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

<table>
<thead>
<tr>
<th>Year</th>
<th>Poaching</th>
<th>Natural Death</th>
<th>Total Death</th>
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<tr>
<td></td>
<td>Gun Shot</td>
<td>Poison</td>
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<td>2009</td>
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<tr>
<td>Total Death</td>
<td>101</td>
<td>2</td>
<td>19</td>
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</tbody>
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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 necessary combination of climate, substrate 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 determined 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 characteristics of a particular area, general inference can be drawn about the ability of that area to meet the habitat requirement of different wildlife 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 adaptive 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, footprint 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 km² (8.62%) in the year 1987 to 8.63 km² (10.95%) in the year 1999 and it has increased up to 9.84 km² (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 km² (9.46%) and it increased up to 10.54 km² (13.37%) in the year 2008. In case of dry savannah grassland, an increasing trend from 6.88 km² (8.73%) to 12.41 km² (15.75%) and up to 14.17 km² (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 km² (38.87%) to 20.54 km² (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 km² (8.70%) in the year 1987 to 10.35 km² (13.13%) in the year 1999. Similarly, from 1999 to 2008 it has witnessed an increasing trend and reached up to 12 km² (15.23%) of area. In case of seasonal swampy forest, it was found that it reduced from 3.1 km² (3.93%) in the year 1987 to 2.51 km² (3.18%) in the year 1999. It has also a decreasing trend from 1999 to 2008 covering an area of 1.36 km² (1.72%).
case of water body, it was found that it reduced from 5.76 km² (7.31%) in the year 1987 to 3.13 km² (3.97%) in the year 1999. However, from 1999 to 2008 it increased up to 6.48 km² (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 km² was eroded in RG Orang NP whereas 9.48 km² was deposited during that period in the park. Similarly from 1999 to 2008 almost 2.54 km² was eroded in the park and 0.18 km² 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 ($\chi^2 = 134.09$, 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.