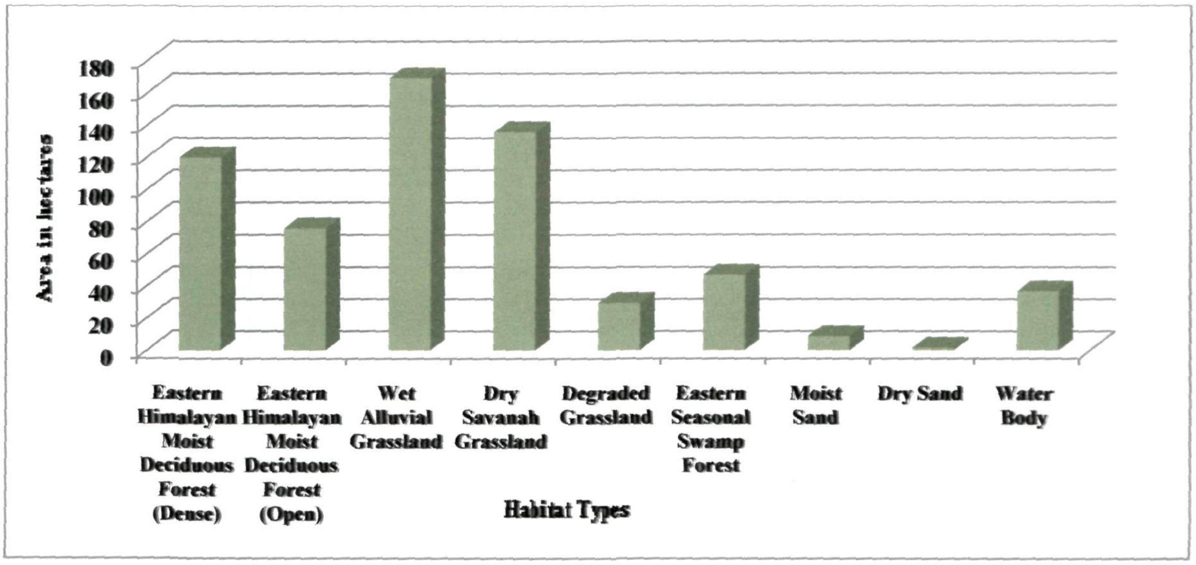
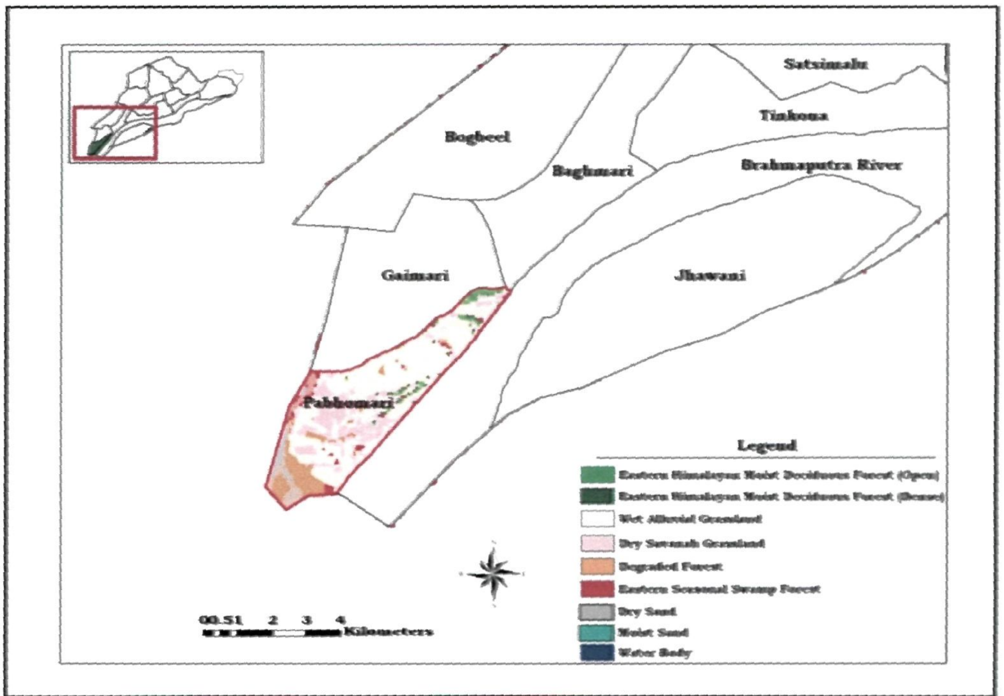


Fig. V j. Habitat pattern of Oogli Block

5.3. x Pabhomari Block:

The Pabhomari block of RG Orang NP is located in the western most part of the park (Map No. 39). The total area of this block is 222.3 hectares. Here also wet alluvial grassland is prominent, covering an area of 113.58 hectares, which is 51.09% of the total geographical area of the block. Dry savannah grassland covers an area of 49.86 hectares, which is 22.43% of the total area of the block. Degraded grassland is covering an area of 20.25 hectares in this block. This degradation of grassland in Pabhomari block is mainly due to the grazing pressure by the domestic cattle from the nearby villages. The detail of the habitat types and their area cover in Pabhomari block is shown in the table – V k. and figure – V k.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 39

Table: V k. Habitat pattern of Pabhomari Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	5.4	2.43
Eastern Himalayan Moist Deciduous Forest (Open)	7.02	3.16
Wet Alluvial Grassland	113.58	51.09
Dry Savanah Grassland	49.86	22.43
Degraded Grassland	20.25	9.11
Eastern Seasonal Swamp Forest	5.94	2.67
Moist Sand	9.09	4.09
Dry Sand	5.31	2.39
Water Body	5.85	2.63

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

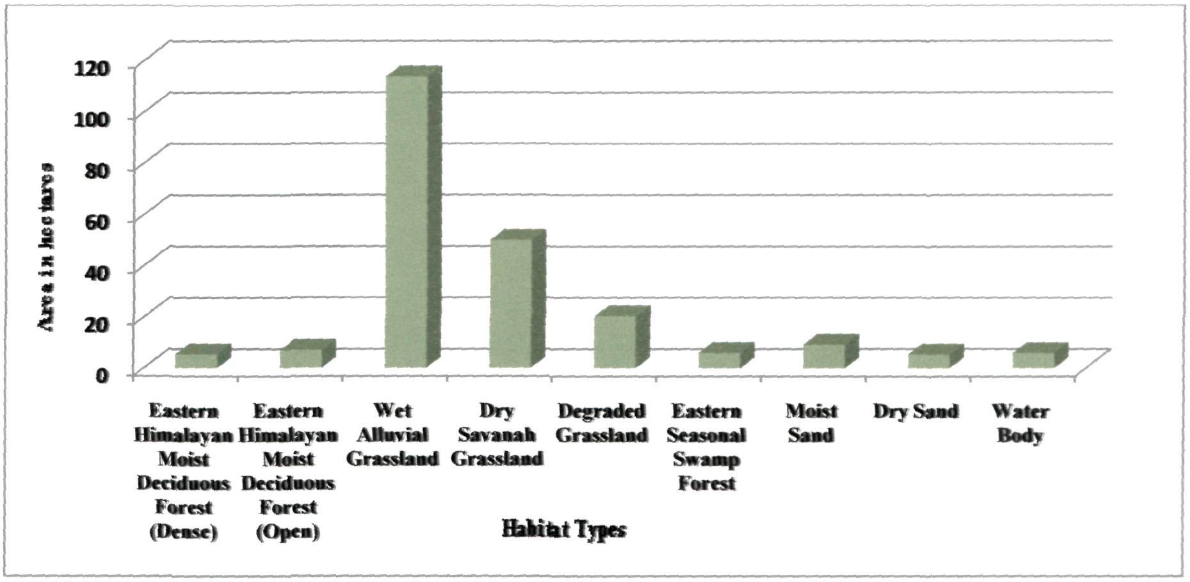
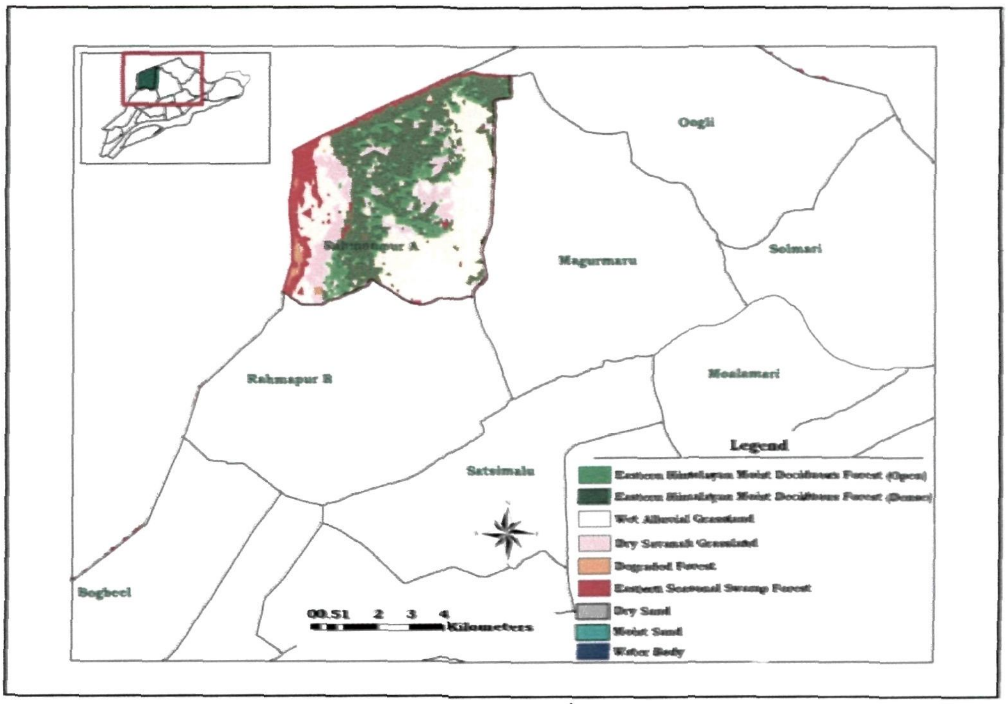


Fig. V k. Habitat pattern of Pabhomari Block

5.3. xi Rahmanpur A Block:

The Rahmanpur A block of RG Orang NP is located in the north western part of the park (Map No. 40). The total area of the block is 477.72

hectares. Here in this block dry savannah grassland is more prominent in comparison to other habitat types. Dry savannah grassland covers an area of 167.22 hectares in the block, which is 35.00% of the total area of the block. Eastern Himalayan most deciduous forest (Dense and Open) covers an area of 203.78 hectares which is 42.61% of the total area of the block. This block is mainly covered by woodland. Wet alluvial grassland is covering an area of 68.76 hectares in this block. The detail of the habitat types and their area cover in Rahmanpur A block is shown in the table – V 1. and figure – V 1.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. – 40

Table: V l. Habitat pattern of Rahmanpur A Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	147.78	30.93
Eastern Himalayan Moist Deciduous Forest (Open)	55.8	11.68
Wet Alluvial Grassland	68.76	14.39
Dry Savanah Grassland	167.22	35
Degraded Grassland	6.3	1.32
Eastern Seasonal Swamp Forest	31.68	6.65
Moist Sand	0.18	0.03

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

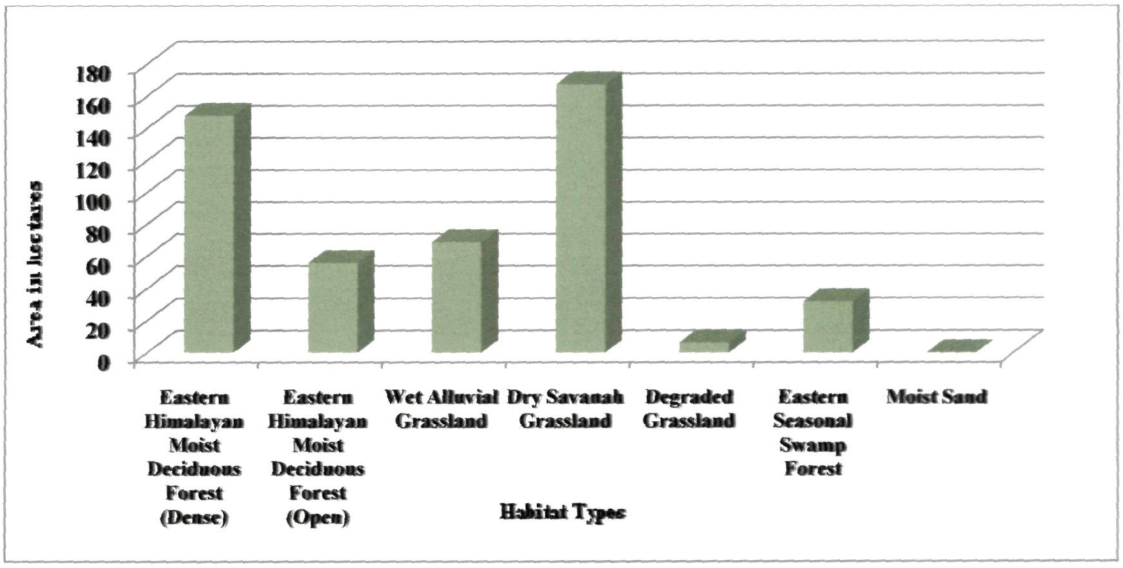
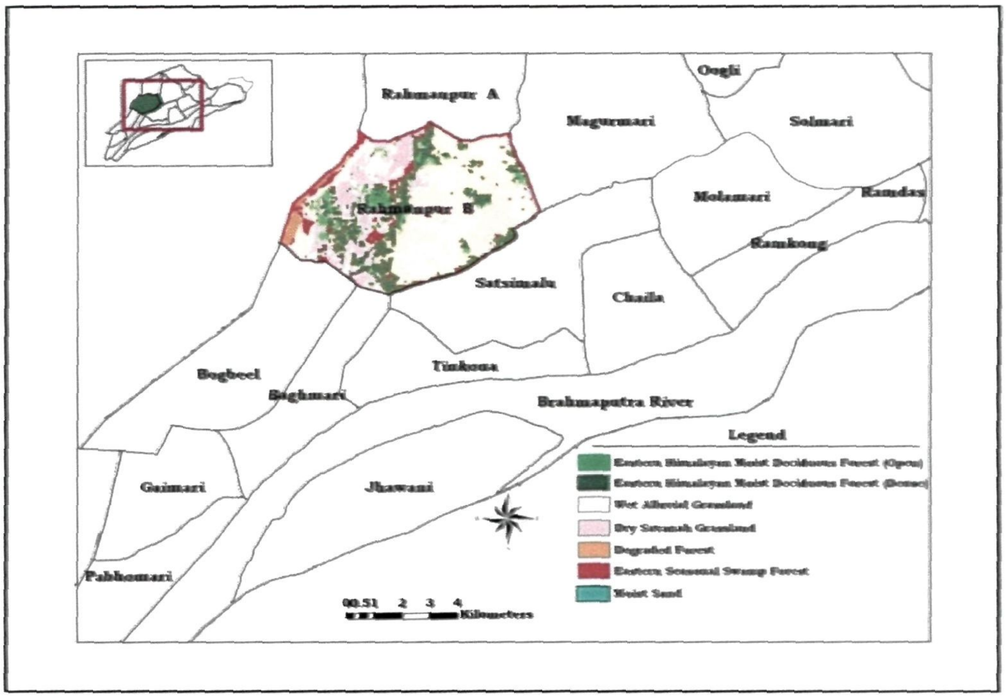


Fig. V l. Habitat pattern of Rahmanpur A Block

5.3. xii Rahmanpur B Block:

The Rahmanpur B block is located in the western part of the RG Orang NP (Map No. 41). The Rahmanpur B block covers an area of 593.64

hectares. Here in this block dry savannah grassland is more prominent in comparison to other habitat types. Dry savannah grassland covers an area of 273.69 hectares, which is 46.10% of the total geographical area of the block. The eastern Himalayan moist deciduous forest (Dense and Open) covers an area of 141.84 hectares, which is 23.89% of the total area of the block. The wet alluvial grassland covers an area of 141. 03 hectares in this block, which is 23.75% of the total area of the block. The detail of the habitat types and their respective area cover is shown in the table – V m. and figure – V m.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 41

Table: V m. Habitat pattern of Rahmanpur B Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	106.29	17.86
Eastern Himalayan Moist Deciduous Forest (Open)	35.55	5.98
Wet Alluvial Grassland	141.03	23.76
Dry Savanah Grassland	273.69	46.15
Degraded Grassland	14.85	2.5
Eastern Seasonal Swamp Forest	21.42	3.61
Moist Sand	0.81	0.14

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

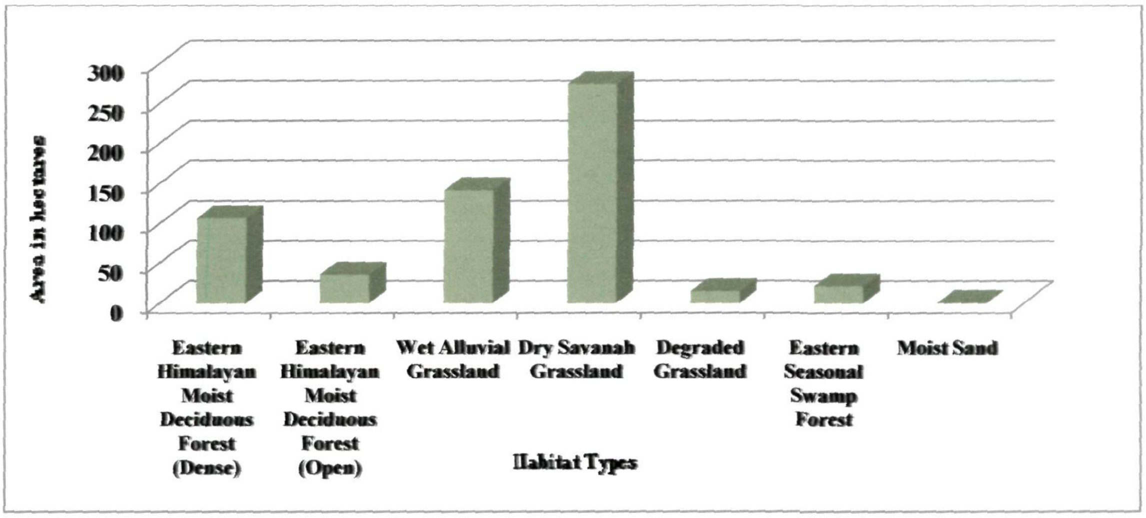
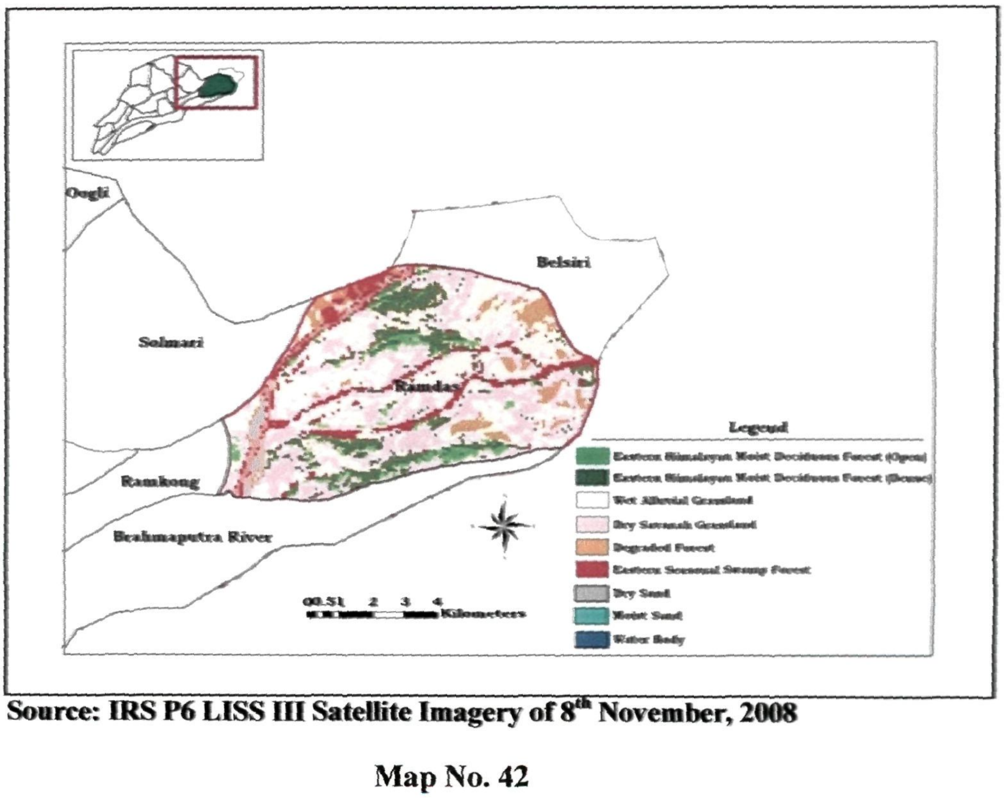


Fig. V m. Habitat pattern of Rhamanpur B Block

5.3. xiii Ramdas Block:

The Ramdas block of RG Orang NP is located in the eastern part of the park (Map No. 42). The total area of this block is 748.8 hectors. Wet alluvial grassland is mostly seen in this block. The total area covered by wet alluvial grassland is 269.82 hectares, which is 36.03% of the total geographical area of the block. Dry savannah grassland is covering an area of 219.42 hectares, which is 29.30% of the total area of the block. Here in this block 52.02 hectares of land is covered by degraded grassland. This degradation of grassland in this block is mainly due to the impact of grazing pressure from the nearby villages and also due to the impact of *Mimosa invesa.* The detail of the habitat types available in Ramdas block is shown in the table – V n. and figure – V n.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 42

Table: V n. Habitat pattern of Ramdas Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	89.46	11.95
Eastern Himalayan Moist Deciduous Forest (Open)	34.11	4.56
Wet Alluvial Grassland	269.82	36.03
Dry Savanah Grassland	219.42	29.3
Degraded Grassland	52.02	6.95
Eastern Seasonal Swamp Forest	55.08	7.36
Moist Sand	9.54	1.27
Dry Sand	4.68	0.62
Water Body	14.67	1.96

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

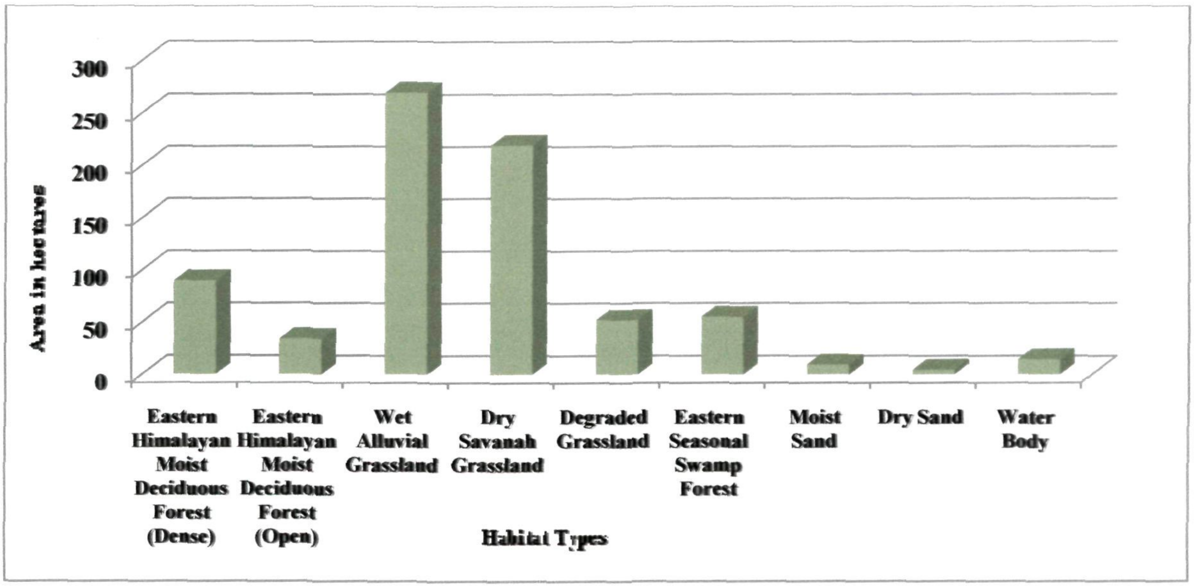
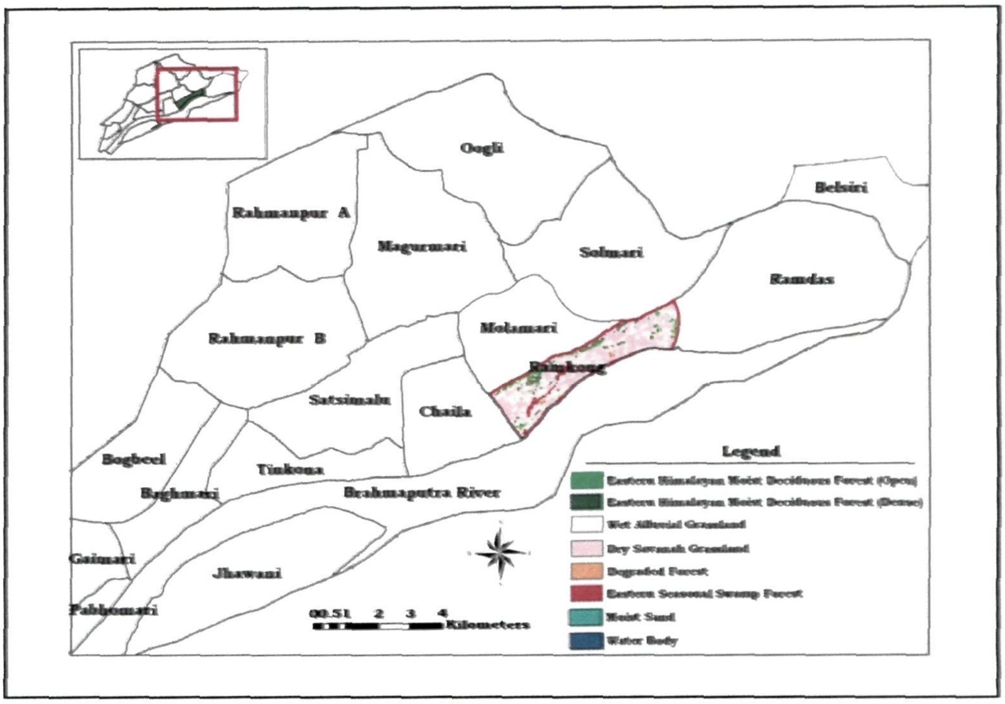


Fig. V n. Habitat pattern of Ramdas Block

5.3. xiv Ramkong Block:

The Ramkong block is located in the southern part of the RG Orang NP along the bank of the river Brahmaputra (Map No. 43). The total area of the block is 233.37 hectares. In this block dry savannah grassland is most commonly seen. It has covered an area of 102.6 hectares, which is 43.96% of the total geographical area of the block. Wet alluvial grassland covers an area of 76.05 hectares, which is 32.59% of the total area of the block. The eastern Himalayan moist deciduous forest (Dense and Open) covers an area of 33.66 hectares, which is 14.42% of the total geographical area of the block. The detail habitat patterns and their respective area cover are shown in the table – V o. and figure – V o.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 43

Table: V o. Habitat pattern of Ramkong Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	17.73	7.6
Eastern Himalayan Moist Deciduous Forest (Open)	15.93	6.8
Wet Alluvial Grassland	76.05	32.59
Dry Savanah Grassland	102.6	44
Degraded Grassland	5.13	2.19
Eastern Seasonal Swamp Forest	9.81	4.2
Moist Sand	0.09	0.04
Water Body	6.03	2.58

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

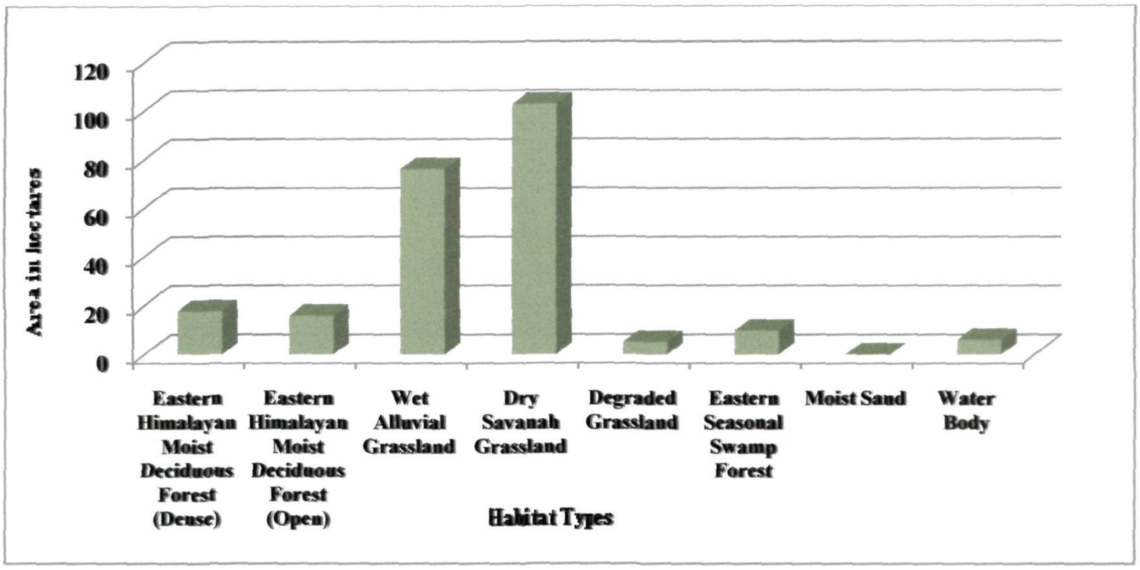
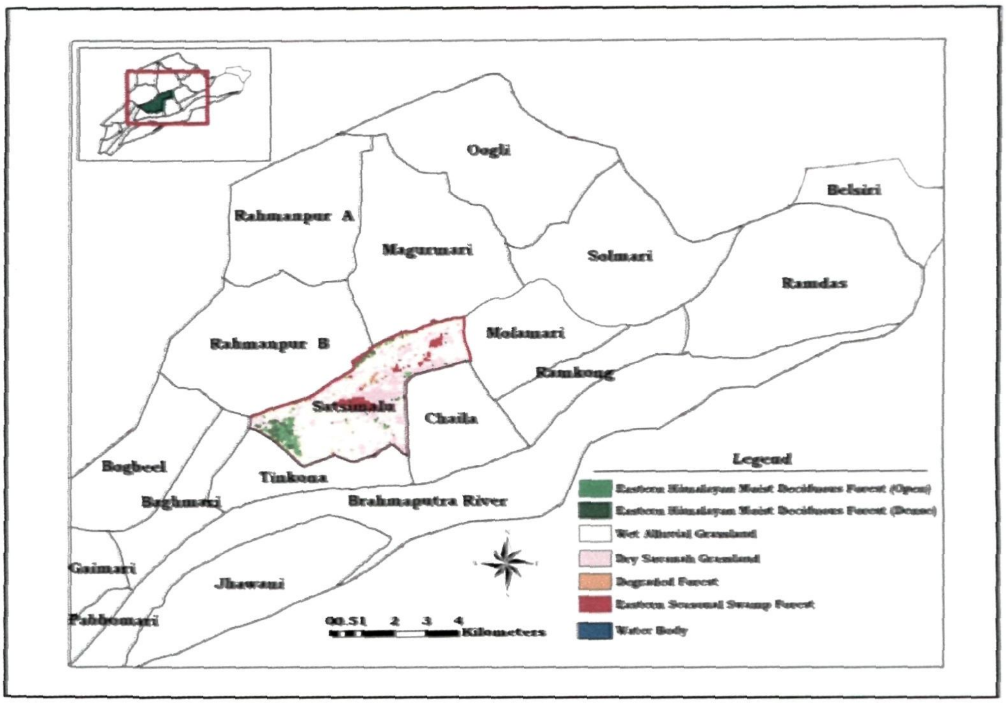


Fig. V o. Habitat pattern of Ramkong Block

5.3. xv Satsimalu Block:

The Satsimalu block is located in the centre of the RG Orang NP (Map No. 44). The total area of this block is 432.16 hectors. This block is basically low lying area covered by wet alluvial grassland habitat. Rhinos of RG Orang NP have extensively used this block throughout the year. In this block wet alluvial grassland is quite prominent covering an area of 245.07 hectares, which is 56.07% of the total geographical area of the block. Dry savannah grassland covers an area of 113.76 hectares area, which is 26.32% of the total area of the block. Eastern Himalayan moist deciduous forest (Dense and Open) covers an area of 47.25 hectares, which is 10.93% of the total area of the block. The detail of the habitat types and their area cover is shown in the table – V p. and figure – V p.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 44

Table: V p. Habitat pattern of Satsimalu Block

Land Cover Type	**Area in hectares**	**% of Area Cover**
Eastern Himalayan Moist Deciduous Forest (Dense)	24.75	5.73
Eastern Himalayan Moist Deciduous Forest (Open)	22.5	5.21
Wet Alluvial Grassland	245.07	56.69
Dry Savanah Grassland	113.76	26.34
Degraded Grassland	4.41	1.02
Eastern Seasonal Swamp Forest	18	4.16
Water Body	3.67	0.85

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

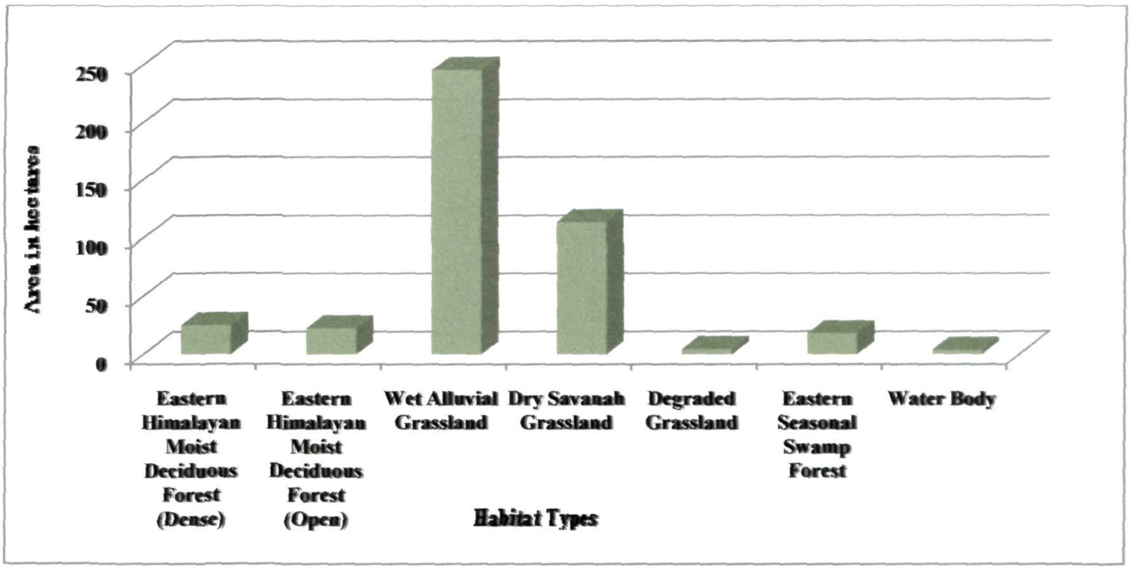
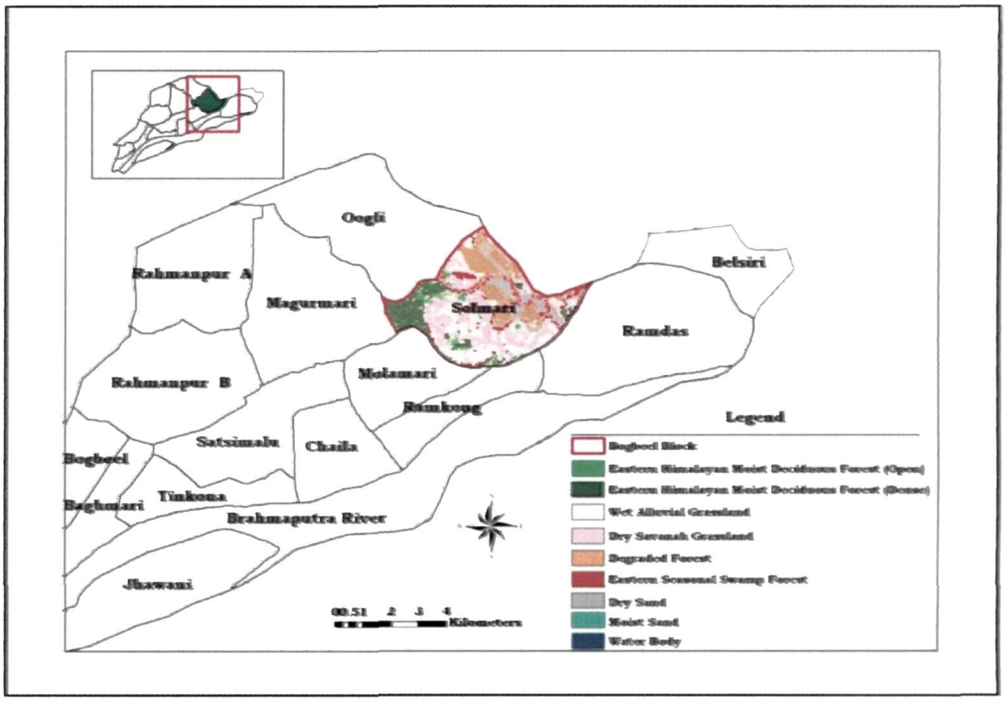


Fig. V p. Habitat pattern of Satsimalu Block

5.3. xvi Solmari Block:

The Solmari block is located in the eastern part of the RG Orang NP (Map No. 45) . The total area of this block is 568.08 hectares. In this block wet alluvial grassland is quite prominent covering an area of 148.86 hectares, which is 26.20% of the total geographical area of the block. Dry savannah grassland covers an area of 133.47 hectares, which is 23.49% of the total area of the block. Degraded grassland is also covers an extensive area in this block. It covers 85.05 hectares of area, which is 14.97% of the total area of the block. The detail of the habitat types and their respective area cover is shown in the table V q. and figure V q.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. – 45

Table: V q. Habitat pattern of Solmari Block

Land Cover Type	**Area in hectares**	**% of Area Cover**
Eastern Himalayan Moist Deciduous Forest (Dense)	73.26	12.62
Eastern Himalayan Moist Deciduous Forest (Open)	28.53	5.02
Wet Alluvial Grassland	148.86	26.5
Dry Savanah Grassland	133.47	23.49
Degraded Grassland	85.05	14.97
Eastern Seasonal Swamp Forest	26.46	4.66
Moist Sand	43.2	7.6
Dry Sand	15.48	2.72
Water Body	13.77	2.42

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

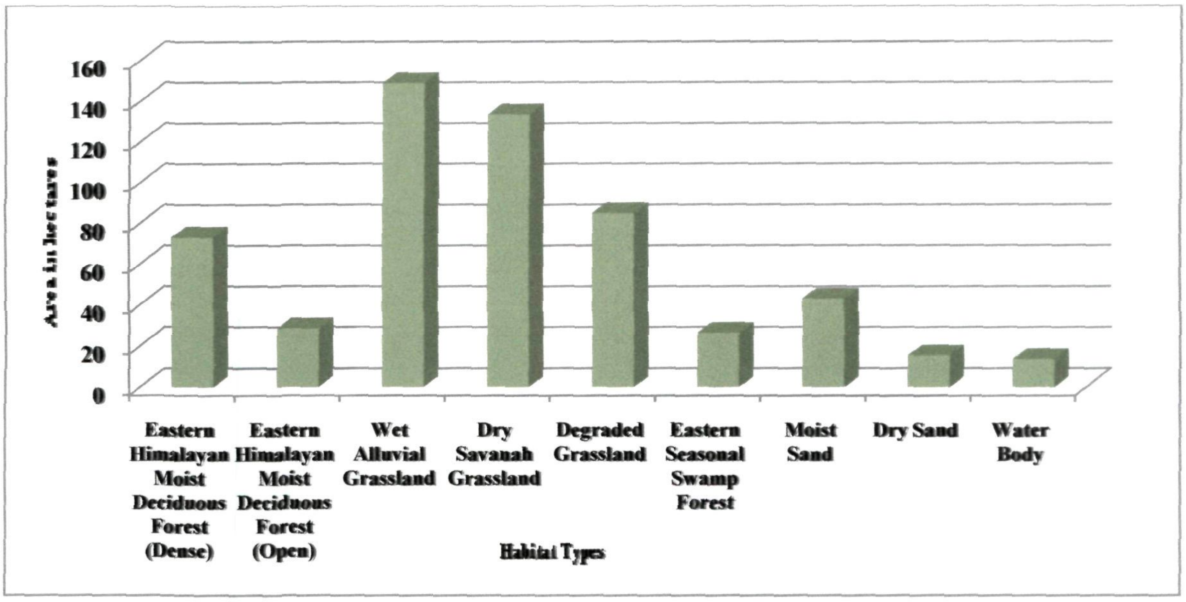
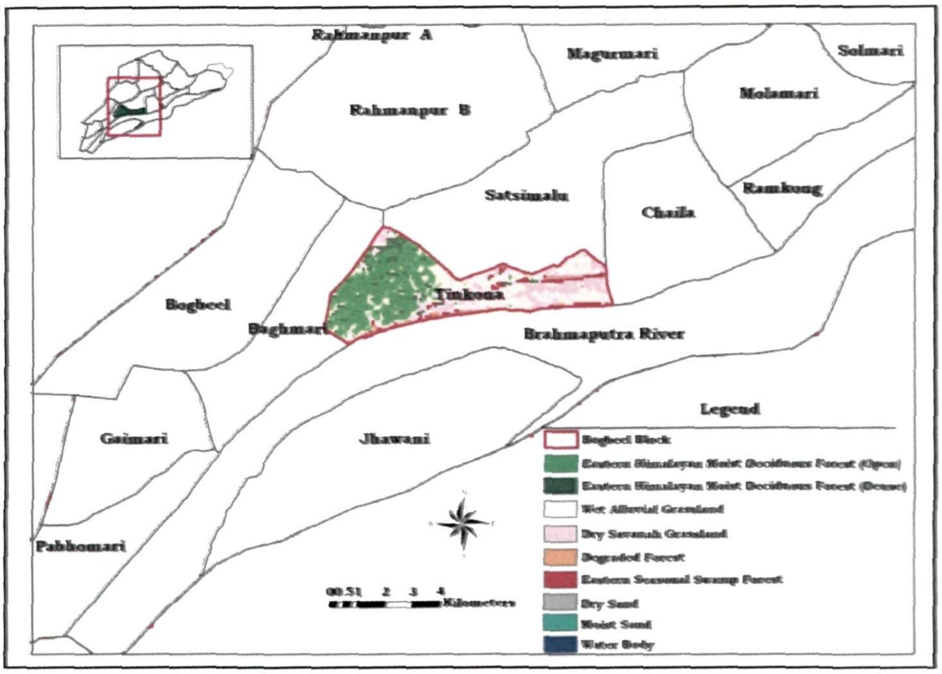


Fig. V q. Habitat pattern of Solmari Block

5.3. xvii Tinkona Block:

The Tinkona block of RG Orang NP is located in the southern part of the park (Map No. 46). The total area of this block is 244.53 hectares. The eastern Himalayan moist deciduous forest (Dense and Open) is prominent in this block, covering an area of 93.06 hectares, which is 38.05 % of the total area of the block. Wet alluvial grassland is covering an area of 76.86 hectares, which is 31.43% of the total area of the block. Dry savannah grassland is covers an area of 50.22 hectares in this block, which is 20.54% of the total area of the Tinkona block. The detail of the habitat types and their respective area cover is shown in the table – V r. and figure – V r.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. - 46

Table: V r. Habitat pattern of Tinkona Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Open)	71.01	29.04
Eastern Himalayan Moist Deciduous Forest (Dense)	22.05	9.02
Wet Alluvial Grassland	76.86	31.43
Dry Savanah Grassland	50.22	20.54
Degraded Grassland	1.71	0.7
Eastern Seasonal Swamp Forest	9.45	3.86
Moist Sand	0.45	0.18
Dry Sand	0.18	0.08
Water Body	12.6	5.15

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

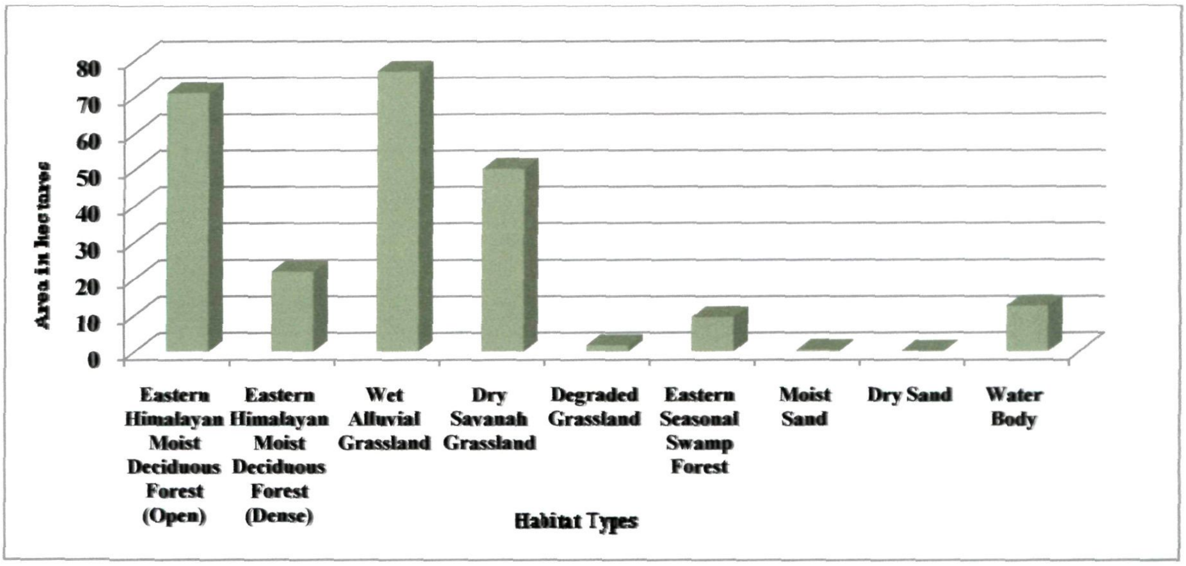
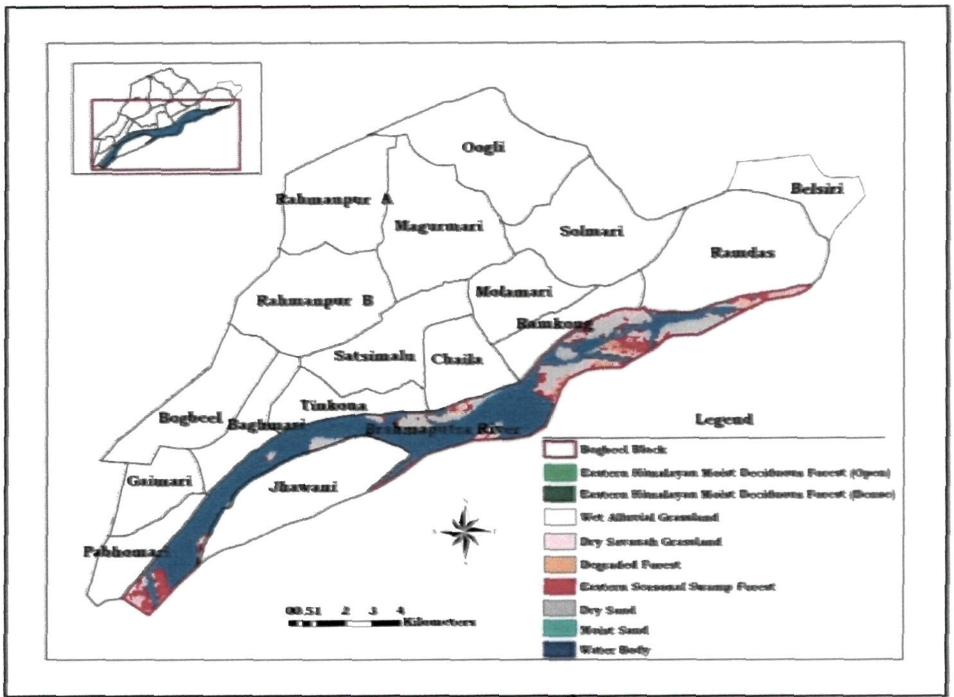


Fig. V r. Habitat pattern of Tinkona Block

5.3. xviii Brahmaputra River Block:

The Brahmaputra river block is the largest block among all the 18 block of RG Orang NP (Map No. 47). This block covers an area of 880.45 hectares of area. Water body and sandy area is prominent in this block. Water body covers an area of 429.4 hectares, which is 48.77% of the total area of the block. Sandy area covers an area of 286.56 hectares in this block, which is 32.56% of the total area of the block. The detail of the habitat pattern of Brahmaputra river block is shown in the table – V s. and figure V s.



Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

Map No. 47

Table: V s. Habitat pattern of Brahmaputra River Block

Land Cover Type	Area in hectares	% of Area Cover
Eastern Himalayan Moist Deciduous Forest (Dense)	2.34	0.27
Eastern Himalayan Moist Deciduous Forest (Open)	0.54	0.06
Wet Alluvial Grassland	16.56	1.88
Dry Savanah Grassland	10.17	1.16
Degraded Grassland	32.13	3.66
Eastern Seasonal Swamp Forest	100.75	11.47
Moist Sand	102.42	11.66
Dry Sand	184.14	20.96
Water Body	429.4	48.88

Source: IRS P6 LISS III Satellite Imagery of 8th November, 2008

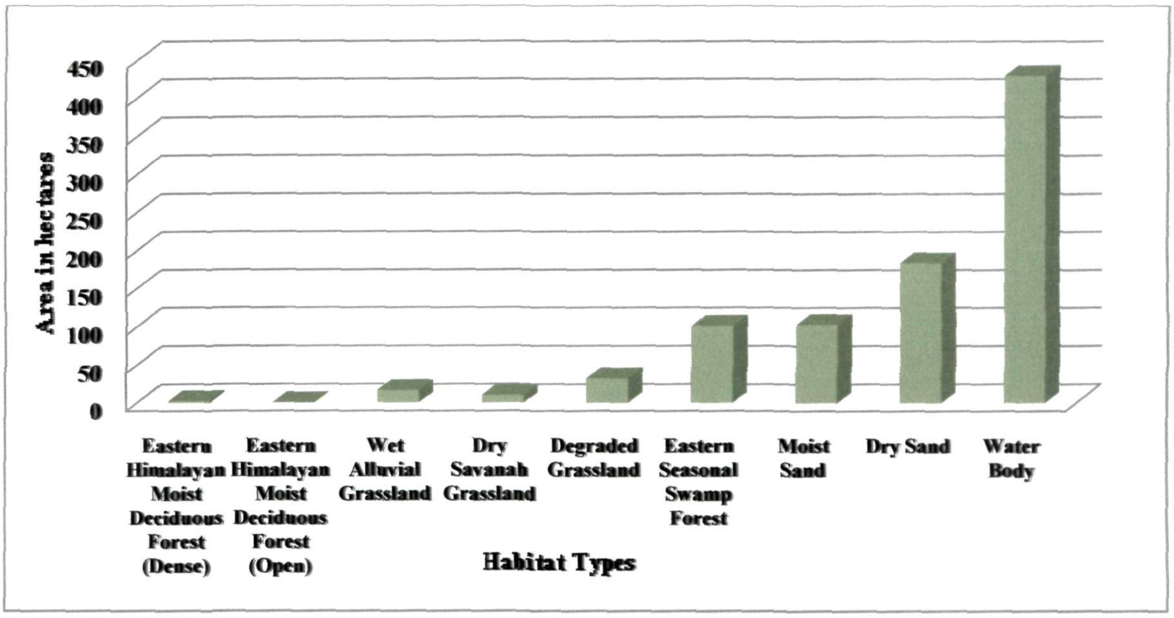


Fig. V s. Habitat pattern of Brahmaputra River Block

5.4 Discussion:

The result shows that different habitat types are prominent in different blocks in RG Orang NP. The eastern Himalayan moist deciduous forest (Dense) is more prominent in Rahmapur A block. It has 30.93% of the total geographical area coverage of the block. It is the highest percentage of area covered by eastern Himalayan moist deciduous forest (Dense) in comparison to any other blocks of the park. Similarly eastern Himalayan moist deciduous forest (Open) is more dominated in the Baghmari block of the park. It has 22.52% of the block and it is the highest percentage of area covered by eastern Himalayan moist deciduous forest (Open) than any other blocks of the park.

In case of wet alluvial grassland, the result shows that it has the maximum concentration in Satsimalu block. It has 56.69% of the total geographical area of the block. Satsimalu block is a low lying area dominated by wet alluvial grassland. It is also be mentioned that during field survey period maximum rhino was sighted in this block. Since, it indicates that rhino prefer wet alluvial grassland with low lying areas in RG Orang NP, which is also very clear from the fourth chapter of this thesis. In case of dry savannah grassland maximum concentration is found in Rahmanpur B block. It has 46.15% of the total geographical area in this block. It has the highest percentage of area covered by dry savannah grassland than any other blocks of the park. Degraded grassland is more prominently seen in Belsiri block covering 20.28% of the total area of the block. Eastern seasonal swamp forest has its highest concentration in Jhawani block covering 13.56% of the total area of the block. In case of sandy area highest concentration is found in Brahmaputra river block covering 32.62% of the total area of the block. In case of water body highest concentration is also found in Brahmaputra river block covering 48.88% of the total geographical area of the block. The block wise percentage of area cover by different habitat types in RG Orang NP is shown in (Appendix II).

Finally it is found that geospatial technology is quite useful for understanding the wildlife habitat characteristics and its micro level evaluation. This kind of micro habitat evaluation of wildlife habitat is quite useful for conservation and management of wildlife like rhino and its habitat. This study also suggests that regular monitoring and evaluation of wildlife habitat through geo-spatial technology is quite necessary for conservation of wildlife habitat for future generation.

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CHAPTER - VI

Chapter VI

Habitat Suitability Model for Rhino

6.1 Introduction:

With the decreasing size of habitat and increasing fragmentation, it has become essential to develop species-specific habitat suitability maps. Habitat is a place occupied by a specific population within a community population (Smith, 1974). Habitat selection is important part of organism's life history pattern. Roy *et al.* 1986 states that preservation of wildlife requires a complete knowledge of their spatial requirements commonly referred to as habitat. Habitat evaluation is the assessment of the suitability of land or water as habitat for specific wildlife species. To achieve this one need a model to predict the suitability of land in a given particular set of land conditions. Such model is called a habitat (environmental) suitability model (De Leeuw and Albricht , 1996).

The wildlife habitat suitability assessment from remote sensing is considered to be complex due to indirect approach by inter relation of other information to the wildlife population in their environmental setup. In every theme (land use, elevation, water availability, human habitation), there are areas, which are suitable and unsuitable for a particular species. The population characteristics of an animal are a reflector to its total surroundings i.e. the habitat in which it lives. The species habitat information is required to be known by the wildlife managers in order to prepare proper habitat suitability analysis of a species in an integrated scientific manner (Parihar et. al. 1986). Conservation biologists and managers need a range of both classical analyses and specific modern tools to face the increasing threats to biodiversity (Caughley, *et al.* 1996). Among these tools, habitat-suitability modeling using geo-spatial tools has recently emerged as a relevant technique to assess global impacts, for example, those due to climate change, (Berry, *et al.* 2002) to define wide conservation priorities (Margules, *et al.* 1994) and to evaluate the completeness of regional nets of protected areas (Araujo, *et al.* 2002).

A wildlife habitat suitability map is defined as a map displaying the suitability of land or water as a habitat for a specific wildlife species (Leeuw *et al.* 1997). Since the 1980s, remote sensing has been used to localize the distribution of areas suitable for wildlife (Cannon *et al.* 1982). These studies depended on a vegetation map, derived from remote sensing, as the only explanatory variable. The assumption was that mapping units efficiently reflect the availability of resources and other relevant environmental factors determining suitability. However, the suitability of land for wildlife may be determining by more than one factor. A single explanatory variable, such as a vegetation map or a land-unit map, does not effectively represent such multiple factors, especially when they were poorly correlated with each other.

In the second half of the 1980s, wildlife habitat suitability maps integrating various explanatory variables were implemented in a GIS context. Such a scheme consists of a suitability model that allows one to predict the suitability of land for a specific species, given a number of landscape attributes. Additionally, it contains number of spatial databases describing the distribution of these landscape attributes. The suitability model is then used to process these spatial databases to generate a suitability map (Toxopeus 1996).

GIS based habitat studies generally combine information on vegetation types or some other land cover descriptor, with other land attributes, reflecting the resource base as well as other relevant factors. GIS is a powerful set of tools used to collect, store, retrieve, transform and present spatially referenced environmental data from the real world. Although primarily a tool used in landscape ecology, GIS is now used for a wide range of application for answering questions on the ecology and distribution of individual species and communities (Vogiatzakis, 2003). The US Fish and Wildlife Service has developed Habitat Suitability Index (HIS) for some species and these models have been useful for management of wildlife and their habitat (Verner *et al.* 1986; Davis *et al.* 1990), and for environmental impact studies. Here in this chapter rhino habitat suitability modeling and assessment is done using geo-spatial tools and also using field based spatial datasets which have its relationship with rhino and its habitat.

6.2 Rhino habitat suitability modeling:

Wilderness area for rhinos continues to shrink and fragment due to multiplicity of natural phenomena as well as ever increasing anthropogenic pressures. Rhinos are in critical demographic crisis; primarily by over-exploitation through poaching for rhino horn and other products and secondarily by loss of habitat due to expanding and developing human populations (Foose and Strien, 1997). Revised IUCN categories and criteria, approved by the 40th meeting of the IUCN council has rated vulnerable to the parameters viz. population reduction, population estimate and probability of extinction. However extent of occurrence has been rated to be endangered. Consequently greater one-horned rhinoceros status falls under endangered category with special emphasis put to in-situ conservation with adequate protection measures (Foose and Strien, 1997). In-situ conservation, in turn, is directly dependent on its habitat parameters that decide whether the site is suitable for rhino conservation demanding habitat suitability analysis for the species.

Habitat suitability modeling is a tool for predicting the quality or suitability of habitat for a given species based on known affinities with habitat characteristics. Habitat evaluation is the first step towards meaningful wildlife conservation and management. Realizing the afore mentioned facts this study was taken up to evaluate rhino habitat in RG Orang NP, that has been serving as a potential site for rhino conservation in perpetuity.

RG Orang NP is a prime habitat of rhino, located in the north bank of river Brahmaputra. This park enjoys a flood plain ecosystem and is a prime habitat for other important species of conservation importance like Royal Bengal Tiger, Asiatic Elephant and different Deer species. The population of rhino in RG Orang NP is fluctuating from 35 rhinos in the year 1972 to 97 rhinos in the year 1991 and which is again reduce to 64 rhinos in the year 2009. This unpredictable population fluctuation in the floodplain ecosystem of RG Orang NP demands habitat suitability evaluation for identifying the key habitat factors and total suitable area for determining fate of rhinos in the park.

During the last four decades, development of remote sensing and GIS techniques has made significant contribution in the management of natural resources (Marble *et al.* 1983; Gugan 1993) and environmental monitoring (Kushwaha 1990, 1997). Remote sensing and GIS have been widely used in wildlife habitat studies (Roy *et al.* 1995; Porwal *et al.* 1996; Kushwaha *et al.* 2000, 2004; Hazarika *et al.* 2005). Remote sensing and GIS technologies together provide vital geo-information support for relevant, reliable and timely information needed for conservation planning (Nellis *et al.* 1990). GIS has assumed a central role over the years in numerous species-specific applications but there are more scope for GIS in modeling species assemblages, scale-dependent habitat preferences and geographical fragmentation of population, habitat heterogeneity and ecological integrity (Duncan *et al.* 1995). However these techniques have not been widely used for wildlife habitat studies in Assam. Here in this research geo-spatial tool with a modeling approach was adopted to address the questions of habitat suitability of rhinos in RG Orang NP.

6.2.1 Habitat parameters used for suitability modeling:

Wildlife habitat suitability analysis is considered as most important criteria for the conservation and management of wildlife and its habitat (Kushwaha *et al.* 2000). Such suitability analysis includes a wide variety of factors like habitat pattern, habitat quality, distance from road, availability of water, topography, land cover characteristics including human interferences. It is very essential to understand the relationship between these controlling factors and the species distribution, to make an assessment of the species habitat suitability in a landscape. A variety of analytical techniques have been used to investigate species-environment relationships. These include logistic regression (Pereira *et al.* 1991; Buckland *et al.* 1993; Osborne *et al.* 1992; Walker 1990), discriminant analysis (Haworth, *et al.* 1990), classification and regression trees (Walker *et al.* 1988; Skidmore *et al.* 1996), correlation analysis (Andries *et al.* 1994) and artificial neuron network (Skidmore *et al.* 1997). Here in this research an integrated effort was made to identify the rhino habitat suitability status in RG Orang NP using geo-spatial tools and field observation of rhino and its habitat. Various factors were identified based on field observation, which have its direct and indirect impact on the distribution of rhino and its habitat utilization pattern. Correlation coefficient statistical method was used to understand the relationship of rhino and the environment. Identification of the causal relationship among different characteristics of any study is an essential concern of a scientific investigation (Mahmood 1993). The factor which is supposed to be the cause is known as the independent variable and the one which is supposed to be the effect is known as dependent variable in a correlation analysis. Here in this research habitat parameters were considered as independent variable and the distribution of rhino was considered as dependent variable. The relationships of rhino and its different habitat parameters are discussed below.

i) **Rhino-Habitat relationship:**

Habitat was considered as an important parameter in suitability modeling for rhino in RG Orang NP. Out of total 183 rhinos sighted in all the seasons of the park, 109 (59.56%) rhinos were found in wet alluvial grassland habitat, 45 (24.59%) rhinos were found in dry savannah grassland habitat and rest 29 (15.84%) rhinos were found in woodlands and wetland habitats. It was also observed that there is an increasing trend of rhino sighting with the increase of wet alluvial grassland area. There is a positive correlation between rhino sighting and wet alluvial grassland (**r = 0.582**). This indicates that rhino prefers wet alluvial grassland more than dry savannah grassland, woodland and wetland habitats. Thus in selection of habitat suitability parameters, areas with wet alluvial grassland were considered as most suitable for rhino. Similarly, areas with dry savannah grassland were considered as moderately suitable, whereas areas with woodland and wetlands were considered as less suitable habitat for rhino.

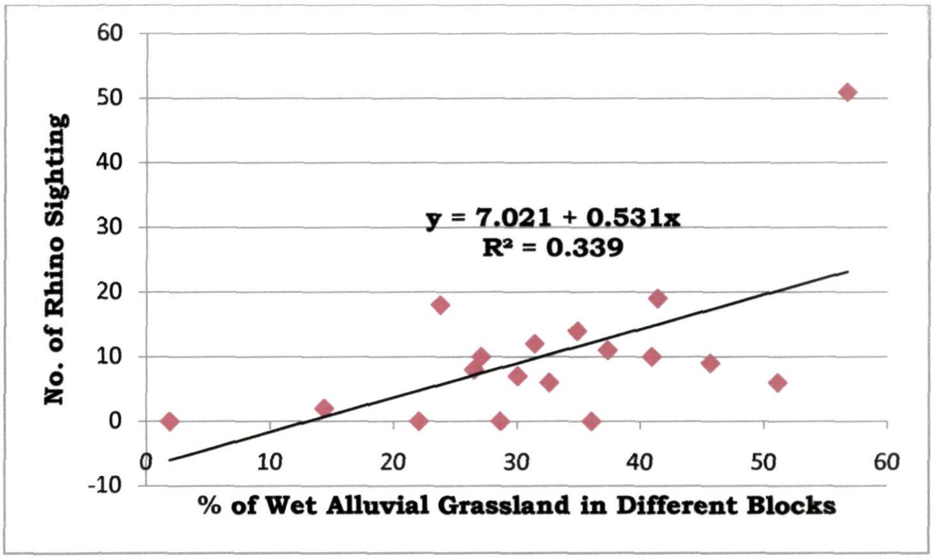


Fig. VI a. Correlation between wet alluvial grassland and rhino sighting.

ii) **Rhino-Roads relationship:**

Roads of RG Orang NP were considered as one of the parameters for habitat suitability modeling for rhino. It is observed that the sighting or presence of rhino was increased with the increasing distance from roads. During ground survey period from September 2008 to September 2009, a total 183 rhinos were sighted, out of which 71 (38.79%) rhinos were found within 200 meters distance from roads whereas 112 (61.20%) rhinos were found beyond 200 meters from the roads. The results of the correlation coefficient shows a positive relationship between distance from road and rhino sighting (**r = 0.9**). Hence, in selection of habitat suitability parameters, areas beyond 200 meters from roads were considered as most suitable for rhino. Similarly, areas less than 200 meters but more than 100 meters away from roads were considered as moderately suitable and areas within 100 meters from the roads were considered as less suitable for rhino.

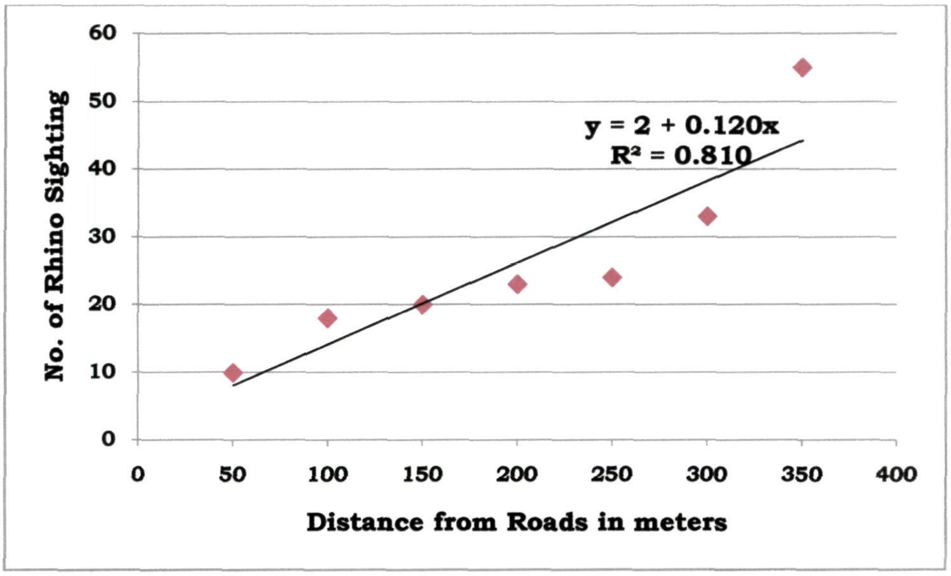


Fig. VI b. Correlation between distance from road and rhino sighting

iii) **Rhino-Wetlands relationship:**

Wetlands of RG Orang NP were identified as another important habitat parameter for rhino habitat suitability modeling. It was observed that out of total 183 rhinos sighted, 158 (86.34%) rhinos were found within 500 meters distance from wetlands, where as rest 25 (13.66%) rhinos were found beyond 500 meters from the wetlands. It was also observed that there was a negative correlation between distance from wetlands and number of rhino sighted (**r = - 0.881**). Thus in the selection of habitat suitability parameters, areas within 500 meters distance from the wetlands were considered as most suitable areas for rhino. On the other hand areas which area more than 500 meter, but less than 1km away from the wetlands were considered as moderately suitable and areas more than 1 km distance from the wetlands were considered as less suitable for rhino in RG Orang NP.

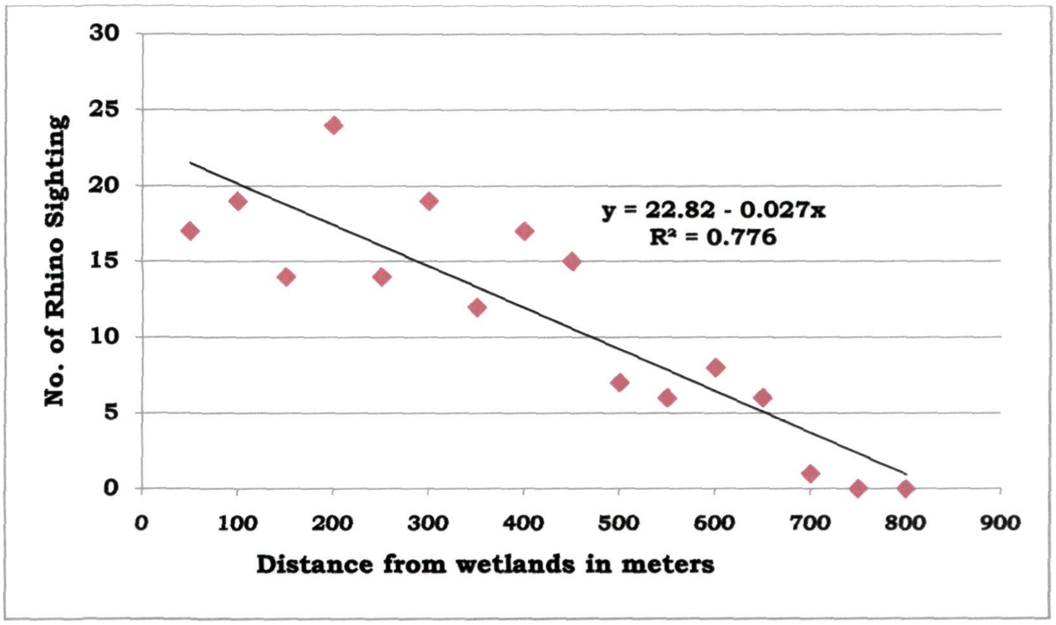


Fig. VI c. Correlation between distance from wetlands and number of rhino sighting

iv) **Rhino-Elevation relationship:**

Elevation or height was identified as an important habitat parameter used for the suitability modeling of rhino in RG Orang NP. From the ground observation it was observed that out of total rhino sighted 129 (70.49%) rhinos were present within 50 meter elevation in RG Orang NP. Total 41 (22.40%) rhinos were found in more than 50 meter height but less than 60 meter height and rest 7 (3.82%) rhinos were found in more than 60 meter elevation zone. The figure VI d) shows the graphical representation of height range and rhino sighting. In the selection of habitat parameters in suitability modeling for rhino, areas less than 50 meter elevation were considered as most suitable for rhino. In case of moderately suitable areas, areas more than

50 meter but less than 60 meter elevation was selected and area more than 60 meter elevation were considered as less suitable for rhino in RG Orang NP.

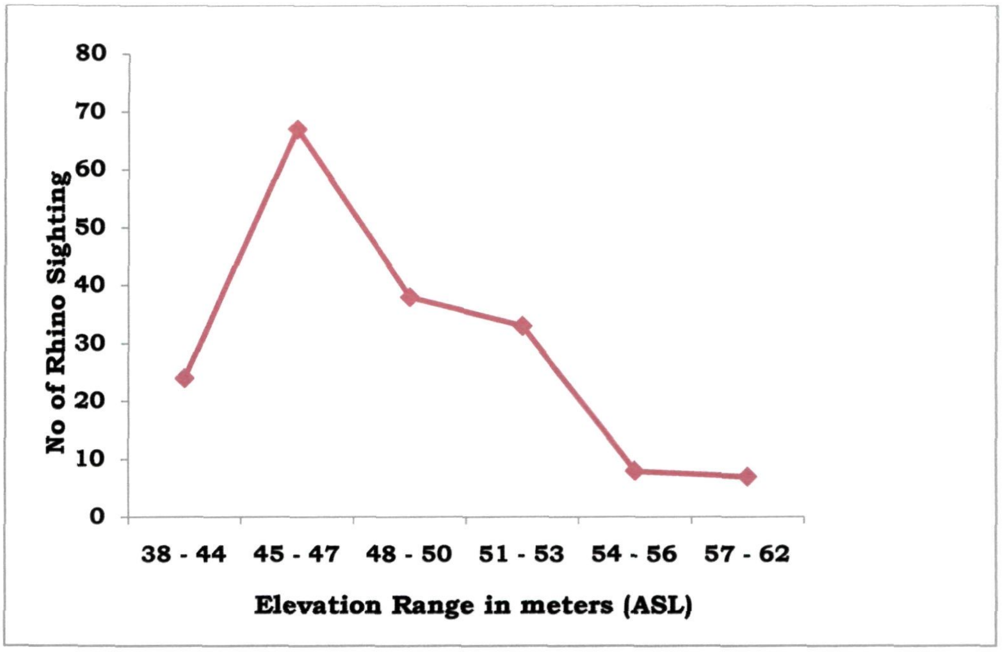


Fig. VI d. Distribution of rhino in RG Orang NP in different elevation zones

v) **Rhino-Forest Camp distance relationship:**

Human interference or disturbance is always as an important factor for the distribution of wild animals. Proper understanding of the relationship between human interference and wildlife animal distribution is always important before any habitat suitability analysis of any species. In this current research forest camps within the RG Orang NP were considered as human disturbance factor. During the field survey period out of 183 rhinos sighted, 167 (91%) rhinos were found beyond 100 meter distance from the forest camps, rest 11 (9%) rhinos were found within 100 meter distance from the forest camps. It indicates that the rhino sighting increases with the increase of distance from the forest camps. There is a positive correlation between distance from forest camps and the number of rhino sighting (**r= 0.507**). Thus in selections of habitat suitability parameter areas which are beyond 100 meter distance from the forest camp were considered as most suitable for rhino. Similarly areas within 50 meter to 100 meters distance from the forest camps were considered

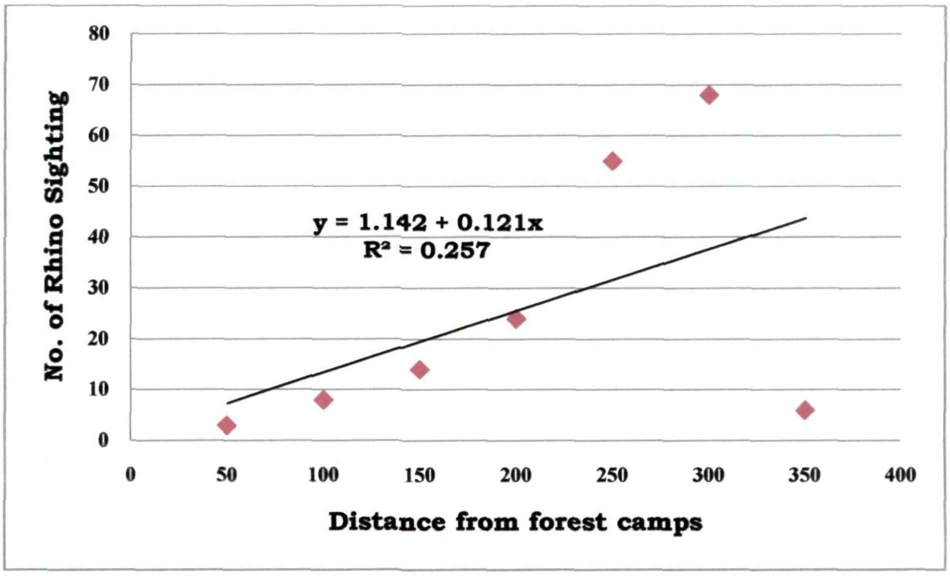


Fig. VI e. Correlation between distance from forest camps and number of rhino sighting

The habitat parameters that were used in the habitat suitability modeling for rhino is shown in the table VI a.

Table: VI a. The parameters used for rhino habitat suitability model

No	Habitat Suitability Classes	Elevation	Vegetation Types	Proximity to water source	Proximity to roads	Proximity to forest camps
1	Most Suitable	< 50 mts	Wet Alluvial Grassland	Within 500 mts	More than 200mts	More than 100mts
2	Moderately Suitable	>50 mts < 60 mts	Dry Savannah Grassland, Eastern Seasonal Swamp Forest	More than 500 m but less than 1 km	Less than 200 mts but more than 100 mts	50mts to 100 mts
3	Less Suitable	> 60mts	Woodland, Degraded Grassland, Sandy Area, Running Water	More than 1 km	Within 100 mts	Within 50 mts

Based upon the above mentioned parameters a habitat suitability model for rhino was generated in Arc GIS 9.3 environment. A new tool box in arc tool box was generated under which a model for rhino habitat suitability was designed. The habitat parameters for rhino were placed in the model and spatial analysis tools like select, buffer, erase, union and intersect were used to get the habitat suitability map of RG Orang NP. The model of the rhino habitat suitability analysis in RG Orang NP is shown in the figure VI f.

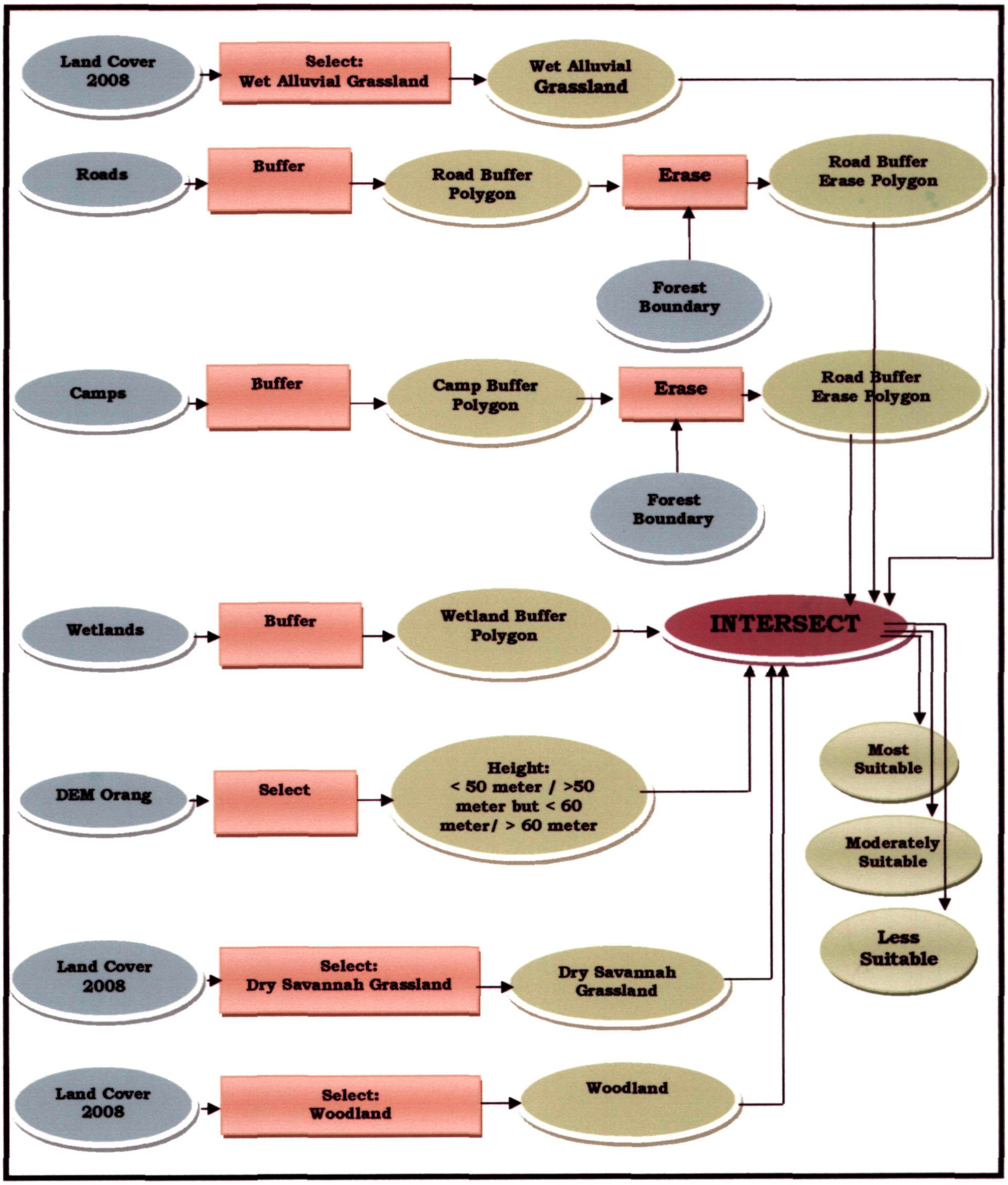
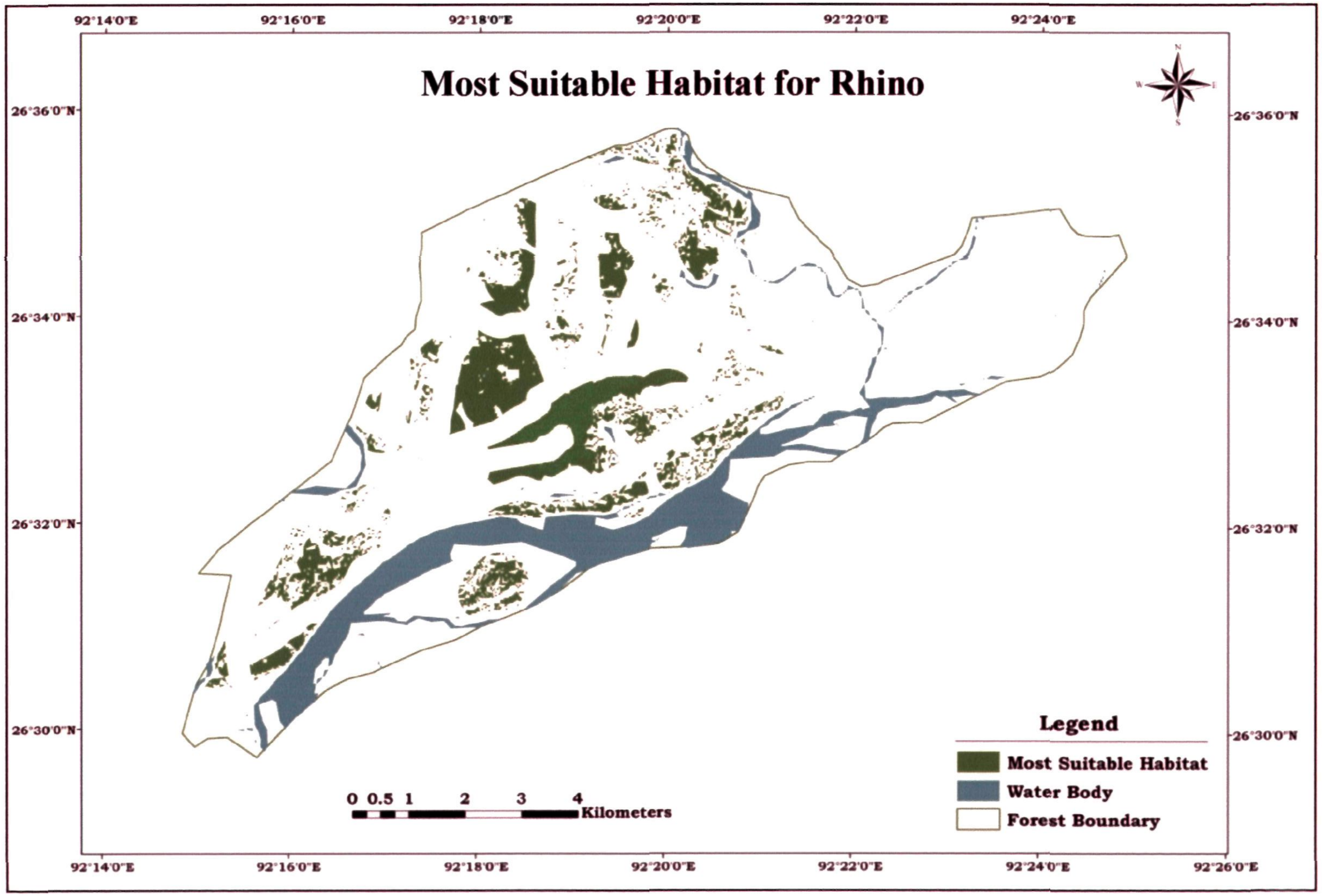


Fig. VI f) Rhino Habitat Suitability Model

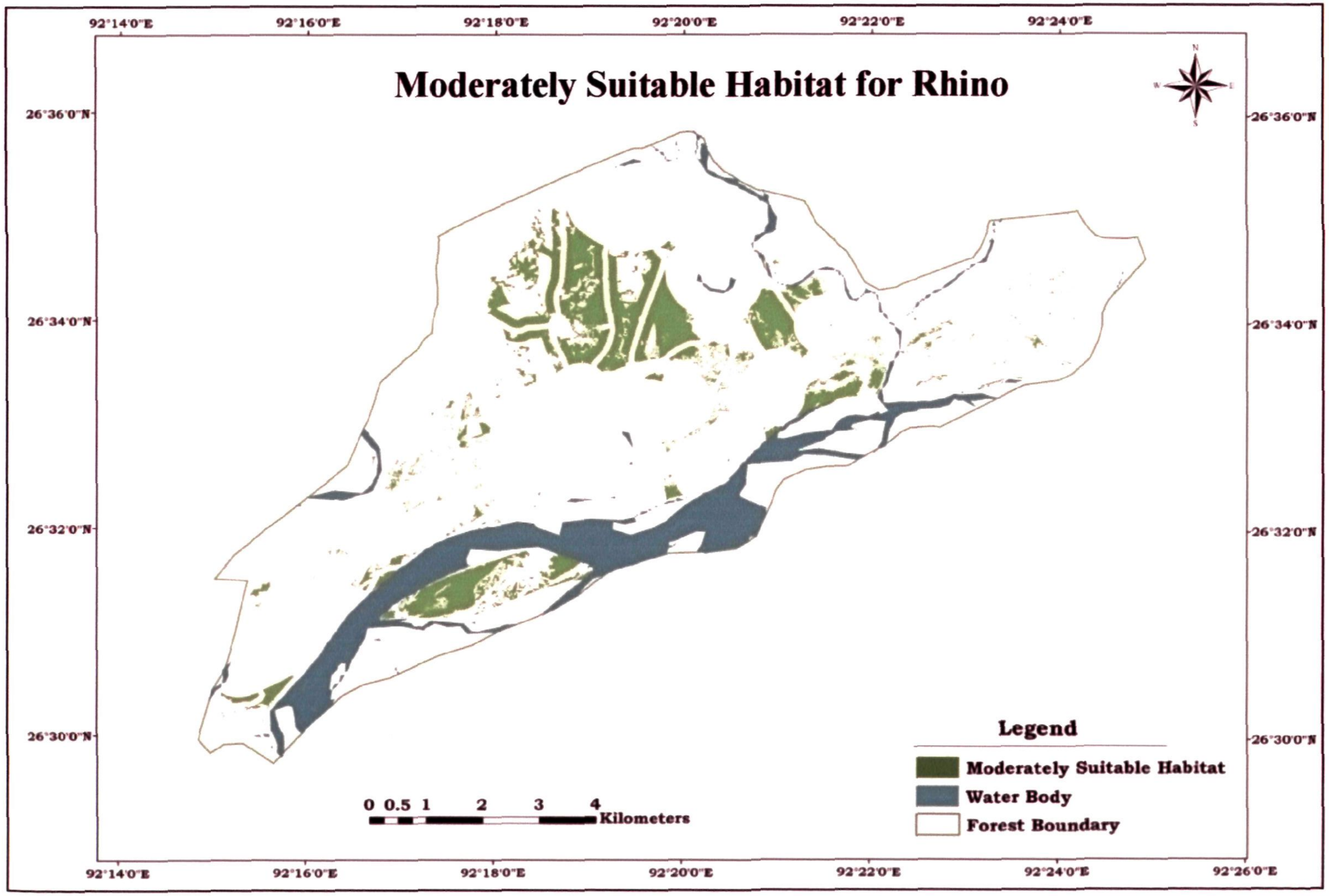
6.2.2 Suitability status of rhino habitat in RG Orang NP:

The results of the rhino habitat suitability modeling of RG Orang NP shows that 19.81 km^2 of the park is most suitable for rhino, which covers 25.13% of the total geographical area of the park. The area covered by moderately suitable habitat for rhino in the park is 10.74 km^2, which is 13.62% of the total geographical area of the park. The area covered by less suitable habitat is 48.25 km^2, which is 61.23% of the total geographical area of the park. Out of 48.45 km^2 of less suitable habitat for rhino, 5.78 km^2 is covered by river Brahmaputra, 5.77 km^2 area is covered by degraded grassland and 5.39 km^2 area is covered by river sands. These are the habitat types which are rarely used by rhino and hence identified through the model as less suitable habitat. Among the blocks Rahmanpur B block has the most suitable habitat for rhino covering 4.73 km^2 area followed by Satsimalu Block covering 3.82 km^2 area. The Map No. 48, 49, 50 and 51 shows the different habitat suitability status and their distribution in RG Orang NP.



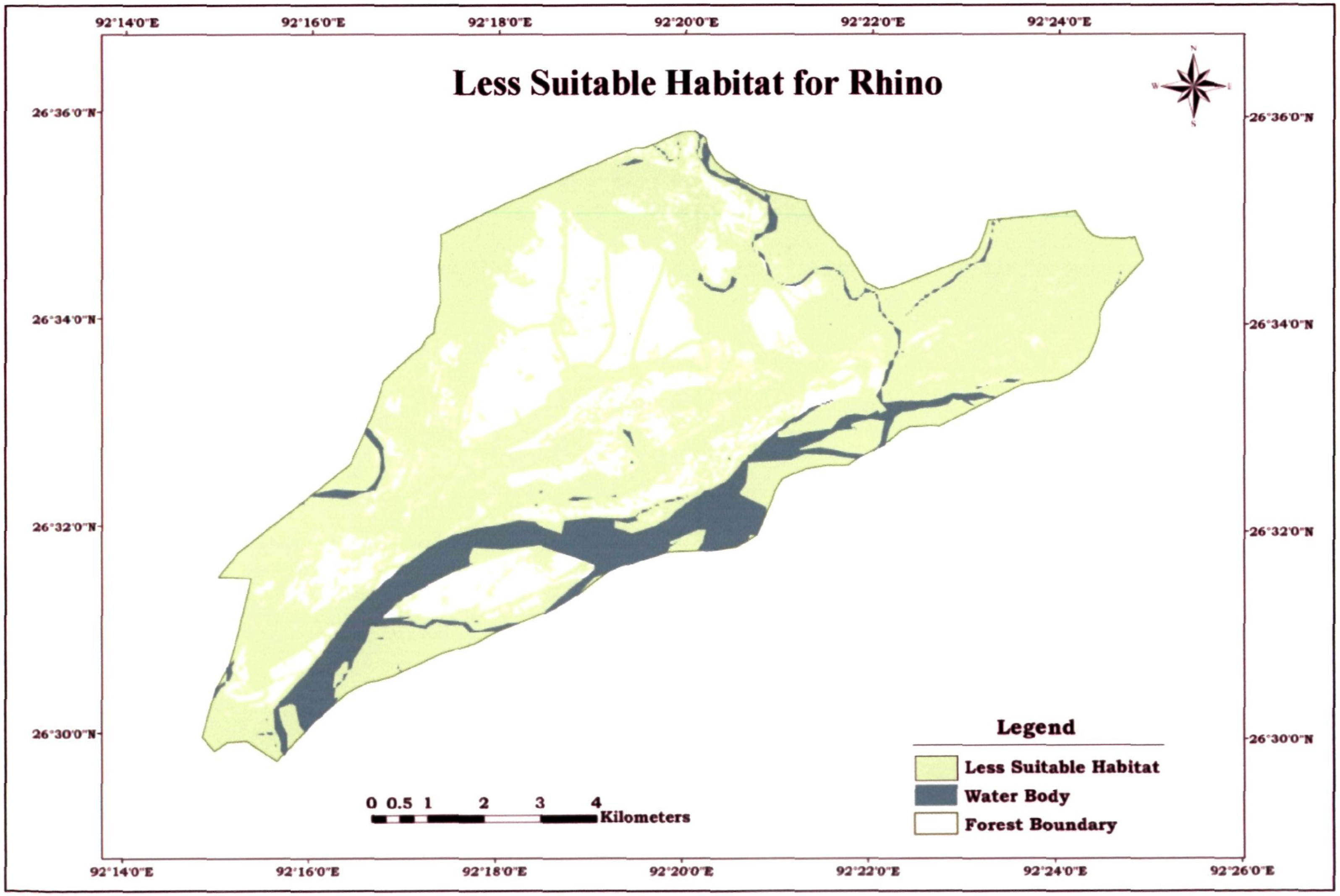
Source: Prepared by researcher based on habitat suitability model

Map No. - 48



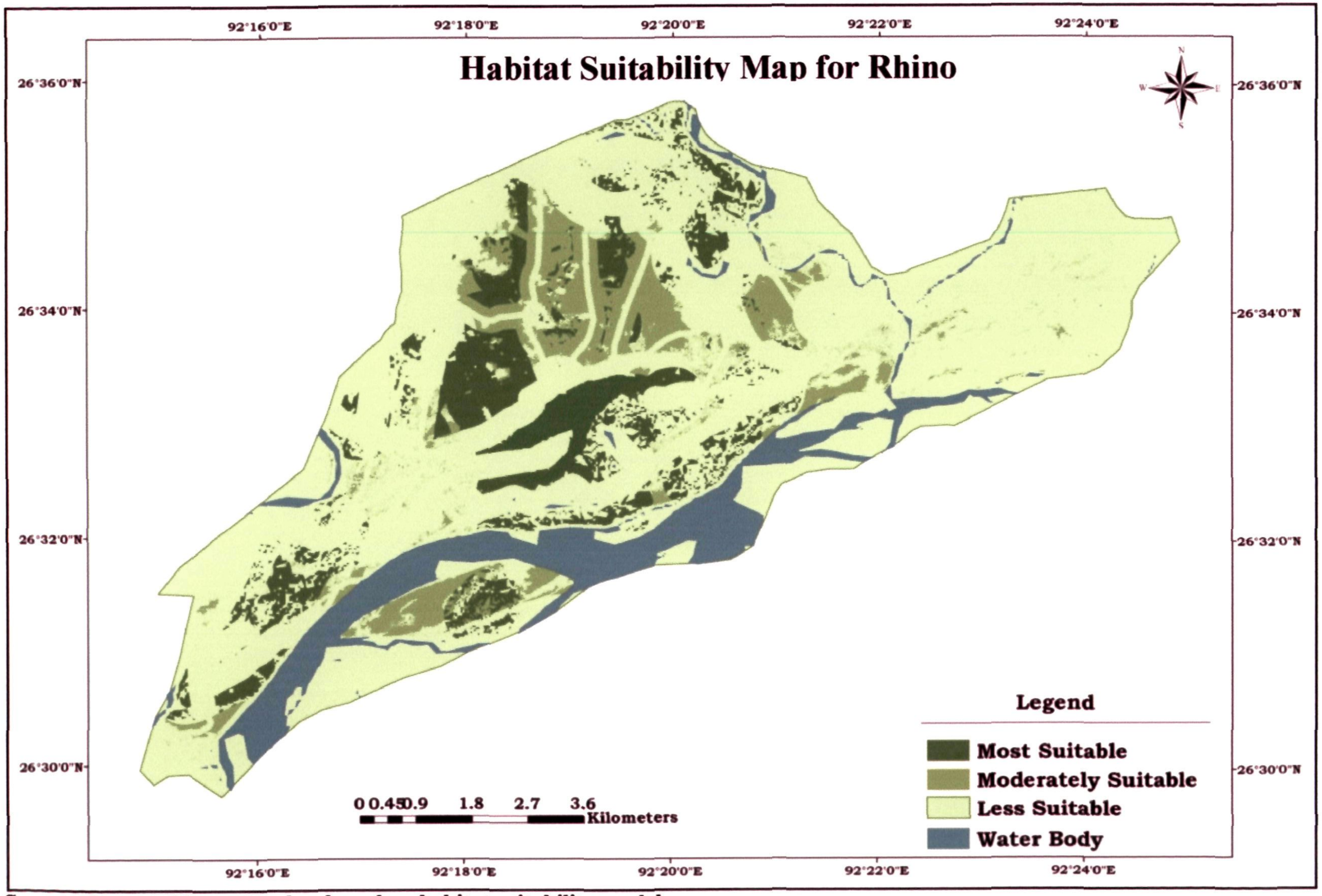
Source: Prepared by researcher based on habitat suitability model

Map No. 49



Source: Prepared by researcher based on habitat suitability model

Map No. - 50



Source: Prepared by researcher based on habitat suitability model

Map No. 51

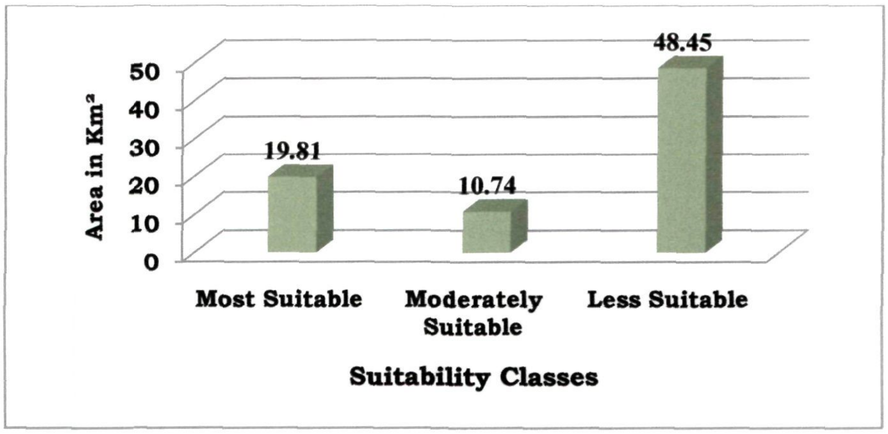
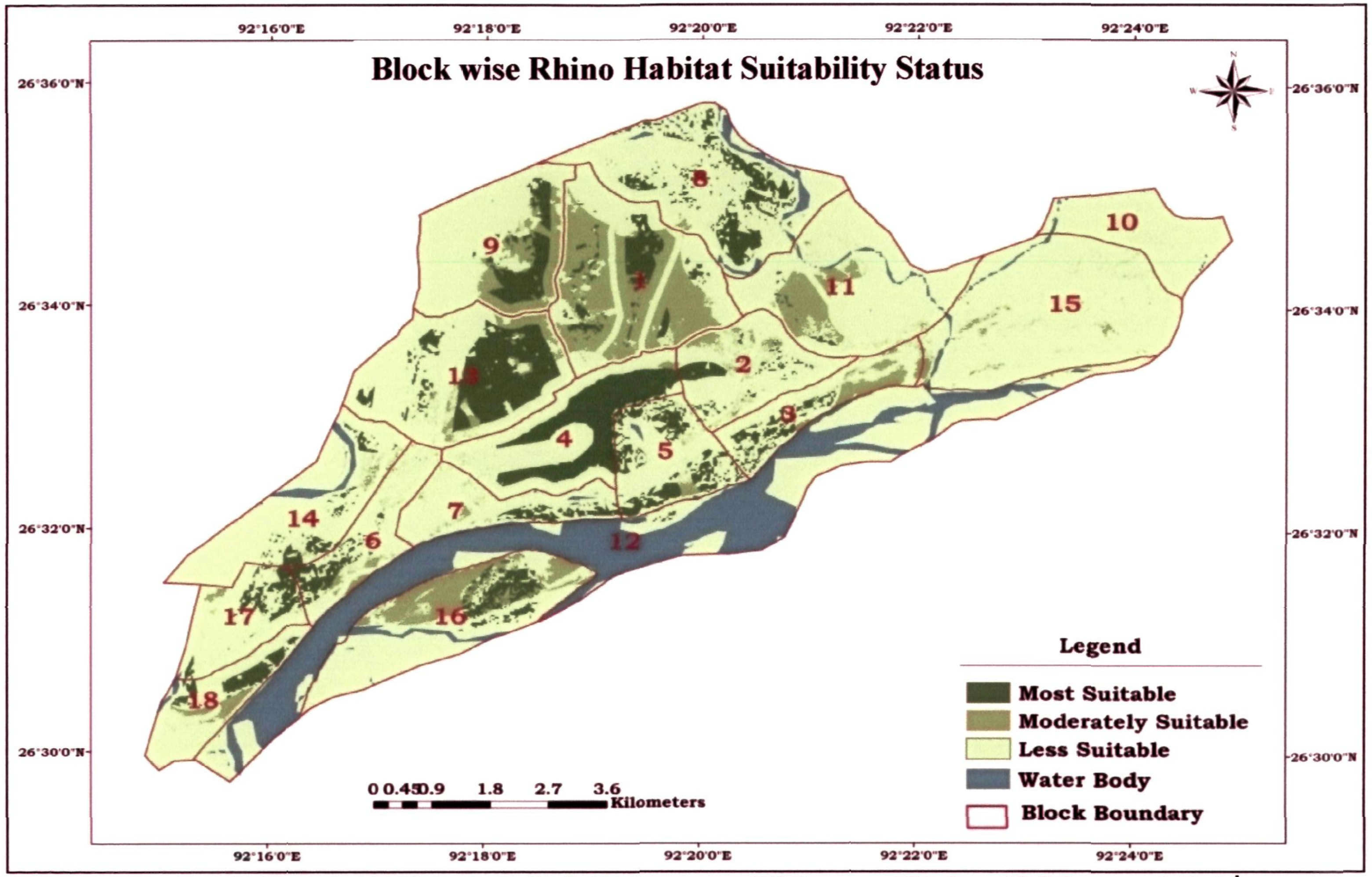


Fig. VI g) Rhino habitat suitability status of RG Orang NP

The habitat suitability condition in each block is also different from one another. The micro level habitat suitability assessment for rhino is quite useful for conservation and management of wild rhino and its habitat. The block wise habitat suitability status of RG Orang NP is shown in the table VI b. The distribution of rhino habitat suitability condition in different blocks is shown in the Map No. 52 and figure VI h.



1. Magurmari Block,
2. Moalamari Block,
3. Ramkong Block,
4. Satsimalu Block,
5. Chaila Block
6. Baghmari Block
7. Tinkona Block
8. Oogli Block
9. Rahmanpur A Block
10. Belsiri Block
11. Solmari Block
12. Brahmaputra Block
13. Rahmanpur B Block
14. Bogbeel Block
15. Ramdas Block
16. Jhawani Block
17. Gaimari Block
18. Pabhomari Block

Source: Rhino habitat suitability model

Map No. - 52

Table: VI b. Block wise distribution of habitat suitability for rhino in RG Orang NP

Blocks	Most Suitable (Area km²)	Moderately Suitable (Area km²)	Less Suitable (Area km²)
Baghmari Block	0.42	0.17	1.77
Belsiri Block	0	0.01	2.33
Boogbeel Block	0.28	0.42	3.59
Chaila Block	1.33	0.08	1.46
Gaimari Block	0.7	0.04	1.63
Jhawani Block	0.52	1.22	3.2
Magurmari Block	1.05	2.8	2.5
Moalamari Block	0.39	2.62	0.01
Oogli Block	1.86	0.03	4.35
Pabhomari Block	0.63	0.18	1.41
Rahmanpur_Block_A	1.06	0.8	2.92
Rahmanpur_Block_B	4.73	0.39	0.82
Ramdas_Block	0	0.25	7.24
Ramkong_Block	1.13	0.4	0.8
Satsimalu_Block	3.82	0.23	0.27
Solmari_Block	0.05	0.84	4.79
Tinkona_Block	1.82	0.07	0.56
Brahmaputra_River_Block	0.02	0.19	8.6

Source: Habitat suitability model.

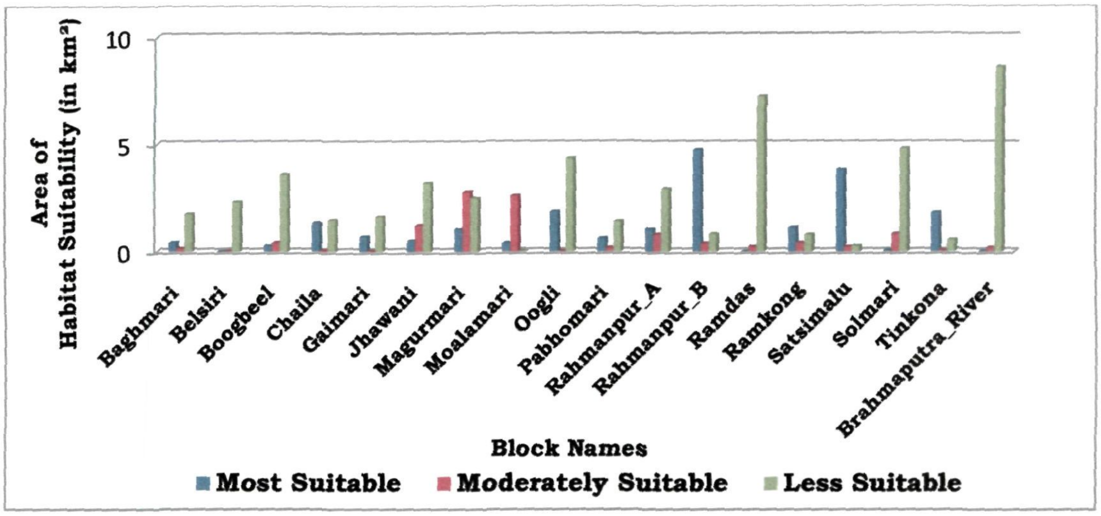


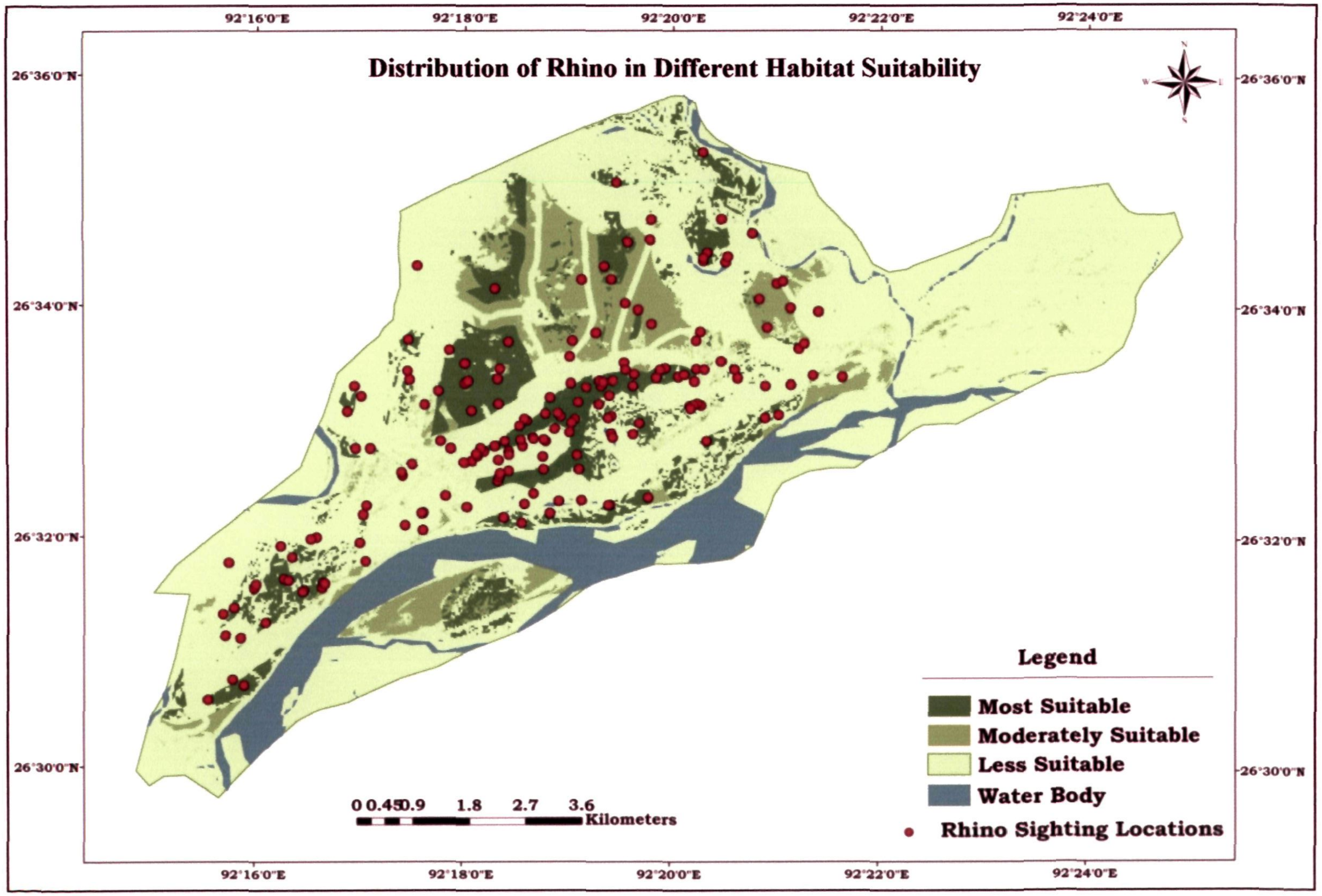
Fig. VI h. Block wise habitat suitability status for rhino in RG Orang NP

6.2.3 Accuracy of suitability map:

Wildlife suitability maps and their underlying suitability models have been criticized because of their assumed poor accuracy (Norton *et al.* 1992). The maps produced by these models have rarely been validated (Stoms *et al.* 1992; Williams 1988), although this was clearly advised in the habitat evaluation procedures (USFWS 1981). The accuracy of a wildlife suitability map depends on how well the output correspondence to reality. The accuracy of suitability models depends on the selection of the relevant variable and an unbiased estimation of the model parameters. In habitat suitability accuracy assessment, the predicted suitability is tabulated against observations on presence and absence of the animal species. But in some cases animal would not be recorded in suitable areas or would be observed in areas considered unsuitable. Most animal species are mobile; hence suitable land may not be temporarily occupied, while animals may pass through lands otherwise unsuitable for them. Animal differ in this respect from land cover or plant species and because of this accuracy level for wildlife habitat suitability maps may yield relatively low accuracy values. But at the same time accuracy assessment of the wildlife habitat suitability maps is quite important to validate the model for a particular species in a particular habitat pattern. Here in this study two different approaches were adopted to assess the accuracy of the suitability model prepared for rhino in RG Orang NP.

a) Accuracy assessment based on animal presence and absence:

Based on the presence and absence of rhino in different habitat suitability categories, an accuracy assessment of the habitat suitability map for rhino in RG Orang NP was done. Overlaying of all the rhino sighting locations (total 183) over the suitability map was done in Arc GIS 9.3 environment. The result shows that out of 183 rhinos, 100 (54.64%) rhinos were found in most suitable habitat of RG Orang NP, 68 (37.16%) rhinos were found in moderately suitable area and rest 15 (8.20%) were found in less suitable habitat of the park. It indicates that the model prepared for the assessment of rhino habitat suitability in RG Orang NP has its validation with the reality. It shows that rhino preferred the most and moderately suitable habitats in comparison to less suitable habitat in the park. The Map No. 53 and figure VI i. shows the distribution pattern rhino in different habitat suitability categories.



Source: Prepared by researcher based on field data Map No. - 53

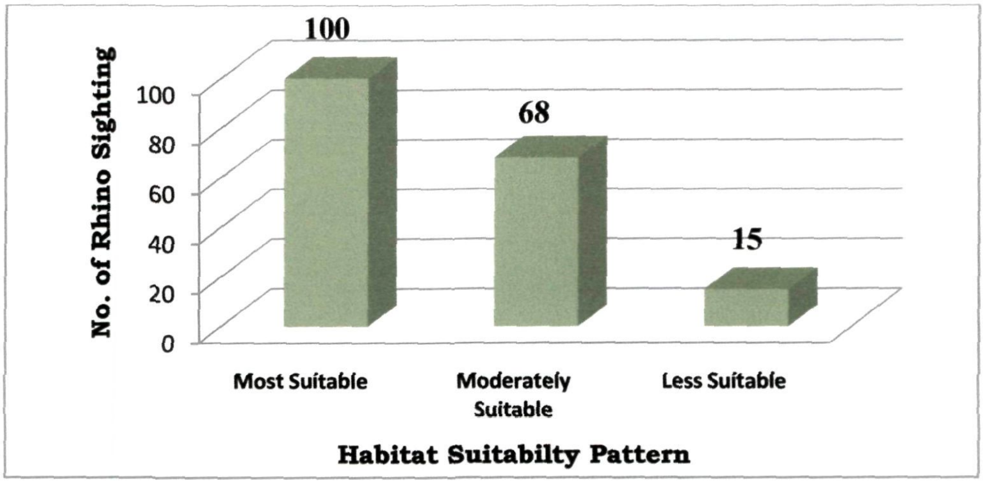


Fig. VI i) Distribution of rhino in different habitat suitability categories

a) Accuracy assessment based on relationship of habitat suitability and animal sighting:

Accuracy assessment of the rhino habitat suitability map was also done using correlation coefficient to understand the relationship between habitat suitability and number rhino sighting. The suitability condition was taken as an independent variable and number of rhino sighting was taken as dependent variable. The result shows that there is a positive correlation between most suitable habitat and number of rhino sighting (**r = 0.682**). This indicates that the number of rhino sighting increases with the increase of most suitable habitat in RG Orang NP. The figure VI j. shows the relationship between most suitable habitat and number of rhino sighting.

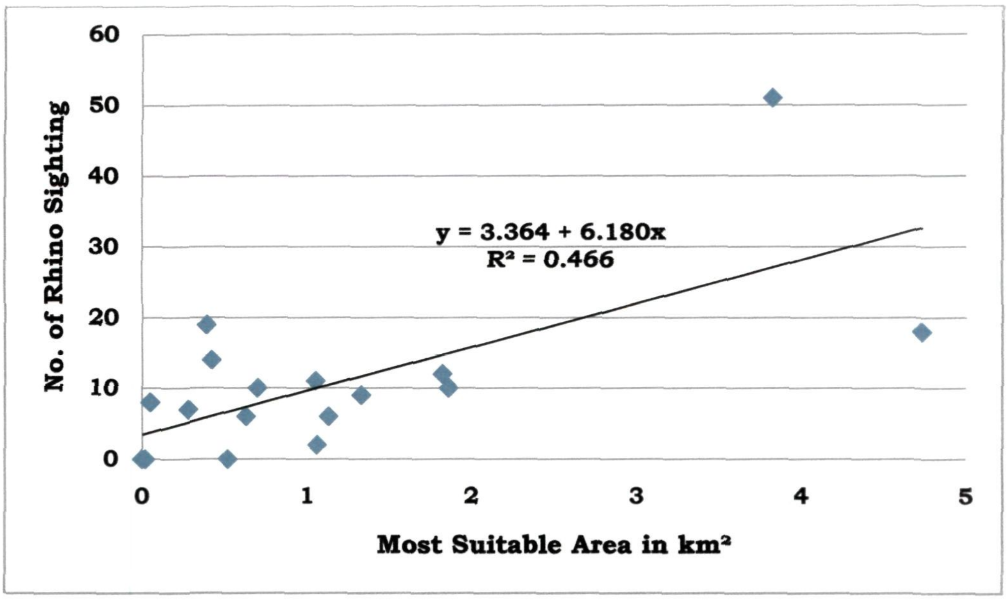


Fig. VI j. Relationship between most suitable habitat and number of rhino sighting

Similarly correlation coefficient was done between less suitable habitat and number of rhino sighting. Here less suitable habitat was considered as independent variable and the number of rhino sighting was considered as dependent variable. The result shows a negative correlation between these two variables (**r = - 0.525**). It indicates that the number of rhino sighting decreases with the increase of less suitable habitat in RG Orang NP. The figure VI k. shows the relationship between less suitable habitat and number of rhino sighting.

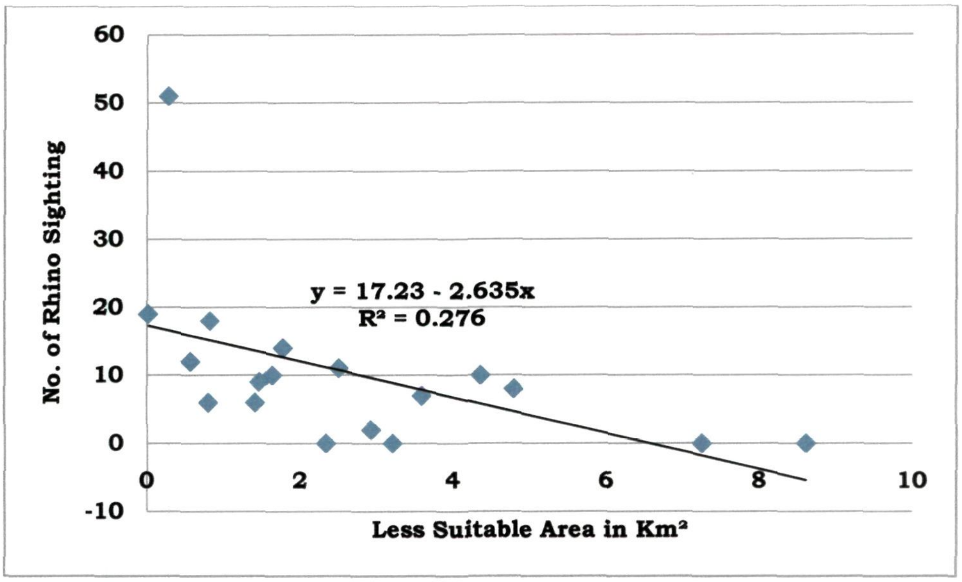
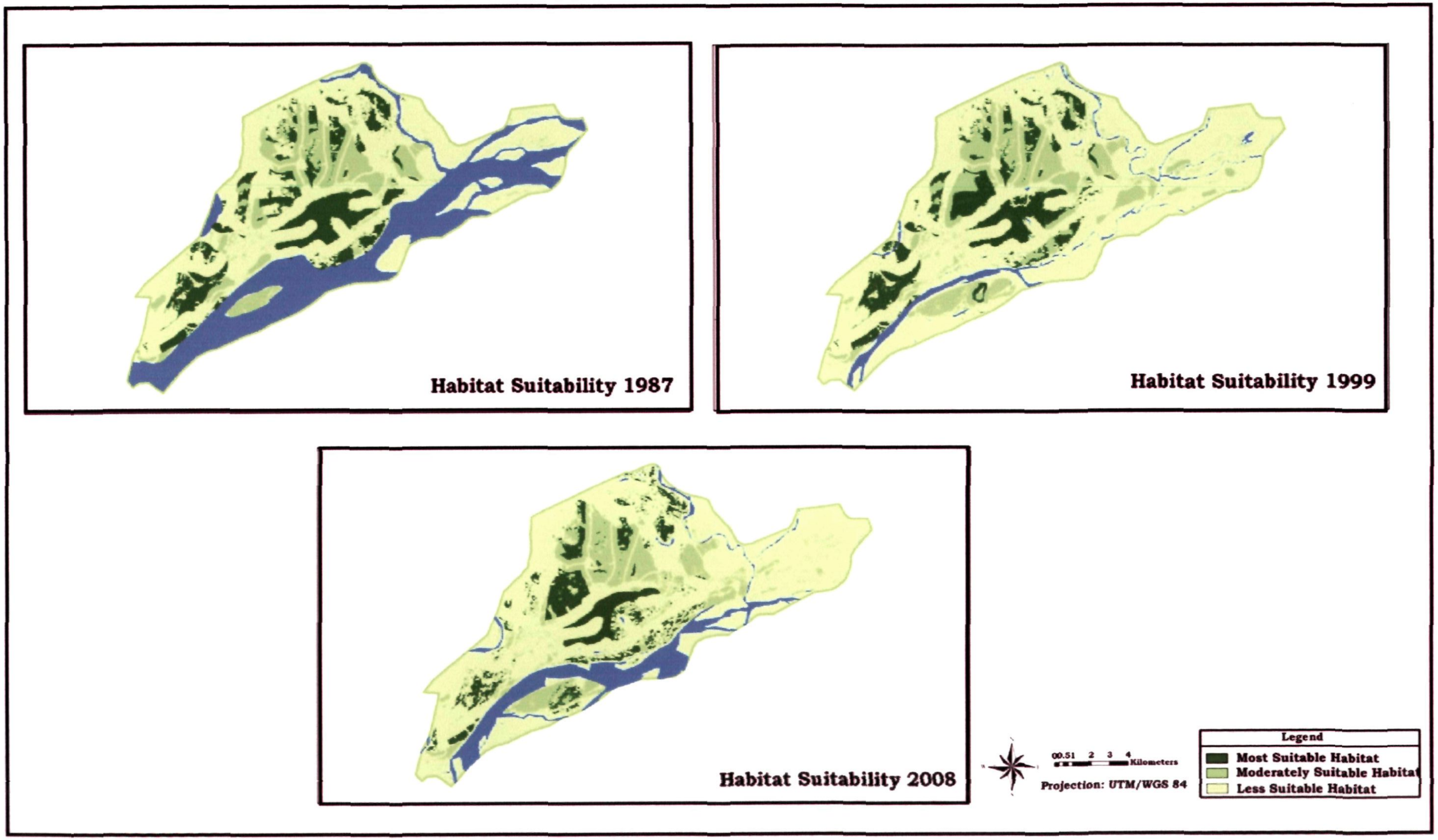


Fig. VI k. Relationship between less suitable habitat and number of rhino sighting

The above discussion on the accuracy assessment of the rhino habitat suitability model of RG Orang NP shows that the output of the model is well correspond to reality, hence it can be assumed that the model is accurate and well validated and this model can be implemented in other rhino bearing areas of Assam like Pabitora Wildlife Sanctuary and Kaziranga National Park.

6.3 Changes in rhino habitat suitability from 1987 to 2008:

The suitability condition of rhino habitat in RG Orang NP is dynamic in nature. Integrating the historical habitat condition and current geo-spatial dataset on rhino, a change detection of rhino habitat suitability in RG Orang NP was done using GIS tool. The result shows a massive change in rhino habitat suitability pattern in RG Orang NP. It shows that the most suitable habitat in the park has decreased up to 11.99% from 1987 to 2008. Similarly moderately suitable habitat is also decreased up to 4.43% in the park from 1987 to 2008. But in case of less suitable habitat there is an increase of 16.68% from 1987 to 2008. This indicates that most suitable and moderately suitable habitats for rhino in RG Orang NP has decreased from 1987 to 2008 and less suitable habitat has increases in the park during the same period of time. These changes in the rhino habitat suitability condition are mainly due to the changes in the land cover or habitat pattern of RG Orang NP. It has already been discussed in the chapter III that the wet alluvial grassland in the RG Orang NP is drastically reducing due to the impact of invasive species like *Mimosa inveas* and also due to the excessive grazing pressure by domestic cattle from 1987 to 2008. Rhino prefer wet alluvial grassland most in all the seasons and this kind of habitat is considered as mostly preferred habitat for rhino. Similarly due to the improper management of grassland habitat the rate of succession from grassland to woodland in the park is high during the period from 1987 to 2008, which has also its impact on the changes in rhino habitat suitability condition in the park. The Map No. 54 and table VI c. shows the changes in rhino habitat suitability in RG Orang NP from 1987 to 2008. The figure Vi l. graphically represents the changes of rhino habitat suitability in RGOrangNP.



Source: Prepared by researcher based on habitat suitability model

Map No. - 54

Table: VI c. Changes in rhino habitat suitability

Suitability Category	Years			Net Change	
	1987	1999	2008	Area in km²	
	Area in km²			1987 to 1999	1999 to 2008
Most Suitable	29.26	24.87	19.81	- 4.39	- 5.06
Moderately Suitable	14.23	11.69	10.74	- 2.54	- 0.95
Less Suitable	35.31	42.24	48.45	+ 6.93	+ 6.21

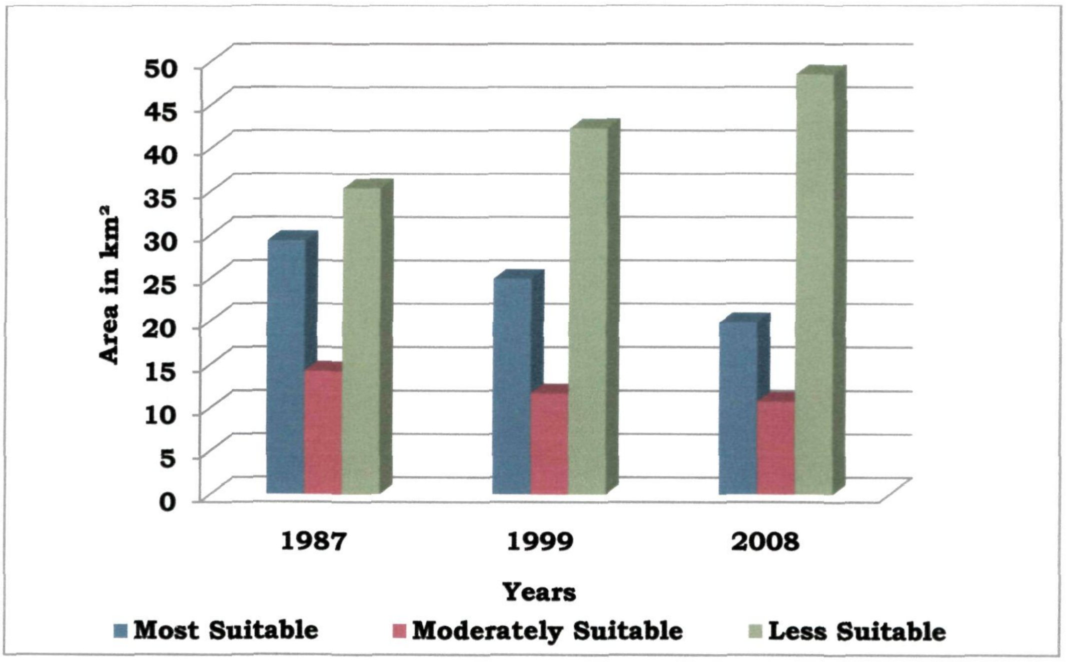


Fig. VI l. Rhino habitat suitability change in RG Orang NP from 1987 to 2008

6.4 Discussion:

It is evident from the present study that the distribution of rhino in RG Orang NP completely depends upon the habitat parameters like availability of food plant, distance from water body, distance from road, distance from human settlement, elevation, etc. The habitat parameters have tremendous impact over the habitat utilization and suitability pattern of rhino in RG Orang NP. From this study it is also clear that most suitable habitat for rhino in RG Orang NP is only 19.81 km^2 which is 25.13% of the total geographical area of the park. This indicates that most suitable habitat for rhino in the park is not sufficient for the rhino population that have in the park. Immediate attention should be taken to conserve the existing suitable habitat for rhino in the park and measures should also be taken to expand the most suitable habitat of the park from 25% to at least 40% to 45% of the total geographical area of the park. The park managers should also take the initiative to increase the wet alluvial grassland habitat in the park, which rhino prefer most in different seasons throughout the year. This study also makes it clear that the suitability status of the rhino is changing in the park with the changing pattern of land cover types. The most suitable habitat for rhino in the park has drastically reduced from 29.26 km^2 in the year 1987 to 19.81 km^2 in the year 2008. This change is mainly due to the changes in the land cover pattern of the park. The wet alluvial grassland area in the park is decreasing in an alarming rate and its leads to the decrease of most suitable habitat for rhino in the RG Orang NP. The park authority should try to control the spread of invasive species like *Mimosa invesa* and also the grazing pressure from the fringe villages of the park to further reduction of wet alluvial grassland areas in the park. The conservation and management of rhino habitat in RG Orang NP is discussed in the chapter VII.

Finally from this study it is evident that geo-spatial technology has the capability to evaluate the habitat suitability condition of wild animals. Through spatial modeling in GIS environment it is quite possible to understand the wildlife habitat suitability condition of any wildlife species.

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CHAPTER - VII

Chapter VII

Conservation and management of Rhino habitat in RG Orang NP

7.1 Introduction:

Habitat management is the art and science of creating, maintaining or enhancing conditions on the landscape to meet specified objectives for population of wildlife. This requires an understanding of the types, conditions and distributions of landscape features that meet the life requisites of the species of interest.

Habitat management has become an important part of wildlife conservation worldwide. Scientist and conservationist have made several simulation studies designing models seeking ways for effective conservation and management of wildlife. The management of habitat will be of little value unless biologist or conservationist first determines an animal's habitat utilization pattern within a specific environment and then consider the evolutionary and human disturbances that influence it.

Conservation and management of grassland habitat in the Indian subcontinent is a major challenge for managers of the protected areas.

Grasslands are formed in regions where climatic and topographic factors prohibit growth of trees (Clements and Shelford, 1939). As per Anderson (1982) Grasslands evolved under a system of grazing, drought and periodic fire and almost all the existing grassland are maintained by either of these or a combination of all these factors. The climax grasslands are supposed to be absent in India, but grasslands as secondary stage are common (Champion and Seth, 1968). Thefore, they are called as preclimax (Champion and Seth, 1968). Ecologists think that the grasslands of India owe their existence primarily to biotic factors, such as fire and grazing or as secondarily as edaphic climaxes (Debadghao *et al.* 1973, Champion and Seth, 1968, Gadgil and Meher-Homji, 1985).

India has little natural grasslands and much of that has been taken over for cultivation (Whyte, 1964). A variety of modifications influence the functioning of the grassland ecosystem. These are conversion of land to agriculture, urbanization/human settlement, desertification, fire, grazing by domestic livestock, fragmentation and the introduction of non-native species (White *et al.* 2000)

Today, in India no major grassland is found outside the protected areas and they are mostly limited to Wildlife Sanctuaries and National

Parks. The grasslands however, do provide essential habitat for many of India's large mammals, including rhinoceros unicornis, wild buffalo, swamp deer and several threaten species of birds like Bengal florican. Maintenance of these mid succession grasslands especially as a wildlife habitat to protect some of the key grassland species thus, depend upon careful planning and management of these grasslands (Rodgers and Sawarkar, 1988; Rahmani *et al.* 1997).

Till very recently grasslands are considered as unproductive, consequently administrative and political decisions in favour of regional development have diverted large tracts of grasslands to other uses. Grasslands are overgrazed, subjected to uncontrolled fire, taken over by an abundance of weeds and subjected to degradation in the entire Indian subcontinent.

In India, grassland maintenance is a new concept for wildlife managers from forestry background, in many protected areas it is being undertaken vigorously (Rodgers and Sawarkar, 1988). Annual burning, either accidental or intentional, can regulate the structure and composition of grassland vegetation (Rodgers, 1986). Fire is one of the most wide-spread and functional ecological factor maintaining many grasslands of the world (Daubenmire, 1968).However, the impact of fire are yet to be fully understood in protected areas of India. Grazing, cutting and ploughing have drawn attention from management point of view in different parts of the world. However, in wildlife sanctuaries and national parks in India these factors have been maintained by annual burning and disturbance factors like livestock grazing and thatch harvesting.

Use of remote sensing and GIS techniques in grassland monitoring has a history of more than 30 years. Both fine- and coarse-grained remote sensing techniques are used to monitor and study grasslands. Fine-grained techniques are used to study landscape scale processes through the use of sensors providing spatial resolution of a few meters, whereas coarse-grained techniques are used to study catchment scale areas, and even entire biomes, using satellite-based sensors with a spatial resolution of kilometers. Remote sensing information is obtained from aerial photography, radar systems, video systems, and satellite-based sensors including the Landsat satellites' Multispectral Scanner (MSS) and Thematic mapper (TM) and the National Oceanic and Atmospheric Administration (NOAA) polar orbiters' Advanced Very High Resolution Radiometer (AVHRR). Various normalized difference vegetation indices (NDVI) have been developed and used extensively with data from the Landsat sensors (MSS and TM) and NOAA's AVHRR. The NDVI has been used for grassland classification and inventory, monitoring grassland-use change, determination of site productivity and herbivore carrying capacity, water and soil conservation, integrated management of grassland pests, and suitability for recreational use and wild life protection.

Special techniques have also been developed for monitoring where fires occur on grasslands. To date the remote sensing techniques have become a powerful tool for scientists, farmers and policy makers to study and manage grassland resources. World demand for sustainable development of grasslands will increase the reliance on remote sensing as a tool in grassland management.

In this chapter, the focus has been given on the immediate effects of practices as management intervention such as burning, grazing and cutting on measured habitats such as grass community structure, population distribution of rhino and other species of conservation importance. The current grassland management in RG Orang NP involves widespread burning during winter and pre-monsoon seasons. Other two issues which are playing major role in maintaining grasslands in RG Orang NP are illegal livestock grazing and invasive species like *Mimosa invesa*. This chapter also discussed about the importance of geo-spatial technology in management and conservation of rhino habitat in RG Orang NP.

7.2 Wildlife habitat management in India and Assam:

It is necessary to review the past and current management practices of wildlife habitat in India and Assam as they bear direct relevance to the habitat quality. These practices also establish managerial traditions, and create a mindset that resist to new ideas.

Management of forests in India has been driven by the institutionalization process of working plans since the year 1870s (FRI, 1961). The Protected Areas (PAs) in India have a long history of vegetation management. The majority of PAs were declared and managed as Reserve Forest that dating back to the last century. The Indian Forest Service was one of the earliest, to develop scientific management, geared to the production of timber and other products of commercial value.

The first forest policy of 1894 (Govt. of India, 1894) recognized the economic dependence of pastoral communities and of others who reared livestock on grasslands. In view of their scattered nature, and the limited resources of the Forest department, most such land areas were either excluded from government control or were more or less ignored since they were not productive in the sense of producing timber or other economically valuable woods. The policy did not have any reference to wildlife or, the ecological productivity of grassland.

The next National Forest Policy of 1952 (Govt. of India, 1952) included most grasslands under category of village forests in recognition of their utility as grazing areas for cattle and production of fodder and most of the remainder were included in the unclassed or vested forests categories. The biological values and ecological functions continued to be ignored and grasslands were considered "unproductive" in the forest dictionary.

The first attempt to establish protected area in grassland of Assam was during 1905 when Manas, Kaziranga and Laokhowa were created as Reserve Forests for conservation of wildlife like rhino and elephant. However, the interest of the Forest Department in the grassland of Assam was focused on plantation of commercially valuable trees like sal (*Shorea robusta*) and khair (*Acacia catechu*). In the year 1919, Mr. Milroy, Forest Officer had introduced fire for first time to clear natural forest (even primary forest) for plantation of commercially valuable trees in Assam (Working planning of South Kamrup Division by P.C.Das, 1973-74)

The first attempt to bring wildlife management under a specified wildlife or Protected Area plan came about in 1972 when this was made mandatory for thr tiger reserves established under Project Tiger (Govt. of India, 1972). It is increasingly realized that vegetation has conservation value both as part of a biotic community (Project Tiger approach, e.g. Panwar, 1985) and in itself as a natural entity (the Biosphere Reserve approach)

The management of wildlife habitat and grassland in Assam also started after 1972 and Prof Paul Lyhausen (IUCN cat specialist) had criticized the burning practice in Manas Tiger Resreve during his visit in 1977 (Deb Roy, 1986). The burning of grassland has been extensively used as a management tool by Forest Department of Assam after 1972. However, emphasis was never been given on fire surveillance and documentation.

7.2.1 Attitude of administration and grassland management practices:

Grassland maintenance is a new concept for wildlife managers, those who came from a forestry background. Wildlife managers are often ambivalent in their attitude towards fire and successive managers in one area may develop different fire policies. Rodgers (1986) mentioned that foresters have been dealing with clearing of woody cover using fire under "working plan" for the plantation commercially valuable trees. However, in grassland burning differs from clearing vegetations to maintain field layers (different vegetation covers) is important for many grassland dependent species.

The impacts of fire on wildlife are commonly overlooked since they most often act indirectly through changes in the vegetation. It has often been observed that frontline staff put fire unsystematically in the grassland, without any scientific guidelines.

The reasons for promoting fire as a grassland management tool by the foresters are as follows

a) Preventing succession from grassland to forest
b) Preventing succession from shorter grasses to taller grass communities which is less favored by ungulates
c) Providing ungulates with high quality forage as the grassland regenerates
d) Regulating the amount and type of grassland accumulation

e) Recycling nutrients

f) Reducing the incidence of insect and fungal disease attack.

With the exception of ungulate of regeneration swards, these claims are largely based on anecdotal information (Bell and Oliver, 1992), with the result that management has largely been based on rumor and a tradition of burning. Although burning has been focused for the mammal, however, there is a strong contrasting evidence that widespread burning has been deleterious to less mobile species and species that are less tolerant of disturbance, including turtles, pygmy hog (Oliver, 1980) and hispid hare (Bell *et al.* 1991). Following widespread fire, the grassland dependent species get confined to small refugia of unburned grassland patches or are force to move into sub-optimal habitat, where they are vulnerable to predation, poaching and disturbance. Very little information available on many faunal groups (particularly the herpetofauna and invertibrates) in the grasslands, it seems likely that there will be other biodiversity that are severely affected by the practice of widespread burning.

7.3 Conservation status of rhino habitat in Rajiv Gandhi Orang National Park:

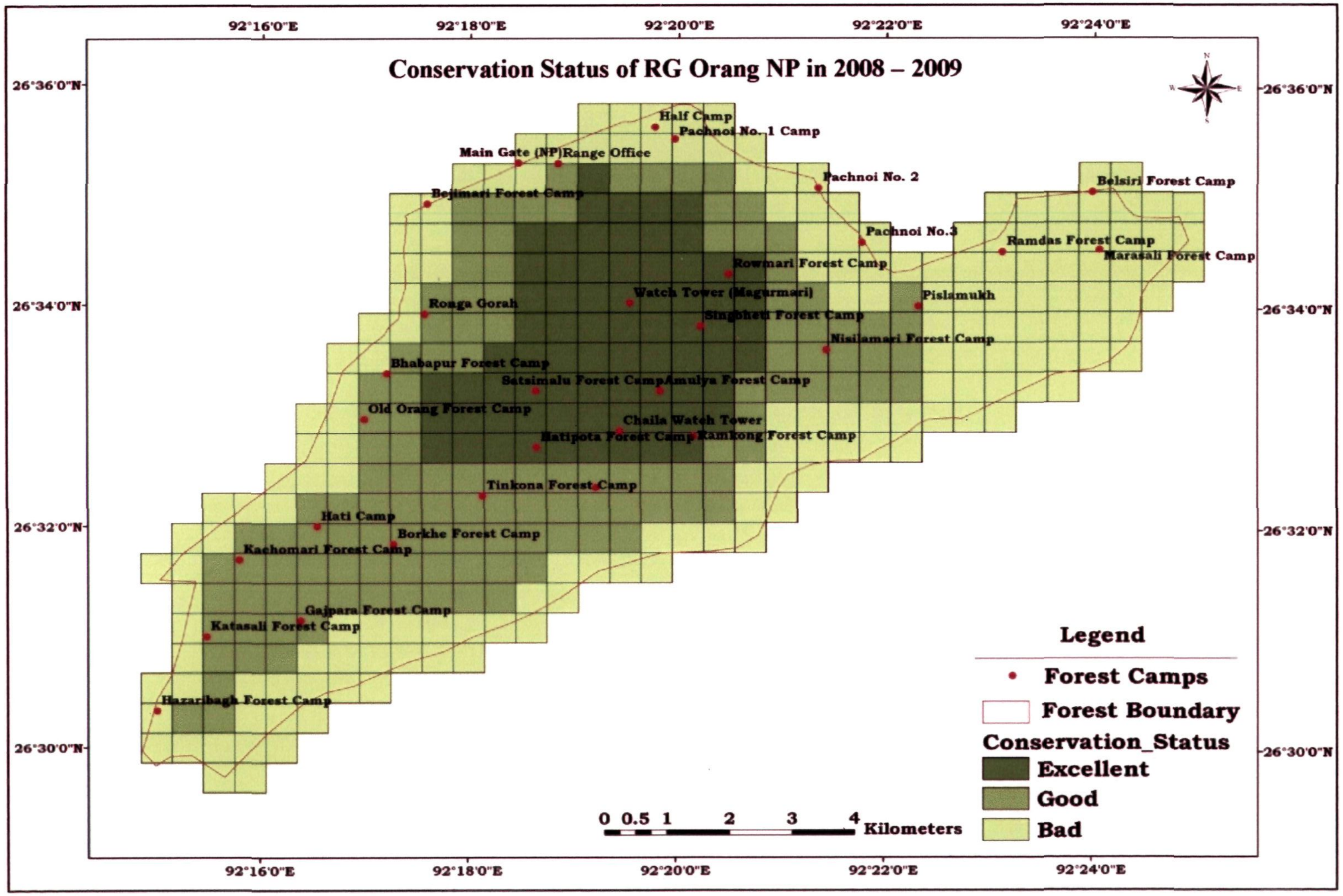
The current conservation status of rhino habitat in RG Orang NP was assessed using a grid based survey of the park and GIS analysis (Ibisch, *et al.* 2003). A total 352 grids were generated for the entire RG Orang NP covering 500 m. X 500 m area in each grid. All the 352 grids were extensively surveyed and information on habitat condition for wildlife, livestock grazing pressure, presence and absence of invasive species (*Mimosa invesa*) and vulnerability of natural hazards (flood) were collected from each grid. Based upon the collected information of each grid, hypothesis, condition/rules and confidence value for each grid was assigned using knowledge engineer tool available in ERDAS Imagine 9.2 software. Confidence values are associated with each condition and these are always assigned by the knowledge engineer depending upon the importance of the input data. If the input data is important, a high confidence value is given. The table VII a. shows the hypothesis, conditions/rules and confidence values for each rule to prepare the conservation status map of RG Orang NP.

Table: VII a. Hypothesis, rules/conditions and confidence value used in the classification of conservation status of RG Orang NP.

Hypothesis	Rules/Conditions	Confidence Value
Excellent Conservation Status	Excellent habitat quality	0.90
	No livestock grazing	0.90
	No invasive species	0.90
	Less vulnerable to natural hazards	0.80
Good Conservation Status	Good habitat quality	0.70
	Less livestock grazing (less than 20%)	0.70
	Presence of invasive species (less than 30%)	0.70
	Vulnerable to natural hazards (flood & erosion)	0.60
Bad Conservation Status	Bad habitat quality	0.50
	More livestock grazing (more than 50%)	0.50
	Presence of invasive species (more than 50%)	0.50
	More vulnerable to natural hazards (flood & erosion)	0.40

Source: Researcher

The result of the conservation status model of the RG Orang NP shows that out of 352 grids, 172 grids have bad conservation status and their distribution is found mainly along the park boundary. These are the grid where habitat quality for rhino and other wild animals are quite bad, livestock grazing pressure is high, impact of invasive species is extensive and more vulnerable to flood and erosion by the river Brahmaputra, Dhansiri and Pachnoi. A total 106 grids shows good conservation status in RG Orang NP and their distribution is mainly in the center part of the park and only 74 grids shows excellent conservation status in the RG Orang NP and their distribution is mainly concentrated in the core area of the park. The conservation status of RG Orang NP is shown in the Map No. 55



Source: Prepared by researcher based on field data

Map No. - 55

7.4 Current management practices of rhino habitat in Rajiv Gandhi Orang National Park:

a) Burning:

Grassland burning in RG Orang NP is a major habitat management practice for conservation of rhino habitat in the park. Burning in RG Orang NP is generally starts in the month of December and it continues up to month of March in every year. During the study period from September 2008 to September 2009 it was observed that grassland burning was extensively done by the park authority from December, 2008 to March, 2009. The main reasons for promoting burning in grassland areas of RG Orang NP is already discussed in above, but during study period it was observed that most of the cases unscientific burning was occurred in the park. This is mainly due to the lack of awareness about the impact of burning on animals and birds among the ground staff. It was also observed that lots of turtles and tortoises of conservation importance as well as birds burnt out due to the unscientific burning by the ground staff and it is a serious concern for the conservation of those species in the park. Immediate attention should be given to make the ground staff aware about the impact of burning on small mammals, herpetofauna and birds. Patch burning method is highly recommended in RG Orang NP for habitat management of not only for rhino but also for other animals of the park.

b) Control over livestock grazing:

In case of control over livestock grazing inside the park very limited attention has been given by the park management in RG Orang NP. The eastern most part of the park is completed degraded mainly due to the over grazing by the livestock from the nearby villages. Similarly western most part of the park is also vulnerable to the severe livestock grazing. During the study period it was observed that approximately 1000 to 1500 cattle enter in to the park every day and they act as a competitor for wild animal particularly herbivorous species like rhino and deer of the park. This has adversely affecting the wildlife habitat of RG Orang Park. Immediate attention and protection should be given in the eastern and western boundary of the park to reduce the pressure of livestock grazing in the park.

c) Control over invasive species (*Mimosa invesa*):

The impact of invasive species like *Mimosa invesa* over the wildlife habitat of RG Orang NP is quite extensive and prominent. Till now no management practice has carried out in the RG Orang Park for uprooting of *Mimosa invasa* and now it is a major threat to the rhino habitat of the park. The Mimosa invasion was first reported from the park in year 2003-04, especially areas along the Brahmaputra River. The invasion of Mimosa has been observed rapidly in the park. Total of 11.56 km^2 area is under Mimosa invasion in the park and affect is more western part along the Brahmaputra

River. This invasion has resulted into disturbance and disruption of rhino habitat in Orang and there is a competition among grasses and Mimosa for space and nutrient. There has been an increasing in straying of rhino from the park. As rhino habitat is decreasing due to invasion weed there might be increasing in stray out of rhino.

7.5 Habitat Management Recommendation:

A number of key management issues that are need to be address. While making these recommendations the long term conservation of mammals, birds, reptiles and all other lower group which are dependent on grassland were also considered.

These are

7.5.1 Enforcement:

Following illegal activities must be stopped

a) **Livestock grazing**: Livestock grazing should be totally stop in grassland, especially in the eastern and western boundary of the RG Orang NP. The cattle of the fringe villages of the eastern and western boundary of the park are serious problem for the park. Measures should be taken that in no case the domestic cattle from the fringe villages should not be allowed inside the National Park.

b) **Thatch harvesting**: Organized and extensive thatch collection must be stop inside the park.

c) **Poaching**: Poaching and poisoning of rhino and tiger must be stop in the park for immediately. Park authority should take immediate attention to reduce poaching of rhino and other animals in the park. Hunting of small mammals or trapping birds and collection of egg of bird must be stopped.

d) **Illegal burning**: In RG Orang NP the fringe villagers use to burn the grassland in the peripheries particularly in the eastern and western boundary mainly to get better grazing field for livestock. Moreover they also burn the grassland to get a better view of the raiding animals into the crop field. Similarly unscientific burning by the park authority particularly by the lower level forest guards should stop in the park. Patch burning should implemented with immediate effect.

e) **Encroachment:** The fringe villagers of the RG Orang NP has a tendency to encroach the park area, particularly in the western most park of the park near Hazarbigha camp. Park managers should take immediate attention to prevent this encroachment.

7.5.2 Sensitization of the management authority from ecological angle:

- Plantation of trees in the grassland should not be encourage and must be stopped.
- A dedicated section within the management plan for "Grassland Burning Action Plan", be made. This should incorporate

  a) A working document with all available background data including a GIS based map into a working document.

  b) Although existing road network, streams and wetlands are acting as fire line during burning, but fire lines must be developed in areas where natural barriers are absent to do the patch burning practices of the grassland.

  c) Same area should not be burnt every year. Repeated burning should be avoided in a same location in the same season, as repeated burning encourages invasion of lemon grass and other unpalatable species.

  d) No burning should start without a clear knowledge of where and how it is to be under control.

  e) A patch-mosaic burning techniques has been widely used throughout the world for grassland management and it is same as traditional burning, where patches are kept unburnt. The technique has been accepted by protected area managers world wide as the understanding of grassland and its related biodiversity is not yet fully understood. Burning of tall grass patches is essential to improve the grassland as feeding grounds to ungulates. As these patches also provide breeding and escape cover to rhino, tiger, large number of birds, herpetofauna. Few patches of such grassland should left unburnt so that feeding ground, cover for escape for breeding are simultaneously available.

f) Burning should not be done at night to avoid the reduction of animal death.

g) After burning the burnt area should be carefully monitored and mapped that will help to interpret post-fire changes and to improve the scientific basis of future burning management of the protected area.

h) Accurate and detail records of the grassland burning should be maintained.

i) Eradication of invasive species like *Mimosa invesa* is must to restore the grassland of RG Orang NP.

7.5.3 Research priority of wildlife habitat:

I. An assessment of weed invasion in grassland required immediate attention. Types and extent of invasion and specific research studies addressing their control either manually or biologically. Is there any relationship between burning and invasion of alien species?

II. Inventorization of the small mammals, herpetofauna and invertebrate groups in grassland and the associations of them with grassland species assemblages to be identified.

III. Is the current grazing and burning regimes are compatible with successful breeding output of rhino and other animals? This aspect is still unknown and requires further study urgently. Monitoring the habitat of rhino and their behavioral study should also be done at regular interval to understand the impact of climate change on rhino and their habitat.

IV. There is also a need to understand the seasonal changes in grass assemblage utilization by mammalian species.

7.5.4 Training and manpower development with involvement of fringe communities and NGOs:

I. Frontline staff should give proper training on impact of burning and grazing on the species like rhino, tiger and other wild animals.

II. NGOs should be involve during burning season like department has been involving NGOs in census and during flood period. The volunteers from NGOs would be help forest officials in monitoring and minimizing adverse affect of burning.

III. To explore the possibilities, from new angle of involving local communities in the management of the wildlife habitat. Eco-development activities be modified to suite such situation.

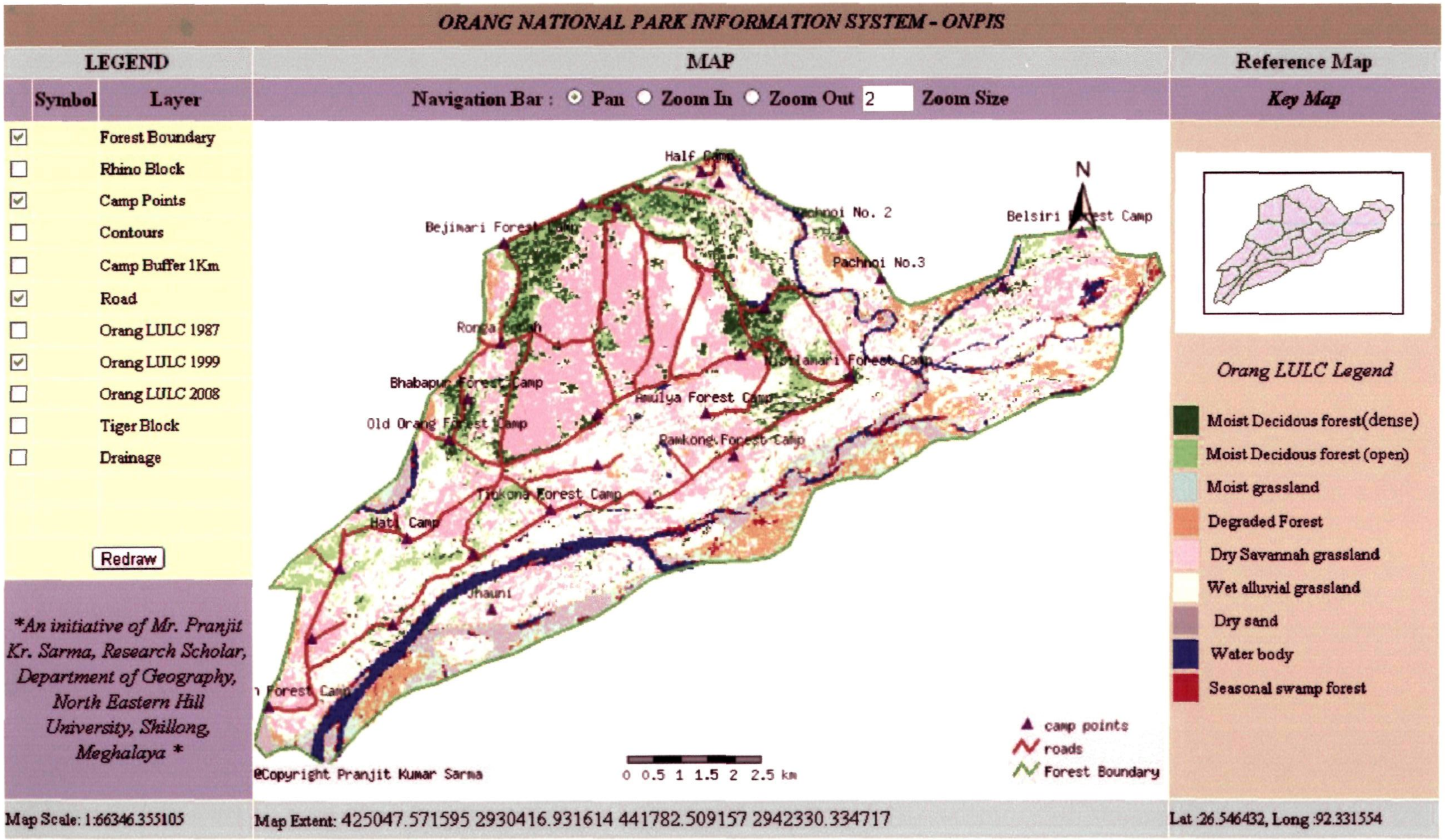
A combination of the above mentioned recommended management activities will certainly maintain the grasslands of RG Orang NP and other protected area located in Brahmaputra flood plain of Assam. This will not only maintain the grassland in primary condition but will also ensure the long term survival of some of key grassland bird and mammal which are highly threatened. These activities will also help other grassland dependent or associated species and will act as a role model for similar areas.

7.6 Role of Geo-Spatial technology in wildlife habitat management:

The role of geo-spatial technology in wildlife habitat management is quite important and significant. Computer based Decision Support System (DSS) has been a popular concept since the emergence of information technology. Database technologies hosted on powerful computers have been adopted to prepare decision support systems in various application areas. The biodiversity conservation planning and management is no exception. Conservationists and decision makers have been involved in generating huge databases on the species, its status, habitats, socio-economic impacts, threats to its existence etc. Such alphanumeric information gives scientific basis for decision-making. However, with the availability of spatial data from remote sensing and advances in Geo-informatics, researcher and managers are witnessing the paradigm shift from 'conventional' Decision Support System to the Spatial Decision Support System (SDSS).

Spatial decision support system for natural resource management is computer base tools that tightly integrate decision theory models with ecological models and GIS analyses and mapping. The information provided by SDSS gives decision makers increased ability to follow outcomes of interacting variables, improves the reproducibility of decision, and documents the reason why (with conflicting alternatives) a particular choice was made (Rauscher 1999). Till the availability of spatial information from remote sensing data, not much thought was given to the spatial dimension to decision support system. In fact, any decision involving conservation issues invariably considers geographical parameters such as location, distance, direction, proximity, adjacency, topography, etc. and there was long pending demand for providing "spatial dimension " to the alpha-numeric decision support system dedicated to biodiversity conservation and management (Ravan 2002).

During the course of this research an attempt has been made to develop a Spatial Decision Support System for RG Orang NP using geo-spatial tools and computer technology. A spatial database was prepared using remotely sensed satellite images, ground data collection and GPS technology. These databases were fed in to GIS domain to prepare the SDSS of RG Orang NP. The primary and secondary spatial data collection and their processing were already discussed in chapter II. Here we will discuss on SDSS of RG Orang NP. For preparation of the SDSS of RG Orang NP, open source software named as **Map Server** was used to integrate all the geo-spatial information of RG Orang NP. Customizations of all the layers were done using programming language named as xml. Here in this SDSS all the spatial information derived or gathered during the research period were integrated and was brought into a single platform. The advantage of this SDSS is that it is quite user friendly as it does not required any professional GIS software, only internet explorer is required to visualize this mapping application of RG Orang NP. This SDSS of RG Orang NP is already shared with the park managers for conservation and management of rhino habitat in the park. The Map No. 56 shows the screen shot of the SDSS of Orang NP.



Source: Prepared by researcher based on field data

Map No. 56

7.7 Discussion:

From the above discussion it is clear that wildlife habitat management is a science and proper understanding of the habitat management practices is a pre-requisite for any wildlife manager. It is also clear that in RG Orang NP habitat management for rhino and other wild animals is not done properly and scientifically. The main cause behind this unscientific management of rhino habitat in the park is due to the unawareness about the scientific habitat management practices among the ground staff. Though the grassland burning is practiced in the park on time to time basis, but unscientific burning has damaged the habitat as well as wild animal species in the park extensively, particularly reptiles, amphibians and birds. So through this study it is recommended to adopt practice patch burning method for proper management of wildlife habitat in the park. This study also shows that there is very limited activity carried out by the park authority to minimize the livestock grazing pressure in the park from the nearby villages. This study reveals that livestock grazing has extensively damage the rhino habitat in the park. It is also recommended through this study that immediate attention should be given to minimized the livestock grazing in the park. Similarly the impact of invasive species like *Mimosa invesa* over the rhino habitat is quite extensive in the park and because of the invasion rhino habitat in the park is gradually degraded at a massive and alarming rate. Through this study it is recommended to take immediate attention to uproot the *Mimosa invesa* from the park. Here in this study recommendation is given for further research on controlling the invasion in the park. Through this study it is also recommended to give training to the ground staffs in the park and to take help from the NGOs during the burning period.

This study also shows the importance of geo-spatial technology in the habitat management practices. Maps and spatial information of a national park provide the support to the decision makers or park managers for conservation and management of wild animals and their habitats. Through this study a spatial decision support system for RG Orang NP was developed entitled as "Orang National Park Information System" and already shared with the park authority for conservation and management of rhino and its habitat in the park. This SDSS will be quite helpful for park managers for proper management and conservation of rhino habitat in RG Orang NP in near future.

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CHAPTER - VIII

Chapter VIII

Summary and Conclusion

The Greater one-horned rhino (*Rhinoceros unicornis)* the most primitive mega herbivore species, represents the vanishing group of ungulate and is now confined to a few protected areas of India and Nepal. Earlier, the one-horned rhino was widely distributed throughout the Indo-Gangetic plain and its neighbouring countries from Pakistan to Myanmar. But due to the tremendous anthropogenic pressure the rhino habitats of Indo-Gangetic plain was fragmented and now it is evident from the present distribution of one-horned rhino is limited to certain pockets of the Himalayan Terai region of Nepal, Jaldapara Wildlife Sanctuary and Garumara National Park of Ganga and Teesta valley and Brahmaputra valley of Assam, India.

The present research is an attempt to understand the rhino habitat suitability pattern, seasonal variation of habitat utilization pattern of rhino, the habitat change and its impact on the habitat suitability condition of rhino in RG Orang NP. The study is divided into eight chapters.

Chapter I encompasses the research problem, its goal and significance. It also includes the relevant review of research in the related fields, which forms the basic foundation and direction of the study.

The chapter II deals with database and methodology used for this study. Satellite imageries of Landsat TM and IRS P6 LISS III of 1987, 1999 and 2008 were used to understand and evaluate the current and past rhino habitat pattern in RG Orang NP. Change detection analysis of land cover pattern of RG Orang NP was done using overlay approach of the multi temporal classified images using image processing software ERDAS Imagine 9.3. Similarly to understand the rhino habitat utilization pattern in the park direct monitoring of rhinos in different seasons of the year was done with the help of trained elephants that were available with the RG Orang NP authority. Monitoring of rhino during pre-monsoon, monsoon, retreating-monsoon and winter seasons were done in the park to evaluate and assess the seasonal variation of rhino habitat utilization pattern in RG Orang NP. Finally a rhino habitat suitability model was generated based on the parameters collected with the help of field visits and by observing their relationship with the environment.

Chapter II is the detailed methodology adopted for this research work.

The chapter III deals with the current rhino habitat evaluation and land cover change in RG Orang NP over a period of 20 years and its impact on rhino habitat in the park. Nine categories of land cover patterns are identified in RG Orang NP based on field visits and satellite data for better understanding and analysis of the results. The categories are the Eastern Himalayan moist mixed deciduous forest (dense), Eastern Himalayan moist mixed deciduous forest (open), Dry savannah grassland, Wet alluvial grassland, Eastern seasonal swamp forest, Degraded grassland, Water body, Dry sand and moist sand. Wet alluvial grassland covers the maximum area in the park with area coverage of 20.54 km^2 (26.06%) followed by Eastern Himalayan moist mixed deciduous forest (dense and open) 20.38 km^2 (25.86%). Dry savannah grassland is covers an area of 14.17 km^2 (17.98%) in the park. Degraded grassland in the park covers an area of 12 km^2 (15.23%) and it is a serious concern for rhino conservation in RG Orang NP. The Eastern seasonal swamp forest is covers an area of 1.36 km^2 (1.72%) in the park and their distributions are concentrated along the rivers and drainage system of the park. Water body covers an area of 6.48 km^2 (8.22%) in the park. Sandy area covers 3.87 km^2 (4.91%) in the park and its distribution is found in the river or along the river. Chapter III deals the land cover change dynamics pattern in RG Orang NP. The Eastern Himalayan mixed moist deciduous forest (dense) has an increasing trend of 6.8 (8.62%) km^2 in 1987 to 8.63 km^2 (10.95%) in 1999 and up to 9.84 km^2 (12.48%) in 2008. The Eastern Himalayan moist deciduous forest (open) has also an increasing trend from 1987 to 2008. The area covered by Eastern Himalayan moist deciduous forest (open) was 7.6 km^2 in 1987 (9.64%) and it increased up to 10.54 km^2 (13.37%) in 2008. In case of Dry savannah grassland, an increasing trends of 6.88 km^2 (8.73%) to 12.41 km^2 (15.74%) and up to 14.17 km^2 (17.98%) in 1987, 1999 and 2008 respectively have been observed. The wet alluvial grassland has a decreasing trend in1987 to 2008 covering areas of 30.63 km^2 (38.87%) to 20.54 km^2 (26.06%) respectively. This decrease of wet alluvial grassland in the park is due to the invasive species like *Mimosa invisa*. The degraded grassland has an increasing trends from 6.86 km^2 (8.71%) in 1987 to

10.35 km^2 (13.13%) in 1999. From 1999 to 2008 it has witnessed an increasing trend and reached up to 12 km^2 (15.22%) of area. The Eastern seasonal swampy forest was reduced from 3.1 km^2 (3.93%) in 1987 to 2.51 km^2 (3.18%) in 1999. It has again shows a decreasing trend from 1999 to 2008 covering an area of 1.36 km^2 (1.72%). The water body, was found to be reduced from 5.76 km^2 (7.31%) in 1987 to 3.13 km^2 (3.97%) in 1999. However, from 1999 to 2008 it increased up to 6.48 km^2 (8.22%), which is due to erosion caused by the river Brahmaputra, Dhansiri and Pachnoi. In case of river sand or sandy area it shows a decreasing trend from 1987 to 2008. The area under sand in 1987 was 10.45 km^2 (13.26%), which was reduced to 4.69 km^2 (5.95%) in the year 1999, and finally it got reduced to 3.87 km^2 (4.91%) in the year 2008. These changes in land cover pattern in RG Orang NP has adversely effects the rhinos and their habitat pattern in RG Orang NP.

The chapter III is about the detailed historical account of bank line erosion and depositional scenario of RG Orang NP from 1987 to 2008. The study reveals that there was deposition in the park by the river Brahmaputra in the year 1987 to 2008. During the year 1987 to 1999 recorded an erosion of about 0.23 km^2 in RG Orang NP where as deposition was recorded about 9.48 km^2 during the same period. Similarly in the year 1999 to 2008 the erosion was 2.54 km^2 and 0.18 km^2 of deposition caused by the river Brahmaputra in the park. Thus the trend shows that the deposition was more than the erosion during the period of 1987 to 1999 and 1999 to 2008.

The chapter III also deals with the impact of land cover change on rhino habitat. The study reveals that there is a significant change of rhino habitat in RG

Orang NP during the period of 1987 to 2008. The habitat change in RG Orang NP are caused due to the non-implementation of habitat management/manipulation programmes which are pre-requisite for supporting viable population of flagship animal like the Indian rhino. The other factor for the change is due to the rapid spread of invasive species like *Mimosa invesa* and grazing of animals of the neighbouring villages in the park areas.

The chapter IV deals with seasonal variation of rhino habitat utilization pattern in RG Orang NP in the year 2008-2009. The study shows that the Indian rhino uses about 59.56 percent of wet alluvial grassland habitats, followed by 24.59 percent dry savannah grasslands, 13.11 percent woodland habitats and 2.74 percent of wetlands habitat in RG Orang NP. The habitat data was collected during the period of September, 2008 to September, 2009. During the field study out of 183 rhinos, 109 rhinos were sighted in wet alluvial grassland habitat, followed by 45 rhinos in dry savannah grassland, 29 rhinos in woodland and wetland habitat. The seasonal variation of rhino habitat utilization pattern shows that, the rhinos of RG Orang NP have used 61.84 percent of wet alluvial grasslands, followed by 22.36 percent of dry savannah grasslands, 15.60 percent of woodland and 0.20 percent of wetland habitat during pre-monsoon season. During monsoon season rhinos have used 48.71 percent of wet alluvial grasslands, followed by 35.89 percent of dry savannah grasslands, 12.82 percent of woodland and 2.58 percent of wetland habitat in RG Orang NP. During retreating monsoon season rhinos have used 65.62% of wet alluvial grassland followed by 21.87 percent dry savannah grassland, 12.50 percent woodland and 0.01

percent of wetland habitat in the park. In the winter season rhinos have used 61.11 percent of wet alluvial grassland followed by 19.44 percent dry savannah grassland, 11.12 percent woodland and 8.33 percent wetland habitat in RG Orang NP. The overall result shows that in all the seasons of the year 2008–2009, rhinos have preferred mostly wet alluvial grasslands in RG Orang NP.

The chapter V is the detailed account of the spatial distribution of rhino habitat at micro level. There are 18 blocks in RG Orang NP developed by park authority for the convenience of conservation and management of rhino habitat in the park. Habitat evaluation study of each block was carried out using satellite imagery at micro level with proper ground survey and verification. The Brahmaputra block covers an area of about 8.81 km^2, which is 11.18 percent of the total geographical area of the park which is the biggest of all. The Pabhomari block is the smallest which covers an area of 2.22 km^2 i.e. 2.82 percent of the total geographical area of the park. The block wise habitat evaluation shows that different habitat types are prominent in different blocks in RG Orang NP. The eastern Himalayan moist deciduous forest (dense) is more prominent in Rahmapur A block which has 30.93 percent of the total geographical area coverage and is the highest in percentage. The Eastern Himalayan moist deciduous forest (open) is more dominated in the Baghmari block has 22.52 percent of the block and is the highest in percentage. In case of wet alluvial grassland, the concentration is in Satsimalu block with a 56.69 percent of the total geographical area. In case of dry savannah grassland maximum concentration is found in Rahmanpur B block. It has 46.15 percent of the total geographical area and has the highest in percentage of area coverage. Degraded grassland is more prominently seen in Belsiri block covering an area of 20.28 percent of the total block. Eastern seasonal swamp forest has its highest concentration in Jhawani block covering 13.56 percent of the total area of the block. In case of sandy area highest concentration is found in Brahmaputra river block covering 32.62 percent of the total area of the block. In case of water body highest concentration is seen in Brahmaputra river block covering an area of 48.88 percent of the total geographical area of the block.

The chapter VI deals with the rhino habitat suitability assessment and modelling in RG Orang NP. In this chapter discussion is about the changing nature of rhino habitat suitability condition with the changing land cover pattern in RG Orang NP. The study reveals that out of 78.8 km^2 about 19.81 km^2 (25.14%) area is most suitable habitat for rhinos in the park followed by 10.74 km^2 (13.63%) moderately suitable habitat and 48.45 km^2 (61.48%) area is less suitable for rhinos in the park. This shows that most suitable habitat for rhinos in the park are not sufficient for the existing population of rhinos in RG Orang NP for their growth and development. Therefore, an urgent attention is needed by the park authority how to increase the most suitable habitats for relocation and restocking of rhinos in RG Orang NP from Pabitora Wildlife Sanctuary and Kaziranga National Park. The study also shows that the habitat suitability condition for rhinos in RG Orang NP is changing with the changing in land cover pattern of the park. The most suitable habitat for rhinos in the park has reduced from 29.26 km^2 (37.13%) in the year 1987 to 19.81 km^2 (25.14%) in the year 2008. On the other hand the less suitable habitat for rhinos in the park has increased from 35.31 km^2 (44.81%) to 48.45 km^2 (61.48%) from 1987 to 2008. These changes are due to the changing land cover pattern of the park. The wet alluvial grassland area in the park is decreasing in an alarming rate and thus most suitable habitats for rhinos are decreasing in the RG Orang NP.

The chapter VII deals with the conservation and management of rhino habitat in RG Orang NP. In this chapter habitat management practices in RG Orang NP are discussed and conservation status of the park is also assessed. Some habitat management recommendations are suggested in this chapter for proper conservation and management of rhino habitat in RG Orang NP. Importance of geo-spatial technology in wildlife habitat management was also elaborated in chapter VII. A spatial decision support system for RG Orang NP was developed by the researcher for the RG Orang NP park authority for conservation and management of the park in a more systematic and scientific way. The name of the system is Orang National Park Information System and it is a web based GIS mapping application which will be useful for the park authority in near future in their conservation effort. The detail of the system is also discussed in the chapter VII.

The chapter VIII illustrates and summarized all the seven chapters of the present research. The major findings of the current research are also incorporated in the chapter VIII.

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APPENDICES

Appendix – I a.

Vegetation Survey Datasheet

Date:

Lat.:-

Long:-

Sl. No	Grid No.	Species Composition

Appendix – I b.

Rhino Monitoring Datasheet

Name of the data collector:

Date: **Time:**

Season: Pre monsoon/ Monsoon/ Retreating Monsoon/ Winter

March – May/ June – Aug. / Sept. – Nov. / Dec - Feb.

GPS Point:

N

E

Elevation: -----------m.

Weather:

Rainy / Cloudy/ Clear/

Fogy

Vegetation Type

Rhino Type

Male

Female

Juvenile

Block Name:

Specific Identification Character

Remarks

Appendix – II (Percentage of area cover by different habitat types in each block)

	BLOCKS								
Habitat Types	**Baghmari**	***Belsiri***	***Boogbeel***	**Chaila**	***Gaimari***	**Jhawani**	***Magurmari***	***Moalamari***	**Oogli**
Eastern Himalayan Moist Deciduous Forest (Open)	7.86	9.42	2.66	1.72	3.84	1.16	17.16	19.97	19.18
Eastern Himalayan Moist Deciduous Forest (Dense)	22.52	4.14	7.17	1.47	5.51	0.53	4.91	12.35	12.15
Wet Alluvial Grassland	34.88	22.05	30.02	45.63	40.9	28.65	37.33	41.37	27.09
Dry Savanah Grassland	29.77	32.63	32.75	41.62	36.99	20.64	39.74	24.88	21.76
Degraded Grassland	2.09	20.28	4.28	2.41	7.52	9.63	0.05	0.09	4.71
Eastern Seasonal Swamp Forest	0.99	9.74	4.55	4.73	4.52	13.56	0.8	1.34	7.53
Moist Sand	N/A	0.31	3.88	0.35	0.34	14.24	N/A	N/A	1.4
Dry Sand	N/A	N/A	9.36	0.09	N/A	5.05	N/A	N/A	0.28
Water Body	1.89	1.43	5.33	1.98	0.38	6.54	0.01	N/A	5.9

	BLOCKS								
Habitat Types	**Pabhomari**	**Rahmanpur_A**	**Rahmanpur_B**	**Ramdas**	**Ramkong**	**Satsimalu**	**Solmari**	**Tinkona**	**Brahmaputra_River**
***Eastern Himalayan Moist* Deciduous Forest (Open)**	2.43	30.93	17.86	11.95	7.6	5.73	12.62	29.04	0.27
Eastern Himalayan Moist Deciduous Forest (Dense)	3.16	11.68	5.98	4.56	6.8	5.21	5.02	9.02	0.06
Wet Alluvial Grassland	51.09	14.39	23.76	36.03	32.59	56.69	26.5	31.43	1.88
Dry Savanah Grassland	22.43	35	46.15	29.3	44	26.34	23.49	20.54	1.16
Degraded Grassland	9.11	1.32	2.5	6.95	2.19	1.02	14.97	0.7	3.66
Eastern Seasonal Swamp Forest	2.67	6.65	3.61	7.36	4.2	4.16	4.66	3.86	11.47
Moist Sand	4.09	0.03	0.14	1.27	0.04	N/A	7.6	0.18	11.66
Dry Sand	2.39	N/A	N/A	0.62		N/A	2.72	0.08	20.96
Water Body	2.63	N/A	N/A	1.96	2.58	0.85	2.42	5.15	48.88

Source: IRS P6 LISS III satellite imagery of 8th Nov. 2008

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EDUCATIONAL QUALIFICATION

2010 12 weeks training on remote sensing and GIS from National Remote Sensing Centre, Hyderabad.

2002 B.Ed from Gauhati University, Guwahati, Assam

2001 12 weeks training on remote sensing and GIS from National Remote Sensing Centre, Hyderabad

1999 M.A in Geography from Gauhati University, Guwahati, Assam.

1996 B.A from Gauhati University, Guwahati, Assam.

Exam. Passed	**Year**	**Board/ University**	**Class**	**% of Marks**	**Specialization**
H.S.L.C.	1991	S.E.B.A	III	**37.6%**	
H.S.S.L.C.	1993	A.H.S.E.C	I	**62%**	
B.A.	1996	Gauhati University	I	**64.25%**	Geography
M.A.	1999	Gauhati University	I	**62.25%**	Geography (Adv. Geomorphology)
B.Ed	2001	Gauhati University	II	**50%**	Geography & History as Method Paper

RESEARCH EXPERIENCE

1. Working on the topic "Habitat Suitability for Rhino (*Rhinoceros unicornis)* and utilization pattern in Rajiv Gandhi Orang National Park of Assam" for the attainment of Ph.D. Degree under the supervision of Prof. B.S.Mipun, Department of Geography, North-Eastern Hill University (NEHU), Shillong, Meghalaya, India.
2. Four years of research experience in the field of biodiversity conservation and remote sensing and GIS technology.

FIELD EXPERIENCE

- Field experiences on wildlife habitat evaluation and assessment in all the protected areas of Assam i.e. Kaziranga National Park, Manas National Park, Nameri National Park, Dibru-Soikhowa National Park and RG Orang National Park.

WORK EXPERIENCE

- Presently working as Head, Geo-Spatial Technology Application Programme of Aaranyak, a scientific & industrial research organization recognized by Department of Science and Technology, Govt. of India.

- Worked as a project scientist in Assam Remote Sensing Application Centre, Guwahati, Assam.

- Worked as a GIS Analysis in ERDAS IMAGINE, Hyderabad.

- Worked as a research fellow in a DST sponsored project in the Department of Geography, Cotton College, Guwahati, Assam.

EXPERIENCE IN COMPUTER APPLICATION AND GIS

- Ten years of extensive experiences in the field of remote sensing and GIS from 2001 to 2010.
- Image processing and GIS software handled: ERDAS Imagine 9.3, Arc GIS 9.3, Map Infor, Arc Info, Geomatica, etc.

AWARDS / MEMBERSHIP ACHIVED

- Awardee of International Foundation for Science, Sweden.

- Awardee of Asian Rhino Project, Australis.

- Member of IUCN, Asian Rhino Specialist Group from 2009 to 2012.

PROJECT COMPLETED

- "Integration and management of multi source data using GIS for development of plan/strategies of development blocks of Assam with case study of Kathiatoli development block of Nagaon district. (DST, Govt. of India Sponsored)

- "Identification of potential forest plantation sites of West Khasi Hills district of Meghalaya" (MOEF, Govt. of India sponsored)

- Wasteland Mapping of Assam under the project "updation of wasteland mapping, Sponsored by Department of Space Govt. of India.

- Database creation in GIS environment for Disaster Management System Project, sponsored by Dept. of Space, Govt. of India.

- Village level database creation of Assam in GIS environment, (sponsored by DLR, Assam)

- Identification and Mapping of Elephant Corridors of Assam, sponsored by U.S.Fish and Wildlife Services.

- Identification and Mapping of Rhino Stray out Routes of Pobitora Wildlife Sanctuary of Assam, sponsored by Rufford Foundation, U.K.

- Infrastructure Mapping of Namari National Park of Assam. Sponsored by Dept. of Forest and Environment, Govt. of Assam.

- A study of habitat utilization patterns of Asian elephant *Elephas maximus* and current status of human elephant conflict in Manas National Park within Chirang-Ripu Elephant Reserve, Assam. Sponsored by US Fish and Wildlife Service.

- Multi-dimentional mitigation initiatives of human-elephant conflict in Golaghat district and adjoining areas of Karbi Anglong , Assam, India. Sponsored by US Fish and Wildlife Service.

- Spatial modeling and preparation of decision support system for conservation of biological diversity in Barnadi WLS of Assam, India. Sponsored by Rufford Foundation, UK.

- Land Use / Land Cover mapping and GIS database creation for Karbi Anglong and North Cachar Hill district of Assam. Sponsored by Department of Space, Govt. of India.

- Wetland mapping for the state of Meghalaya under the programme of "National Wetland Inventory and Assessment." Sponsored by Department of Space, Govt. of India.

- "Analysis of landmass dynamics, habitat utilization and habitat suitability modeling of Greater one horned rhino (Rhinoceros unicornis) in Orang National Park of Assam, India". Sponsored by International Foundation for Science, Sweden.

- "National vegetation carbon pool assessment project for the states of Assam and Meghalaya". Sponsored by Department of Space, Govt. of India.

- "Analysis of landmass dynamics, habitat utilization and preparation of habitat suitability model for Greater One-horned rhino (*Rhinoceros unicornis*) in Orang National Park, Assam, India." Sponsored by International Foundation for Science.

- Spatial modeling and preparation of decision support system for conservation of biological diversity in Orang National Park, Assam, India." Sponsored by Asian Rhino Project, Australia.

- Preparation of web mapping application for Manas Tiger Reserve entitled as "Manas Tiger Reserve Information System (MANTRIS). Sponsored by Critical Ecosystem Partnership Fund.

PUBLICATIONS/ PAPER/REPORTS

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- **Sarma, P.K**, Lahkar B.P, Ghose, S, Rabha,A, Das, J.P., Nath N. K, Dey S, Brahma , N. (2008) Land-use and land-cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data, *Current Science*, Vol. 95 (2), pp 223 – 227

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REFERENCES

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Religion:	Hinduism
Mother tongue:	Assamese
Language known:	Assamese, Hindi, English
Date of Birth:	03rd March, 1975

Personality: The most important aspects of my personality are positive attitude towards life, openness towards learning new skills and my ability to work hard in adverse circumstances, tenacity to work well in aggressive schedules

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