Spatial Modeling and Preparation of Decision Support System for Conservation of Biological Diversity of Barnadi Wildlife Sanctuary, Assam, India.

Final Technical Report Submitted to

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EXECUTIVE SUMMERY:

The Barnadi Wildlife Sanctury with an area of 26.22 sq.km. is situated in the north western part of the Udalguri District under BTAD in the foot hills of Eastern Himalaya. It was declared as wildlife sanctuary on 11th August, 1980. Barnadi Wildlife Sanctuary is an integral part of Manas Tiger Reserve, which lies along the foot hill of Eastern Himalaya landscape. Barnadi Wildlife Sanctuary is quite rich regarding the availability of biodiversity. Pigmy Hog, Bison, Asiatic Elephant, Hispid Hare, Pangolin, Tiger, Leopard, Capped Langur, Parcupine, etc. are the important species, which are available in the wildlife sanctuary. In case of birds both migratory and local birds viz. Peacocks, Bengal Florican, Hornbills, King Fisher, Woodpecker, etc are available in this wildlife sanctuary. So the importance of Barnadi Wildlife Sanctuary is very high in respect of conservation of biodiversity. Unfortunately till now comprehensive scientific research is lacking behind in this wildlife sanctuary leading to bottleneck of key information needed for pragmatic management. This study aimed to create a complete GIS base database for the entire sanctuary using ancillary data of the sanctuary as well as using recent technology i.e. Remote Sensing and GIS, habitat characterization pattern of Barnadi WLS, create a decision support system (DSS) of Barnadi WLS using geo-informatics and analyze the change detection of habitat pattern in Barnadi WLS. A complete GIS base database has been prepared using ancillary data (toposheet, map available with forest department and old satellite data of Barnadi WLS) as well as recent primary and secondary data collected from field and also using geo-spatial technology. Habitat characterization pattern of Barnadi WLS of recent time has also been studied using IRS P6 LISS III satellite

imagery of 2006. It has been observed that 45.57 % of the total geographical area is covered by woodland, 27.72% is covered by high density grassland, 1.90% is covered by low density grassland, 15.29% is covered by degraded forest, and 5.83 % is covered by scrub forest. A decision support system is also prepared using GIS where all the information such as available water bodies, roads, location of anti poaching camps, road buffer, water body buffer, name of forest guards, casual labors etc has been integrated into GIS domain. Anyone interested to get information about Barnadi WLS can access this database. A change detection analysis of Barnadi WLS has also been carried out using multi dated satellite imageries. Satellite imageries of 1977, 1990, 2002 and 2006 have been used to analyze the land use / land cover change in Barnadi WLS. It has been observed that woodland of the sanctuary has increased up to 5.72% of the total geographical area from 1977 to 2006. Similarly there is also increase in high density grassland from 1977 to 2006 by 3.35%. Encroachment in Barnadi WLS is a major problem which ultimately leads to an increase of 4.96% of degraded forest from 1977 to 2006.

As a result of the work developed in this report, it was concluded that all the objectives of this research has been achieved and this report will help concerned authorities, personals and NGOs to do further work in Barnadi WLS.

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CHAPTER I

1. Introduction:

Since the advancement in information technology, computer based Decision Support System (DSS) plays a very important role in most of the decision making whether it may be in national defense, hazards management, risk assessment, urban planning, industrial set-up, socio-economic improvements etc. There is also tremendous application of information technology in biodiversity conservation planning. Conservationist and decision makers have been involved in gathering huge databases from species level to ecosystem level with the help of satellite Remote Sensing and Geographic Information System (GIS). Such alphanumeric information gives scientific basis for decision making. Remote sensing data can be interpreted in many ways and provides lots of input for biodiversity conservation. Information that can be directly interpreted from satellite images includes forest cover mapping, forest type mapping, ecosystem mapping (such as wetlands), watercourse mapping, settlement mapping, agricultural area mapping etc.

Ravan 2002 has described Decision Support System (DSS) as:

1. It is computer based information systems, which offers decision-making capabilities, based on integration of alphanumeric information with geographical parameters.
2. It models spatial processes using geographical parameters.
3. It allows to perform series of spatial analysis to generate new information.
4. It allows to perform interactive, iterative and systematic process of decision making.
5. It captures the decision making rules and filters voluminous information based on decision making criteria.

6. The resultant information is depicted essentially in the form of maps. Representation of information in textual/table/graphical form is also an integral feature.

Most of the data related to biodiversity conservation are synthesized from different sources, compiled at different times, by different methods, and with different reliability. For rapid assessments of the status of biodiversity the researchers, conservationist and policy makers must utilize these existing sources, but the problem remains of how to best utilize each of them for its strengths and to track areas of uncertainty or ignorance. Recent advances in computerized systems that handle spatial data change the way we can represent distribution of plants and animal species. Traditional dot maps, grids or line drawings used until very recently to show species ranges are being replaced by applications of models to maps of habitat variables (e.g., Walker 1990, Scott et al. 1993). Models of ranges of populations or metapopulations now take explicit account of spatial effects e.g., patch size, distance between suitable habitat patches and the qualities of contiguous habitats (e.g. Hanski and Gilpin 1991). Models of the behaviour and movements of individual organisms now are carried out on spatial grids, which accommodate effect such as territoriality and foraging (e.g. Folse 1989). The range of environmental data to support these modeling efforts has also grown exponentially, due to technological advances (i.e. improvements in digitizing, satellite and aircraft remote sensing, telemetry, and global positioning system).

Barnadi Wildlife Sanctuary of Udalguri District under Bodoland Territorial Autonomous District, Assam is one of the protected areas on which scientific documentation of floral and faunal diversity is very less. Presence of extremely rare and critically endangered Pigmy Hog *Sus Salvanius* (Oliver 1980) along with other endangered animals such as Asian Elephant, Royal Bengal Tiger signifies the importance of this landscape. There is no up to date and reliable data on geographical extent of the WLS, forest type, plant and animal distribution within the sanctuary, habitat characteristics and utilization by different animal species. This is perhaps the first attempt to work on Barnadi WLS using Satellite Remote Sensing and GIS to investigate the present status of the sanctuary and its resources. This study will also help in preparing spatial model using GIS showing habitat characteristics and habitat utilization by different species within the Sanctuary, to develop a Decision Support System (DSS), where all relevant information will be fed in to GIS domain, to strengthen management plan and further research on species level in long run.

2. Project Objectives:

In order to address the problem above stated, the specific objectives of this research are the following-

a. The first objective is to collect spatial and non-spatial information of the study area i,e Barnadi Wildlife Sanctuary. The source of these information are mainly multi date remote sensing data (satellite imageries), available maps of forest department and other organization, field survey data as well as the information that will derive from the local people of the nearby villages of the study area.

b. The Second objective of this project is to create spatial models using GIS showing habitat characteristics and habitat utilization by different species within the Barnadi Wildlife Sanctuary.

c. The third objective is to develop a Decision Support System (DSS) for the entire wildlife sanctuary, where all the information will be fed in to GIS domain, which will help the concerned authorities to make plan to conserve the biodiversity of the area in near future.

d. The fourth objective of this study is the change detection of the Barnadi Wildlife Sanctuary from 1970s to till date and its impact on wildlife habitat.

3 Study Area

3.1 Location:

The Barnadi Wildlife Sanctuary (WLS) is an integral part of Manas Tiger Reserve (MTR). The sanctuary is located in the northwestern part of the district of Udalguiri under Bodoland Territorial Autonomous District (BTAD). The geographical extension of the sanctuary is from 91° 42' E to 91° 47'E longitudes and from 26° 45' N to 26° 52' N latitudes (Fig. 1). The total area of the sanctuary is 26.22 km^2. Earlier the sanctuary was known as Barnadi Reserve Forest and was notified vide Govt. notification GFR. 145/42 dated 25/4/42. Later on in the year 1980, it was converted into a Wildlife Sanctuary vide Govt. notification FRW. 14/80/11 dated 22/8/80. The average annual rainfall in the sanctuary is between 2000 - 2300 mm and average temperature in winter season is 8°c that rises up to 37 °c in summer. Relative humidity is 60% (in March)-95% (in July)

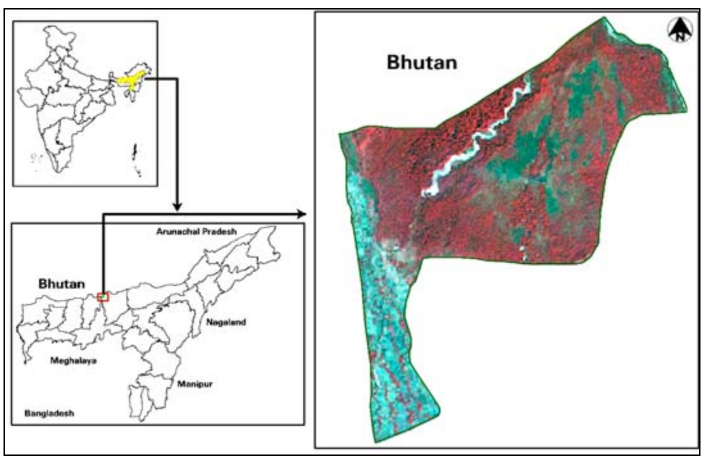


Fig. – 1 Location Map of Barnadi WLS

Criteria for the selection of the study area:-

The criteria for the selection of the study area were the following:

- Barnadi is one of the major conservation priority sites of Assam. It is an important habitat of Pigmy hog (*Sus salvinus),* Elephant (*Elephas Maiximus*) *Hispid* hare (*Caprolagus hispidus)*. Considering this major criteria the project was developed for Barnadi WLS.
- Barnadi WLS is a data poor area located near the international boundary between India and Bhutan. So preparation of a spatial database of this wildlife sanctuary was an immense importance.
- Dimensions of the study area and time available for fieldwork were other criteria for selection of the project site.
- Availability of recent cloud free satellite imagery (IRS P6 LISS III, 25th, March, 2006).
- Last but not the least, Barnadi WLS was earlier located in Darrang district, which is author's native district, so author has a special interest on the resources available in his own district.

3.3. Characterization:

3.3.1 Topography:

The topography of Barnadi WLS is undulating. The maximum altitude of the sanctuary is 700 mt above sea level (ASL) and the minimum 50 mt ASL. The river Deochunga enters the sanctuary from the north (Bhutan) at an altitude of 580 mt ASL and it flows towards south-western side and finally merged with Barnadi river outside the sanctuary boundary. The slope of the sanctuary is gradually decreasing from north-eastern side to south-western side. The main landform types found in Barnadi WLS are undulating hillocks with depressions in between and dry river bed with sand deposition. The figure 2 shows the topography of the Barnadi WLS.

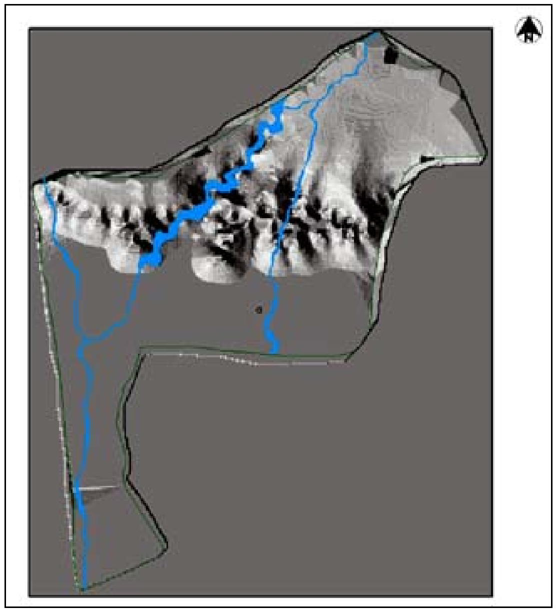


Fig. - 2 Topography Map of Barnadi WLS

3.3.2 Geology, Rock and Soils:

The sanctuary lies in a bhabor zone. So the area is mainly composed with sediments deposited by the river flowing through Bhutan. The sanctuary lies along the foothill region of the Eastern Himalaya. The rocks found in Barnadi WLS are mainly sedimentary rocks developed mostly during the tertiary geological age. The interior of the Barnadi WLS has deep sands and sandy loams soils, with low to medium water holding capacity.

3.3.3 Climate and Natural Hazards:

The area has a typical subtropical monsoon climate. On the basis of variation in temperature, rainfall and humidity, the climate of the area may be divided into four distinct seasons, namely Pre-monsoon, Monsoon, Retreating Monsoon, and winter season.

3.3.3.1 Pre-monsoon (March to May): - It is the transitional period between relatively dry winter and hot summer and is characterized by a rapid rise in temperature. The average maximum and minimum temperatures are 32° C and

20° C respectively. The average rainfall is around 400 mm and average humidity is 65%

3.3.3.2 Monsoon (June to September):- This is said to be a rainy season with rainfall of around 2000 mm. The maximum and minimum temperatures are 36° C and 23° C respectively. The average relative humidity is 82%

3.3.3.3 Retreating Monsoon (October to November): With the advance of the season, the temperature falls and fog appears. The average maximum and minimum temperature are 29° C and 16° C respectively. The average relative humidity is 80% and rainfall is 120 mm.

3.3.3.4 Winter (December to February): This season is characterized by cold weather with average maximum and minimum temperatures are 25° C and 7° C respectively. The average relative humidity is 63% and rainfall is 40 – 50 mm.

The major natural hazards of Barnadi WLS are weather related (sheet-flood and drought). As the sanctuary lies along the foothill region, the slope of the area abruptly decreases and because of this sheet flood is prominent hazard in monsoon season in this area. Besides this, drought in winter season is also another hazard in this area. As the area is in bhabor belt so the water holding capacity of the top soil is very low which ultimately cause drought type situation in winter season when rainfall is quite low which is about 120mm in average.

3.3.4. Vegetation:

3.3.4.1 The Biogeographic Clssisification :

The Barnadi WLS falls under the North East Brahmaputra Valley Biogeographic Province (9A) of the North East India Biogeographic Zone.

3.3.4.2. The forest types:

The Barnadi WLS and its habitat composed of the following forest types

3.3.4.2. a Pioneer Euphorbiaceous Scrub (1/2/2B/C1/2S1)

3.3.4.2. b Eastern Himalayan Moist Deciduous Forest (3C/C3b)

3.3.4.2. c Eastern Hollock Forests-Terminalia Duabanga (1S2(b))

3.3.4.2. d Eastern Wet Alluvial Grassland (1/4/4D/2S30)

3.3.4.2. e Khair-Sissoo Forests (11/5/1S2)

3.3.5 Fauna:

3.3.5.1 Mammals: Barnadi WLS is famous for the Pigmy Hog and Hispid hare. These two were once flagship species of the area. However their sightings have not been reported in the recent past. The other species sharing the habitat are Royal Bengal Tiger, Asiatic Elephant, India Bison, Hog Deer, Wild Bore, etc. commonly seen in the WLS. The other smaller mammals that are commonly seen in Barnadi are Civet cat, Leopard Cat, and Porcupine.

3.3.5.2 Aves: The sanctuary is rich in variety of birds. It is an important habitat of Bengal Florican, which is highly endangered in India. Besides this, the other important birds that are available in Barnadi WLS are Little Cormorant, Great Cormorant, Little Green Heron, Pond Heron, Large Egret, Chestnut Bittern, Black, Bittern, Night Heron, etc.

3.3.5.3 Reptilia: Among the reptiles, Genus Python, Kachuga tecta, Lissemys punctata are common.

3.3.5.4. Amphibia: Among the amphibians, the following species are common in Barnadi WLS – Malayan Box turtle, Eastern Hill Terrapin, Spotted Black Terrapin, Brown Roofed Turtle, etc.

4. Review of related work in the study area.

Very few sources were found (considering both literature and secondary data collection) that covered both work done in the Barnadi WLS and the thematic approached in this report.

William L.R Oliver (1980) presents a summary of the habitat pattern of Barnadi WLS in respect of Pigmy Hog and Hispid Hare in his special scientific report no. 1. The main objectives of the work were to understand the habitat of Pigmy Hog and Hispid Hare and their distribution pattern within Barnadi WLS.

In 2003, the Division Forest Office, Mangaldoi Mr. S.P Vashishtha (IFS) has prepared one management plan of Barnadi WLS where he described habitat pattern of Barnadi WLS as well as the problems and prospects of Barnadi WLS in detail.

In 2005, WWF India's Asian Rhino and Elephant action strategy (AREAS) programme has executed one project work in entire north bank landscape including Manas Tiger Reserve. In their final report some information on Barnadi WLS and its habitat pattern has been explained.

CHAPETR II

General Methodology:

The general methodology followed for this research is presented schematically below

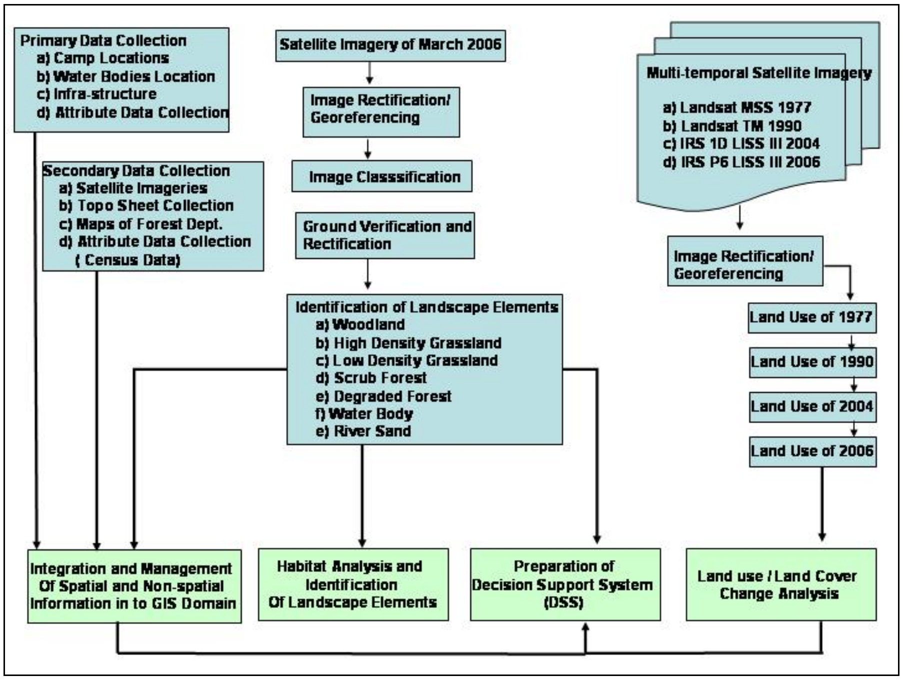


Fig. 3 General Methodology of the study

5. Data available and data collection:

Data available

Satellite Imagery:

The catechization of the satellite imageries that were used to prepared the decision support system and to identify the land use changes in Barnadi WLS are presented in table 1.

Table1

Satellite	Sensor	Pixel Size	Path and Row	Acquisition Date
Landsat MSS	***MSS***	***60 m***	***Path 147 Row 41***	***08th February, 1977***
Landsat TM	***TM***	***30 m***	***Path 137 Row 41***	***07th November, 1990***
IRS 1D	***LISS III***	***23.5 m***	***Path 111 Row 53***	***09th March 2002***
IRS P6	***LISS III***	***23.5 m***	***Path 110 Row 53***	***25th March , 2006***

5.1.2 Ancillary Data

The ancillary data that were used in this study are the following:

- Survey of India topographical sheet at 1:50,000 (No. 78 N/9, 78N/10, 78N/13 and 78N/14) scale and 1:2, 50,000 scale (No. 78N)
- Sketch map of Barnadi WLS prepared by Forest Department.
- Management plan of Barnadi WLS prepared by Dept. of Forest and Environment, Govt. of Assam

Data Collection

5.2.2 Primary data collection

The primary data collection was made within a team of four members, took place from 12 January 2007 to 15 May 2007 and had the duration of 25 working days. During the data collection there was practically no rainfall and the weather was good and dry.

The primary data were mainly composed with location of anti poaching camps, location of water bodies, infrastructures available, habitat pattern and habitat utilization pattern by different species. A data sheet was prepared to note down the data collected from Barnadi WLS. Each of this information was incorporated with a GPS point having latitude, longitude and altitude information. The collected primary data were fed in GIS domain using Arc Info 7.2.1 software.

All the data items collected from Barnadi WLS is used to prepare this report, specifically the habitat sample and mapping unit information, the vegetation description and analysis.

Equipments used in the fieldwork:

- GPS Garmin 72 handheld
- Measuring tapes 5mts and 50mts.
- A hard copy of recent satellite imagery
- A hard copy of classified land use map with grid overlay
- Pencil , clipboard
- First aid kit, field knife.

Sampling Design for Habitat Mapping:

For preparation of habitat mapping of Barnadi WLS a grid base sampling was designed. First of all the entire area of Barnadi WLS was divided in to 1km X 1km grids. A total of one forty five equal (1km X 1km) grids were developed using ERDAS Imagine 9.0 software. These grids were overlapped over the classified satellite imagery (March, 2006). Out of one forty five grids thirty four grids were selected for collection of training sets based upon spectral signatures of the satellite image. These thirty four grids were extensively surveyed to prepare the habitat map of Barnadi WLS. The process of sampling design and data collection is shown in the following figure –

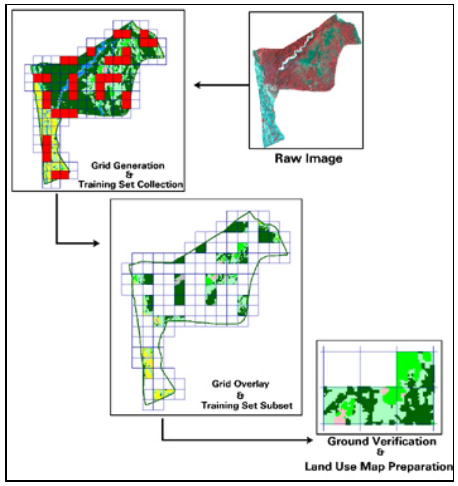


Fig 4 . Process of sampling design and habitat mapping

Using this approach to prepare the habitat mapping there were seven habitat types were identified in Barnadi WLS. These are –

a) Woodland
b) High density grassland
c) Low density grassland
d) Scrub forest
e) Degraded forest
f) River/ Water Body
g) River sand/ Sandy area

5.2.3. Secondary data collection:

A part of the secondary data was collected along with the primary data. The secondary data were mainly composed with satellite imagery of 1977, 1990, 2002 and 2006. The images of 1977 and 1990 were downloaded from internet which are available free of cost at Global Land Cover Facilitator web site (www.glcf.org) The images of 2002 and 2006 were procured from National Remote Sensing Agency (NRSA), Hyderabad. Apart from satellite images the other secondary data were topographical maps of the study area prepared by Survey of India and forest maps prepared by the Dept. of Forest and Environment, Govt. of Assam. Animal census data were also collected from the range office of Barnadi WLS.

These were the primary and secondary data collected to do this work in Barnadi WLS.

6. Data processing

Primary data processing:

The first step of primary data processing after the fieldwork was the organization of the raw primary data collected and registered in the data collection sheets, in order to allow its adequate manipulation and connection with GIS operations. The data were entered in a database built in Microsoft Excel software.

The second step of data processing was the preparation of different spatial layers using GIS software. Here in this study five major layers were prepared. These were –

a) Location of existing camps
b) Location of abandoned camps
c) Location of water body available
d) Road networks
e) Habitat sample points

GPS points that were collected from field were extensively used to create these spatial layers.

The third step of data processing was the attribute adding and editing of above mentioned spatial layers. Here in this stage all the attribute information such as name of the existing and abandoned forest camps, names of the staff available in each camp, number of water body, etc. was added with the spatial layer using GIS software. The table 2 shows the different spatial layers prepared from primary data and their respective attribute information.

Table

2Sl. No	Spatial Layers	Attribute Information	Layer Feature Types
1.	Sanctuary Boundary	a) Forest Boundary b) International Boundary c) Barnadi WLS	a) Line b) Line c) Polygon
2.	Existing camps	a) Name of the camps b) Name of staffs	a) Point
3.	Abandoned Camps	a) Name of the camps b) Name of staffs	a) Points
4.	Water bodies (Ponds)	a) Number of ponds b) Name of ponds if any	a) Polygon
5.	Road networks	a) Name of the road if any b) Nature of road i) Mattel ii) Un-Mattel	a) Line
6.	Habitat sample points	a) Woodland b) High Density Grassland c) Low Density Grassland d) Scrub Forest e) Degraded Forest f) Water Body g) River sand	a) Polygon

All these spatial layers were finally used to prepare the habitat model and decision support system of Barnadi WLS.

Satellite image processing:

The Landsat MSS, Landsat TM, IRS 1D LISS III, and IRS P6 LISS III images pertaining to 1977, 1990, 2002 and 2006 were used in this study to prepare and analyze the habitat pattern, habitat change, habitat modeling and prepare the decision support system. Survey of India topographical sheets at 1:50,000 and 1:2,50,000 scale were also consulted and used as collateral data.

The image processing process stars with the proper registration of topographical sheets of Barandi WLS. The 1:50,000 and 1:2, 50,000 scaled toposheets were geometrically registered using the Polyconic Projection system. The reason behind choosing polyconic projection was that the original hard copies of topographical sheets were in polyconic projection.

In the second step, all the images (Landsat MSS, Landsat TM, IRS 1D LISS III and IRS P6 LISS III) were georeferenced taking the registered toposheets as reference image. In all the images sub-pixel image to map registration accuracy was achieved through repeated attempts. The accuracy was also verified with the ground control points (GCPs) that were collected from the fieldwork.

In the third step all the images (Landsat MSS, Landsat TM, IRS 1D LISS III and IRS P6 LISS III) were resampled and rediometrically corrected using dark pixel subtraction technique (Kushwaha, S.P.S, et al, 2004). All the images were resampled at a pixel size of 23.5 mt. resolution

In the fourth step the Barnadi WLS area was extracted from all the images by superimposing the vector layer of forest boundary, vectorised from survey of India topographical sheet.

In the fifth step the habitat identification and mapping was done using the recent (IRS P6 LISS III) satellite image of Barnadi WLS. A visual interpretation technique was used on screen using supervised classification. Training sites were made for each habitat types by demarcation a polygon or an area of interest (AOI) for the known cover type that were later applied to the entire image. A classification scheme was developed and overall number of classes in each case was kept constant. After preparing the recent habitat mapping a total 145 number of grids having 1km X 1km area in each grid were generated. Out of these145 grids 34 grids (23.5%) were selected for ground verification and also to do the accuracy assessment. These 34 grids were selected based upon the distribution pattern of different habitat in Barnadi WLS. All the 34 grids were extensively surveyed and the accuracy achieved in the habitat mapping was 94%.

In the sixth step all the other images of Landsat MSS, Landsat TM and IRS 1D LISS III were classified using the same process that was used for IRS P6 LISS III imagery.

In the final step all the visually interpreted images of 1977, 1990, 2002 and 2006 were superimposed over each other to detect the changes from one period to the other. This process finally gave us the land use / land cover change or habitat changing pattern of Barnadi WLS.

All these satellite image processing operation were carried out in ERDAS Imagine 9.0 version software.

Accuracy in image classification and spatial modeling:

Image classification is one of the techniques of digital image interpretation, which is that a pixel assigned to a class based on its feature vector, be comparing it to predefined clusters in the feature space. In a supervised classification, the operator defines the clusters during the training process. The final stage in image classification is the validation of the classification. The most commonly used measure of classified map accuracy is the overall accuracy or Proportion correctly classified (PCC). Overall accuracy is computed by dividing the number of correctly classified points by the total number of sample points. Another widely used measures of map accuracy derived from the error matrix is the kappa coefficient or K' statistic,

In this study maximum likelihood classifier algorithm was applied for image classification in ERDAS 9.0 software. 34 observations were used for training and 34 observations used for validation of classification image of Landsat

MSS 1977, Landsat TM 1990, IRS 1D LISS III 2002 and IRS P6 LISS III, 2006. It was observed that the accuracy of the image classification was 94% which was a good accuracy level achieved using digital image classification technique. Similarly the spatial models prepared using GIS was verified in the ground and the average accuracy level in modeling part was found 96% which indicates that the models have resembles with the ground reality.

CHAPTER III

RESULTS AND DISCUSSION

The core findings of this research is described below

7. INTEGRATION AND MANAGEMENT OF SPATIAL AND NON-SPATIAL DATA OF BARNADI WLS USING GIS

One of the major bottlenecks of Barnadi WLS was the lack of systematic spatial data. So considering the importance of this problem this study was carried out in Barnadi WLS to integrate and manage the spatial as well non-spatial information in to GIS domain. Through this study a complete GIS based database of Barnadi WLS has developed where all the spatial and non-spatial information were integrate and manage in to GIS domain. This database was saved in electronic devise and any one at any time can access this database. The systematic integration of spatial and non-spatial information and their management is described below.

7.1 Digitization :

Digitization is the most common method for entering maps into GIS. Earlier manual digitization was done by fixing the map in to digitizing table. But now due to the advancement of GIS software packages on screen digitization is possible. For the on screen digitization the map (satellite image or scan map) should be projected one with latitude and longitude information.

Here in this study an onscreen digitization approach was adopted to prepare the different spatial layers. All the digitization was done using Arc GIS 9.0 software.

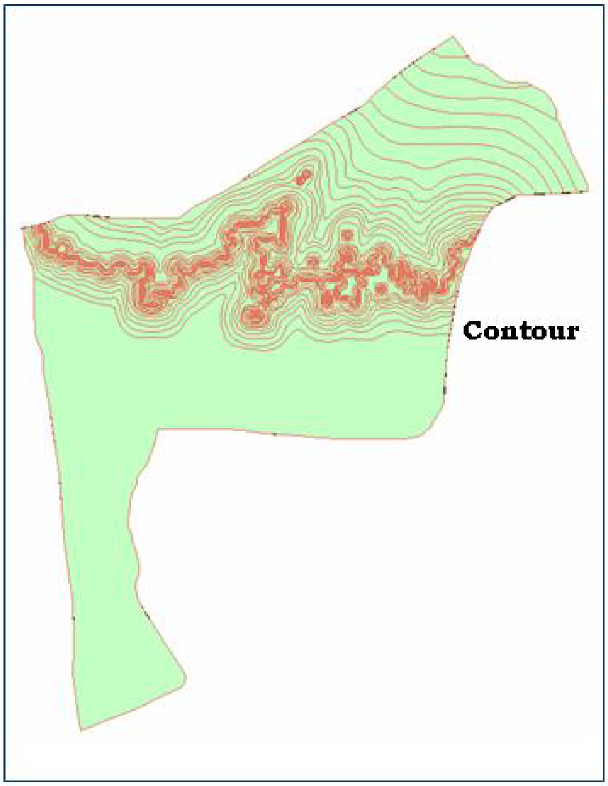
7.2 Topology building:

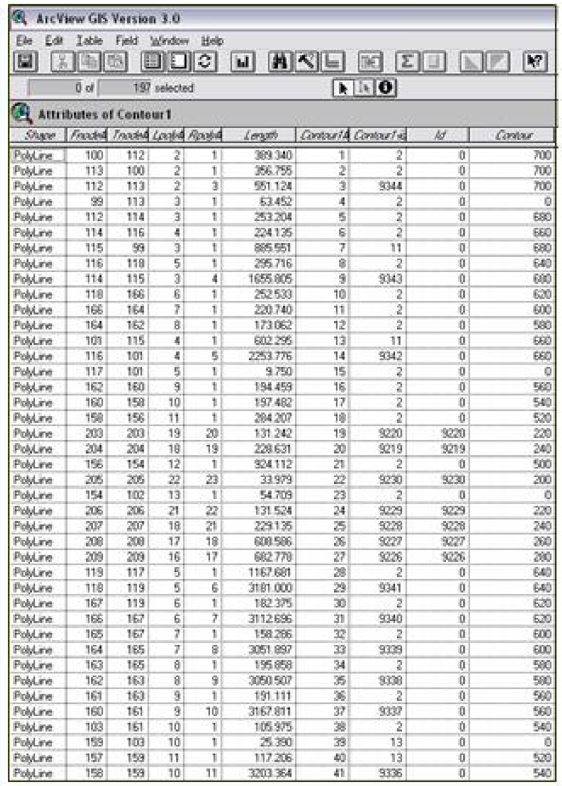
A GIS can recognize and analyze the spatial relationships that exist within digitally stored spatial data. These topological relationships allow complex spatial modelling and analysis to be performed. Topological relationships between geometric entities traditionally include adjacency (what adjoins what), containment (what encloses what), and proximity (how close something is to something else). Topology can be generated in GIS using two commands these are " Clean and Build". The clean command is used for line and polygon features whereas build command is used for point, line and polygon features.

Here in this study topology was generated for all the vector layers that were digitized with proper geocoding. Topology generates an internal database along with the spatial information where non-spatial information can be added at unlimited level.

7.3 Attribute adding and editing:

Attribute data describe specific map features but is not inherently graphic. For example, an attribute associated with a road might be its name or the date it was last paved. Attributes are often stored in database files kept separately from the graphic portion of the map. Attributes pertain only to vector maps; they are seldom associated with raster images. Here in this study attribute information of each spatial layer were collected from the field during the primary data collection period and these were added to the spatial layers using GIS software packages. GIS software packages maintain internal links tying each graphical map entity to its attribute information. The nature of these links varies across systems. In some, the link is implicit, and the user has no control over it. Other systems have explicit links that the user can modify. Links in these systems take the form of database keys. Each map feature has a key value stored with it; the key identifies the specific database record that contains the feature's attribute information.





Shape	Fnode#	Tnode#	Lpoly#	Rpoly#	Length	Contour1#	Contour1-id	Id	Contour
PolyLine	100	112	2	1	389.340	1	2	0	700
PolyLine	113	100	2	1	356.755	2	2	0	700
PolyLine	112	113	2	3	551.124	3	9344	0	700
PolyLine	99	113	3	1	63.452	4	2	0	0
PolyLine	112	114	3	1	253.204	5	2	0	680
PolyLine	114	116	4	1	224.135	6	2	0	660
PolyLine	115	99	3	1	885.551	7	11	0	680
PolyLine	116	118	5	1	295.716	8	2	0	640
PolyLine	114	115	3	4	1655.805	9	9343	0	680
PolyLine	118	166	6	1	252.533	10	2	0	620
PolyLine	166	164	7	1	220.740	11	2	0	600
PolyLine	164	162	8	1	173.062	12	2	0	580
PolyLine	101	115	4	1	602.295	13	11	0	660
PolyLine	116	101	4	5	2253.776	14	9342	0	660
PolyLine	117	101	5	1	9.750	15	2	0	0
PolyLine	162	160	9	1	194.459	16	2	0	560
PolyLine	160	158	10	1	197.482	17	2	0	540
PolyLine	158	156	11	1	284.207	18	2	0	520
PolyLine	203	203	19	20	131.242	19	9220	9220	220
PolyLine	204	204	18	19	228.631	20	9219	9219	240
PolyLine	156	154	12	1	924.112	21	2	0	500
PolyLine	205	205	22	23	33.979	22	9230	9230	200
PolyLine	154	102	13	1	54.709	23	2	0	0
PolyLine	206	206	21	22	131.524	24	9229	9229	220
PolyLine	207	207	18	21	229.135	25	9228	9228	240
PolyLine	208	208	17	18	608.586	26	9227	9227	260
PolyLine	209	209	16	17	682.770	27	9226	9226	280
PolyLine	119	117	5	1	1167.681	28	2	0	640
PolyLine	118	119	5	6	3181.000	29	9341	0	640
PolyLine	167	119	6	1	182.375	30	2	0	620
PolyLine	166	167	6	7	3112.696	31	9340	0	620
PolyLine	165	167	7	1	158.286	32	2	0	600
PolyLine	164	165	7	8	3051.897	33	9339	0	600
PolyLine	163	165	8	1	195.858	34	2	0	580
PolyLine	162	163	8	9	3050.507	35	9338	0	580
PolyLine	161	163	9	1	191.111	36	2	0	560
PolyLine	160	161	9	10	3167.811	37	9337	0	560
PolyLine	103	161	10	1	105.975	38	2	0	540
PolyLine	159	103	10	1	25.390	39	13	0	0
PolyLine	157	159	11	1	117.206	40	13	0	520
PolyLine	158	159	10	11	3203.364	41	9336	0	540

Fig. 5 – Spatial layer and its related attribute information

7.4 Database creation:

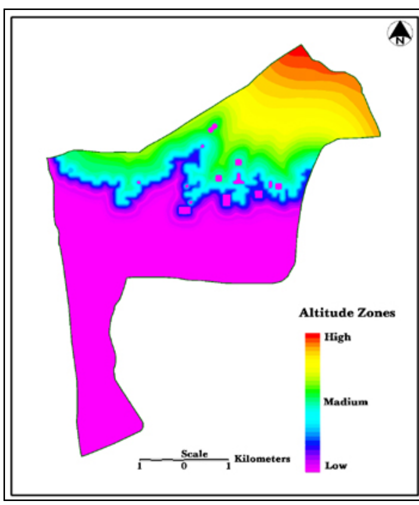
8 Spatial modeling for biodiversity conservation of Barnadi WLS

The technology of GIS has greatly enhanced the ability to visualize natural resources data. Digital geographic data are playing an increasing role in wildlife management, providing computerized representations of wildlife habitat, administrative boundaries, significant cultural features, and wildlife species distribution. The species distribution and its habitat utilization pattern is a complex dynamic phenomena which is poorly represented by a static map. But complex models of a species distribution and its habitat utilization pattern which reflects verity of environmental factors can be developed in a GIS environment.

Here in this study some of the GIS based models were developed which will help the conservation of biodiversity available in Barnadi WLS of Assam.

8.1 Digital elevation model:

Digital elevation model (DEM) is a GIS based model prepared to show the relief and height of the landscape. The prime requirement to prepare this model is the altitude information or the contour lines. Here in this study a DEM of Barnadi WLS was prepared to show the different altitude zones and also the represent the relief of the sanctuary. Contour lines were digitized from survey of India toposheets at 20mt interval and a create surface model was run in ERDAS 9.0 software. The minimum and maximum altitude zones of Barnadi were 50mt and 720mt from ASL. The following figures 5 and 6 shows the different altitude zones of Barnadi WLS   and its relief pattern which were the output of the DEM.



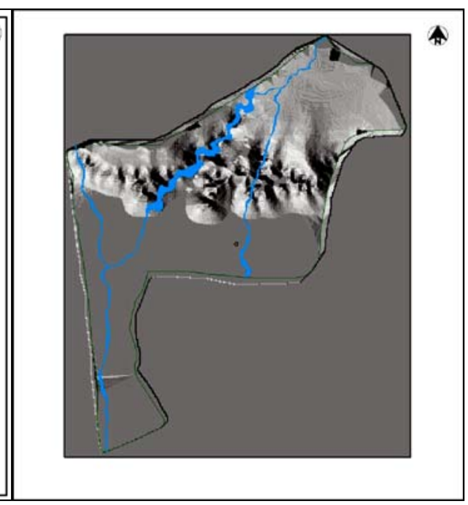
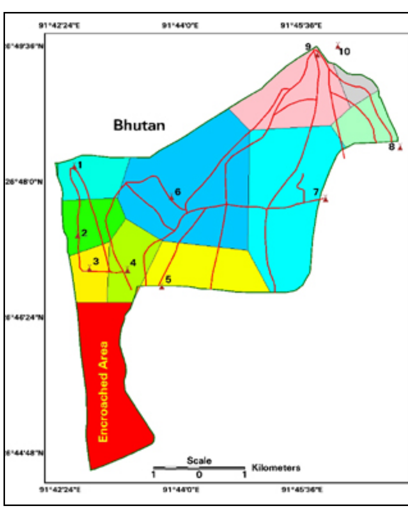


Fig.6 – Altitude zones of Barndi WLS

Fig. 7 - DEM with drainage of Barnadi WLS

8.2 Thiessen model of risk zone identification in Barnadi WLS:

Thiessen model converts point coverage to coverage of proximal polygons. Thiessen polygons can be used to apportion point coverage into regions known as Thiessen or Voronoi polygons. Each region has the unique property that any location within a region is closer to the region's point, than to the point of any other region. Here in this study thiessen model was used to identify the risk zone of Barnadi WLS. The existing and abandoned camps were used as point coverage and this model was run in Arc Info software. From this model two different scenarios of Barnadi WLS has appeared. The following maps were come out after running the model. The model shows that the patrolling areas of camps and its influence zones based upon terrain condition. The Fig 7 shows that the patrolling condition in Barnadi WLS was good enough when the abandoned camps were in function; the total area covered by good patrolling was 23.08 sq.km and the model shows that only 3.14 sq. km area was under risk zone. This was the scenario of Barnadi WLS prior to 1980, where as the Fig 8 shows the present patrolling condition of Barnadi WLS where only four camps are functioning and the model shows that the total area of good patrolling is 12.49sq. km and rest of the 13.73 sq. km area is under risk zone.



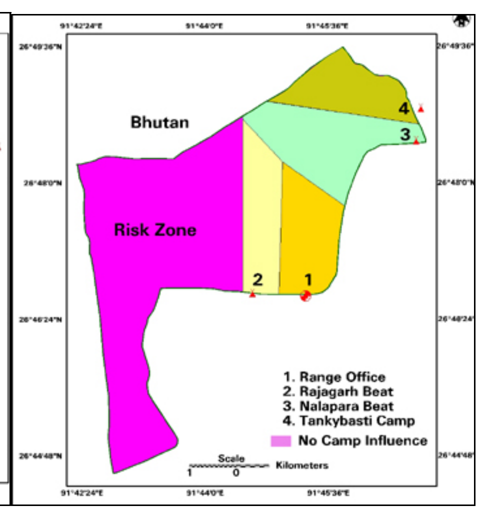


Fig. 8 Patrolling Areas of Barnadi WLS when abandoned camps were active

Fig. 9 Patrolling Areas of Barnadi WLS at present.

The red color in the fig 7 indicates the risk zone of Barnadi WLS before 1980, where as in Fig 8 the magenta color indicates the risk zone of Barnadi WLS at present. This model was also verified in the field it has a clear resembles with the ground reality, which shows that most of the western part of the sanctuary has already encroached. The total area of encroachment at present is 4.01sq. km.

8.3 Risk zones of Barnadi WLS:

A GIS based model of risk zone identification was prepared in Barnadi WLS based upon the human population and hunting pressure from the east, west and southern side of the sanctuary. From the field observation it was observed that the pressure of human population and hunting over the sanctuary is high from the eastern and western part of the sanctuary rather than the southern part. The northern part is almost safe from the human as well as hunting pressure as it is a hilly area and the international boundary is going along with the sanctuary boundary. An area based model was prepared to show the risk zones of Barnadi WLS. A 1km buffer of forest boundary was created in the east and west part of the sanctuary whereas a 500mt buffer of southern boundary was created. Subsequently another buffer of 1km of the first buffer line was created in the eastern and western part and a 500mt buffer of first buffer was created in the southern part. The reason behind taking 1km buffer in the eastern and western part was that the pressure of human population as well as hunting was found prominent from these two sides during the field data collection period. After completion of buffering of all sides these buffers were intersect with each other and finally a map was came out showing different risk zones of Barnadi WLS. The model shows an area of 14.58sq. km is high risk zone, 7.34 sq. km as a medium risk zone and only 4.30 sq. km area as a low risk zone of Barnadi WLS. Following figure 9 shows the different risk zones of Barnadi WLS.

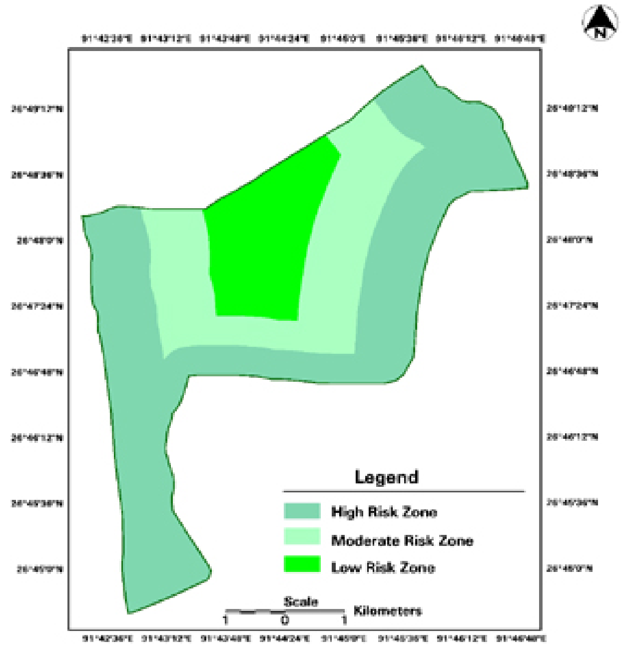
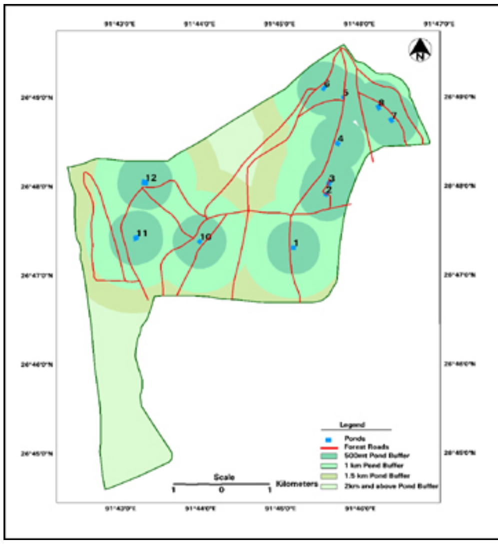


Fig. 10 - Risk zones of Barnadi WLS

8.4 Water buffer model of Barnadi WLS:

An area base buffer model of available water bodies of Barnadi WLS was prepared to show the influence zone of water sources over the different species available in Barnadi WLS. Barnadi WLS lies along the foothill of Eastern Himalaya and it is a bhabar zone with soil having low and medium water holding capacity. During the dry season severe water crisis found in the sanctuary and to overcome this problem the Forest Department of Assam had created 12 artificial ponds and these ponds are the prime source of water during the dry season in the sanctuary. There were four buffer layers of these water sources were created at an interval of 500 mt. These buffer layers were overlapped over the pond layer and finally a map was prepared to show the influence zones of 12 ponds in Barnadi WLS. Similarly these buffer layers were also overlapped by the habitat map of recent time and we get the habitat wise influence zones of these water sources in the sanctuary. The following figures 10 and 11 show the water buffer model prepared by using GIS based algorithm.



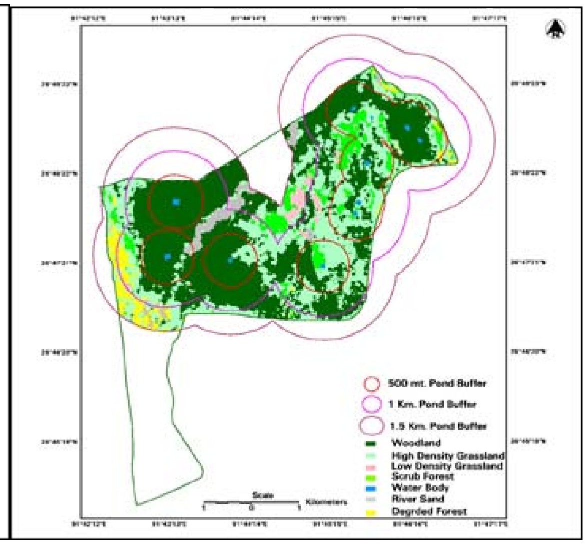


Fig. 11 – Water body and their influence zones. **Fig. 12 – Water body and its influence habitat.**

8.5 Camp buffer model of Barnadi WLS:

A point based buffer model of existing anti poaching camps were made for Barnadi WLS. A 2km buffer were created for the each existing anti poaching camps and it shows that most of the southern and eastern part of the sanctuary is well protected but in the western part of the sanctuary is completely protection free and because of this illegal activities are found to be prominent in those areas. The figure 12 shows the existing anti poaching camps of Barnadi WLS and its buffer zone.

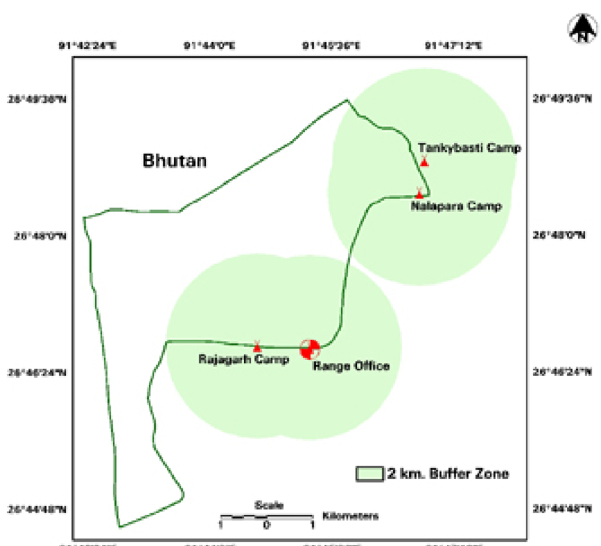


Fig. 13 – Camp buffer of Barnadi WLS

8.6 Road buffer model of Barnadi WLS:

A line base buffer model of road network of Barnadi WLS was developed to show the influence zones of roads. A 200mt buffer of road network was created to show the influence zones of roads. The figure 13 shows that most of the roads in Barnadi WLS passing through the woodland areas. The total length of the road network in Barnadi WLS is 42.06 km. Out of the 42.06 km 11.45 km road passes through the grassland areas, 1.39 km road passes through the degraded forest area. The rest 29.22 km road passing through the woodland area in Barnadi WLS

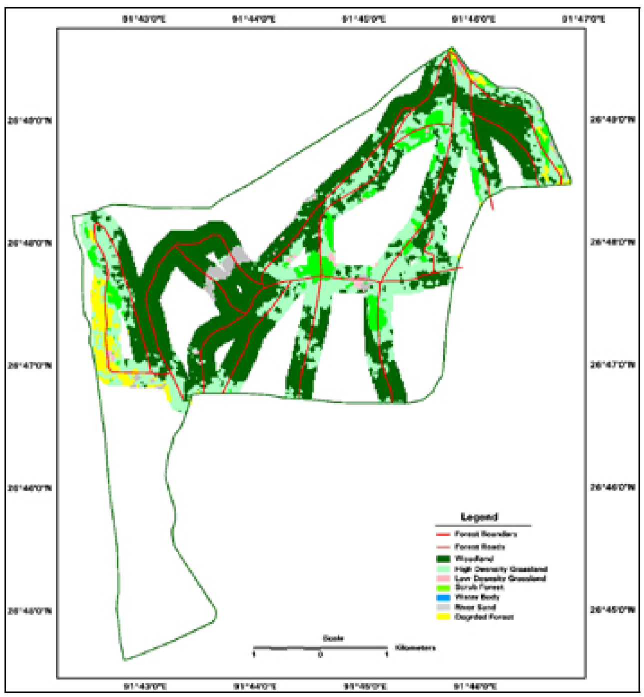


Fig. 14 – Road buffer of Barnadi WLS

8.7 Current conservation status model of Barnadi WLS:

An assessment of current conservation status of Barnadi WLS was made using grid base survey analysis (Ibisch, P.L, et al 2003). A total of 145 grids were prepared and each grid covered an area of 1km X 1km in the ground. Out of these 145 grids, 34 grids were extensively surveyed and information on habitat condition, human pressure, natural hazards and hunting pressure were collected from each grid. These collected information were fed into GIS to make the assessment of present conservation status of Barnadi WLS. The model shows that out of 145 grid, 55 grids have worst conservation status and their distribution were found mainly in the western and eastern part of the sanctuary, 28 no. of grids have bad conservation condition and their distribution were found mainly southern part of the sanctuary and also along the worst conservation grids. A total 36 grid shows good condition and their distribution were found in the central part of the sanctuary whereas 25 grids shows excellent conservation status and their distribution were found along the international boundary between Bhutan and India. The figure 14 shows the conservation status of Barnadi WLS

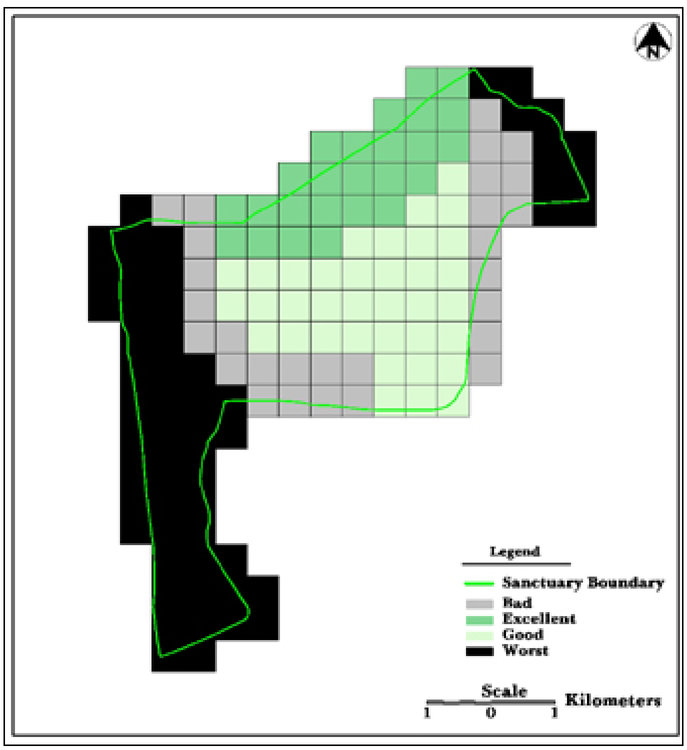


Fig. 15 – Current conservation status of Barnadi WLS

8.8 Habitat difference with altitude model of Barnadi WLS:

A model was prepared by overlapping the contour lines of Barnadi WLS over the habitat map of recent time. This model shows the altitudinal variation of the different habitat pattern in Barnadi WLS. The following figure 15 has come out from the model

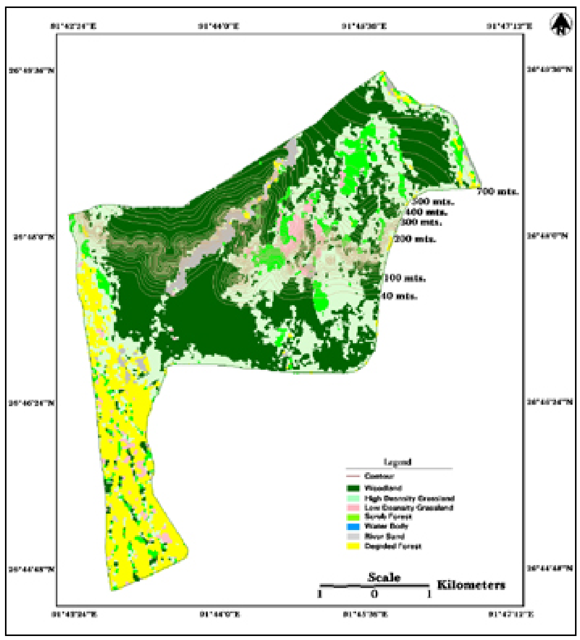


Fig. 16 – Altitudinal variation of habitat

Here in the map we see that the woodland is distributed in all the altitudinal zones of Barnadi WLS. The concentration of scrub forest is more in an altitude between 140mt to 700mt and these are distributed scattered manner. The high density grassland is distributed in western part of the sanctuary at an altitudinal variation between 50mt to 600mt. The low density grassland is found mainly in the 200mt to 500mt altitudinal zone where as the degraded forest is found mainly in the low lying areas of the park.

9. HABITAT CHARACTERISTICS

The Barnadi WLS was classified in to seven major habitat types based upon satellite image classification and extensive ground survey. All of these habitat types are spatially well distributed throughout the sanctuary and all of these habitats are extensively used by different species such as Elephant, Tiger, Pigmy Hog, etc. The seven habitat types and their distribution is shown in the following figure 16.

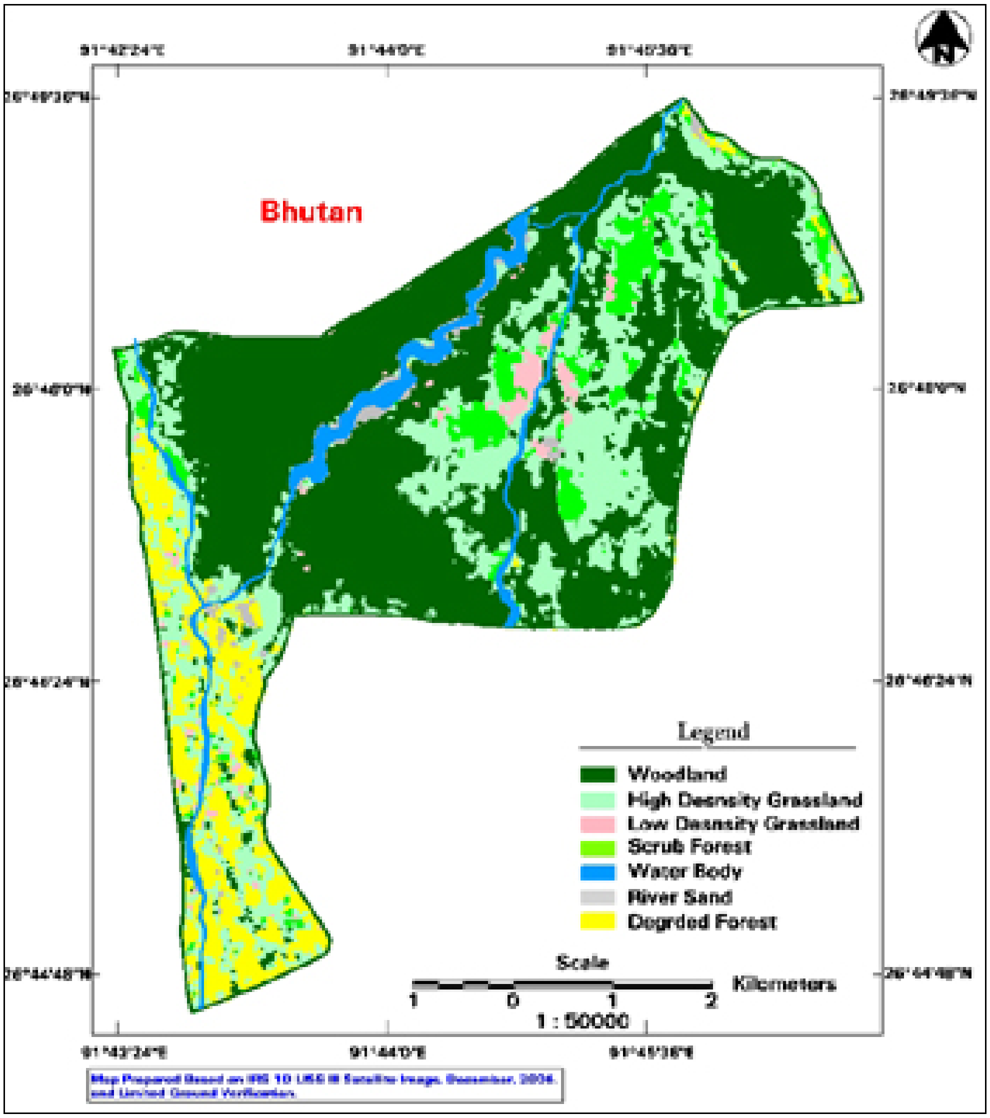


Fig. 17 - Different habitat types of Barnadi WLS

9.1 Woodland:

Woodland is found to be quite prominent in the sanctuary. The area covered by woodland is 11.96 sq. km which is 45.61% of the total geographical area of Barnadi WLS. The concentration of woodland is found high in northern and north western part of the sanctuary. Woodland is also distributed in other parts of the sanctuary but in a scattered manner. The following figure shows the distribution of woodland in Barnadi WLS. It was found during field verification that these woodland patches were extensively used by elephant and these patches have substantial values in elephant's trans- boundary movement and all corridors leading to Bhutan lies in these patches. The figure 17 shows the distribution of woodland in Barnadi WLS.

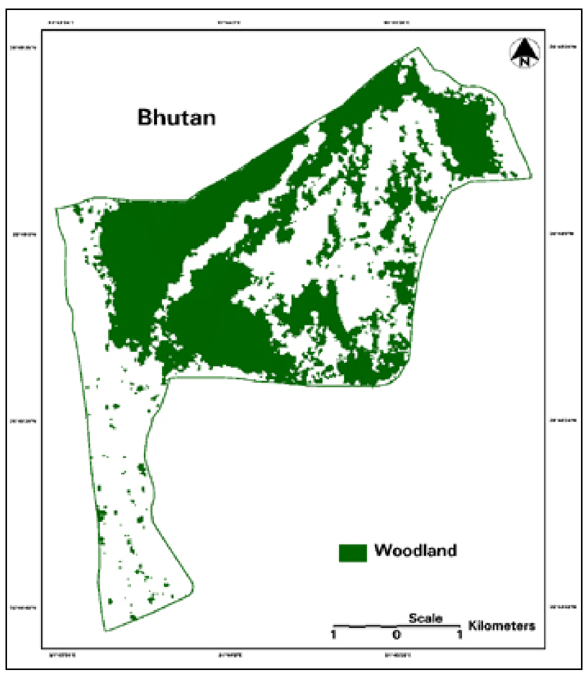


Fig. 18- Distribution of woodland in Barnadi WLS

9.2 Grassland:

Grassland is also prominent in Barnadi WLS. The total area covered by grassland is 7.77 sq. km which is 29.63% of the total geographical area. Grassland are also further classified in two classes based upon density these are high density grassland and low density grassland.

9.2.1 High density grassland:

High density grass covers an area of 7.27 sq.km. in Barnadi WLS which is 27.72% of the total geographical area of the sanctuary. The concentration of high density grassland is found to be prominent in the middle part and the north eastern part of the sanctuary. This high density grassland has an average height of 5 mt from the ground and it has average visibility of 0.50mt. This grassland is used by the different species such as elephant, tiger, deer, etc. The figure 18 shows the distribution of high density grassland in Barnadi WLS.

9.2.2 Low density grassland:

Low density grassland is found to be prominent in the middle of the sanctuary in very small patches. The total area covered by low density grassland is only 0.50 sq. km. which is 1.90% of the total geographical area of the sanctuary. The average height of this grassland type is 2mt. and average visibility is 1.50mt. This grassland patches are extensively used by the wild bore and pigmy hog. The figure 18 shows the distribution of low density grassland in Barnadi WLS

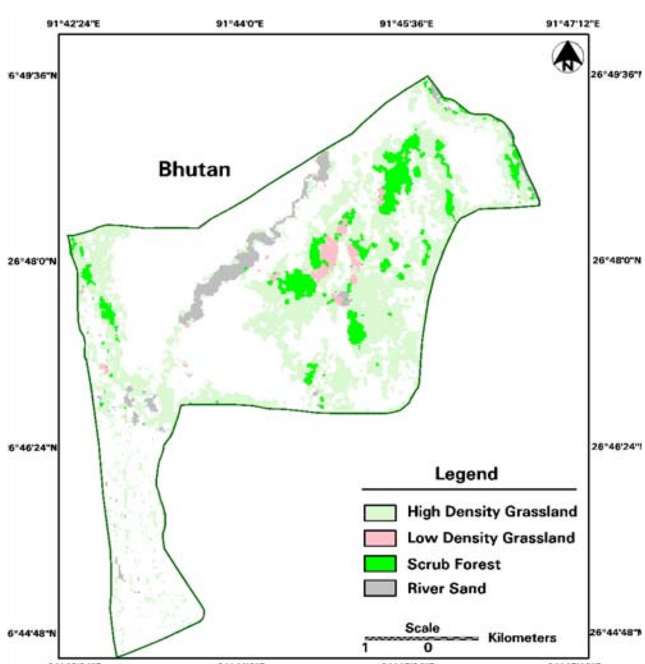


Fig. 19 – Distribution of grassland, scrub forest and river sand

9.3 Scrub Forest:

A total area of 1.53sq.km in Barnadi WLS is covered by scrub forest, which is 5.83% of the total geographical area of Barnadi WLS. Scrub forest is prominent in the central and western part of the sanctuary. Scrub forests are also found along the rivers passing through the Barnadi WLS. The figure 18 shows the distribution of scrub forest in Barnadi WLS.

9.3 Water Body:

Surface water is very less in Barnadi WlS as the sanctuary lies in Bhabar belt. Dry rivers with sand and pebbles are common features in the sanctuary, but the forest department has created some artificial ponds where surface water is available and these are the prominent source of water for wild animals available in Barnadi WLS. The total number of this kind of ponds is 12 which cover an area of 0.10 sq.km. which is 0.38% of the total geographical area of the sanctuary. The figure 19 shows the distribution of artificial ponds in Barnadi WLS

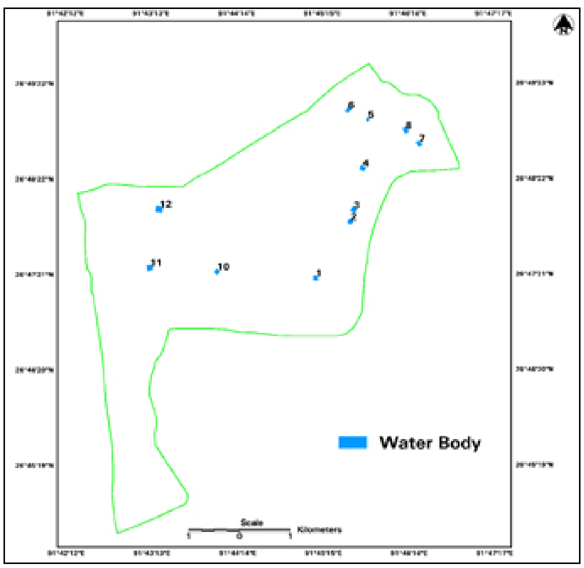


Fig. 20 – Distribution of artificial ponds

9.5 Degraded forest:

Degraded forest in Barnadi WLS is a prominent feature and most of the degraded forest is found in the western part of the sanctuary. The total area of degraded forest is 4.01 sq.km which is 15.29% of the total geographical area of the sanctuary. The main cause behind this forest degradation is encroachment from the fringe villages. The figure 20 shows the area of degraded forest in Barnadi WLS.

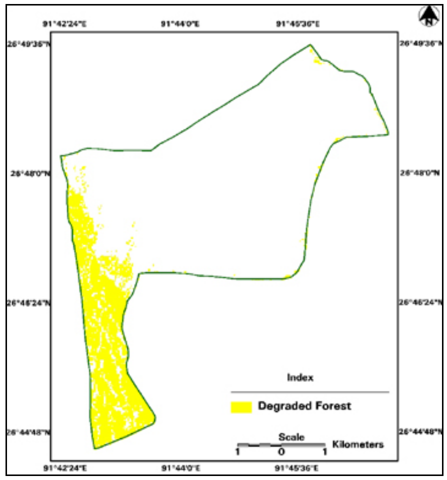


Fig. 21 – Distribution of degraded forest in Barnadi WLS

9.6 River sand:

Dry river with sand is a common feature in Barnadi WLS. Most of the river in Barnadi WLS is completely dry in winter season so river sand is an important habitat pattern in Barnadi WLS. The total area coverd by river sand is 0.96 sq. km which 3.66% of the total geographical area of the sanctuary. The main rivers passing through the sanctuary are Deochunga River and Garo Nala River.

10 PREPARATION OF SPATIAL DECISION SUPPORT SYSTEM

10.1 What is spatial decision support system (SDSS) :

Spatial decision support system for natural resource management are 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 DSS. 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 (Ravan 2002).

The concept of computer based spatial decision support system (SDSS) is shown in the figure 21.

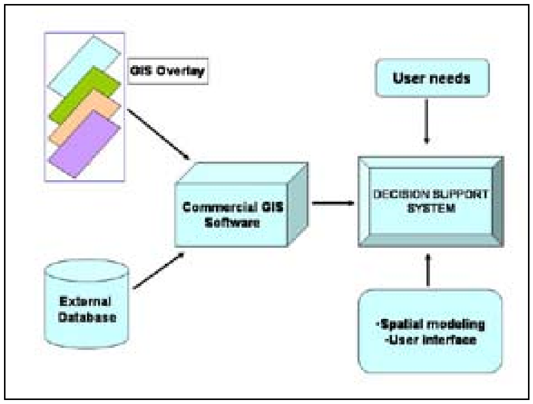


Fig. 22 – Concept of computer based spatial decision support system

10.1.1 Components of spatial DSS:

There are two most important components of DSS, these are

a) Spatial database
b) Software engine

a) Spatial database:

This is the most crucial and specialized component. Satellite remote sensing is the major spatial data provider in real or near real time. Remote sensing data can be interpreted in many ways and provides tots of information for biodiversity conservation. Information that can be directly interpreted from images includes forest cover mapping, forest type mapping, crown density mapping, ecosystems mapping etc. Digital nature of satellite data allows providing information on quantitative aspects of forests such as estimation of biomass, productivity, leaf area index,etc. However, DSS needs much more spatial information such as locations of important species, hotspots, habitats, administrative boundaries, management zones, etc. Huge amount of non-spatial information (such as taxonomic detail) goes in as attribute parameters.

b) The software engine:

This is another important component of SDSS. The most efficient way of preparing SDSS is to customize commercial GIS software. These software provides ready tools for display spatial information, it also offer ready algorithms for often required spatial analysis and modeling.

These are the major components of spatial decision support system (SDSS).

10.2 Spatial decision support system of Barnadi wildlife sanctuary:

An attempt has been made to prepare a complete GIS based spatial decision support system for Barnadi WLS of Assam for conservation of biological diversity in the sanctuary. The main two components of SDSS were extensive used to prepare the SDSS. 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. The primary and secondary spatial data collection and their processing were already discussed in chapter II. Here we will discuss on SDSS of Barnadi WLS.

Spatial Database of Barnadi WLS:

A spatial database of Barnadi WLS was generated from the multiple sources of information. The source of this database includes remote sensing satellite images, survey of India topographical sheets, GPS points, and ground data collection. Besides this land use and habitat pattern of the sanctuary, habitat modeling, risk zone identification, current conservation status, etc. information were also fed in to GIS to prepare the SDSS of Barnadi WLS. Figures 22, 23 and 24 shows the different spatial layers prepared using GIS and their related spatial database for decision making.

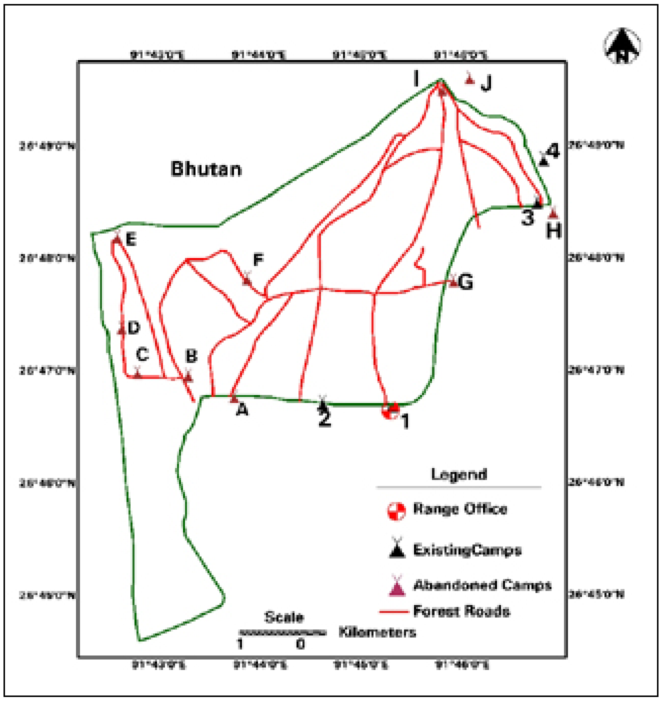


Fig. 23 Spatial database of camps and roads

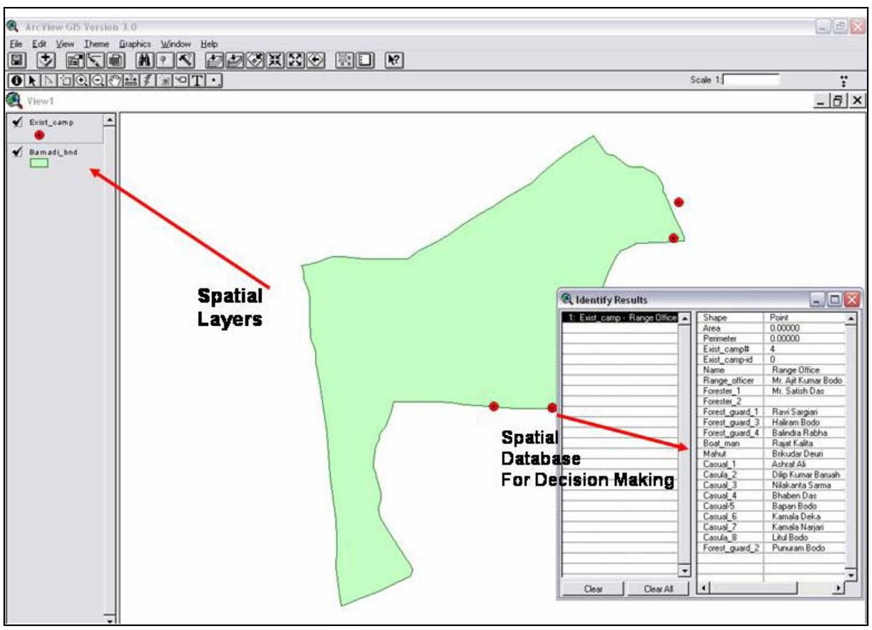


Fig. 24 – Spatial Decision Support System of Barnadi WLS – Staff names and designation in different camps

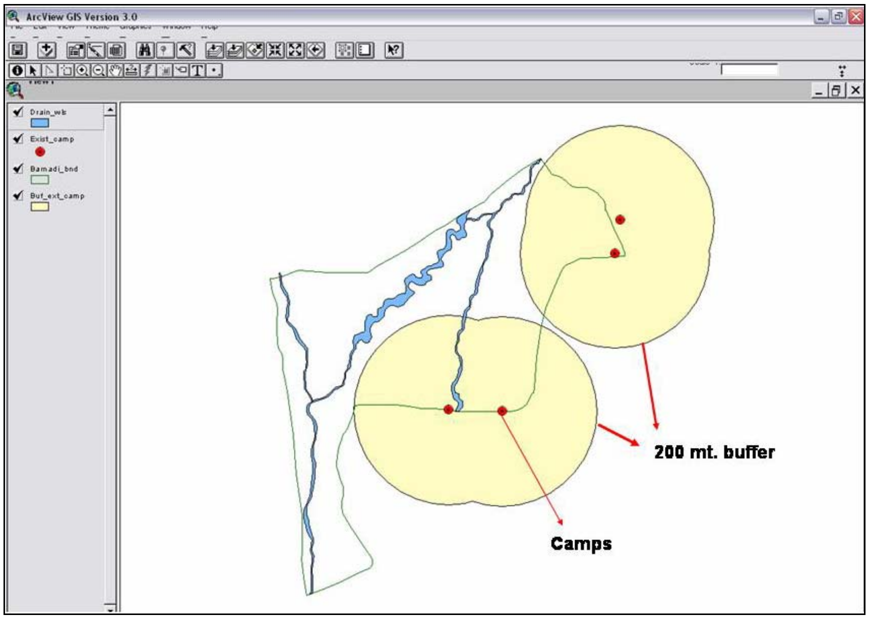


Fig. 25 – Spatial Decision Support System of Barnadi WLS

Camp buffer and good patrolling areas

Software engine used for SDSS of Barnadi WLS:

The commercial softwares that were used to prepare the SDSS of Barnadi WLS were the ERDAS Imagine 9.0, Arc Info 7.2.1 and Arc View GIS 3.0. The ERDAS Imagine software was used to do the satellite image processing and preparation of habitat maps, vegetation maps, etc. The Arc Info 7.2.1 was used to prepare the GIS layers such boundary of WLS, location of camps, water bodies, road networks, etc. The Arc View GIS 3.0 was used for presentation purpose and to view the different spatial information and their attributes in computer scene.

Fig. 26 ERDAS Imagine 9.0 software

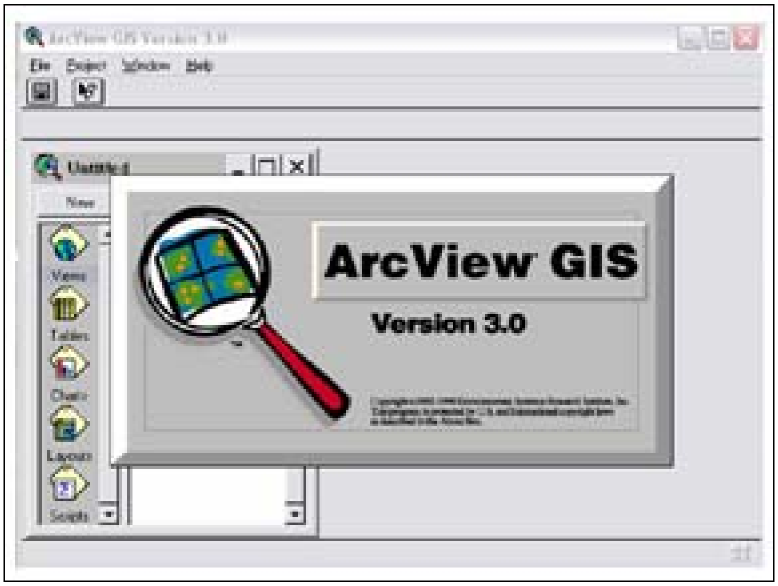


Fig. 27- Arc View GIS 3.0 software

The different models that were discussed above were run in Arc Info 7.2.1 and the map composition of each model was done in ERDAS Imagine 9.0 software.

The SDSS of Barnadi WLS was electronically saved in an Acer computer with Pentium IV processor, 1 GB RAM and 135 GB hard disk. This SDSS of Barnadi WLS is available in Aaranyak GIS laboratory and this will make available to public domain very soon through Aaranyak's web site i.e. www.aaranyak.org.

11 LAND USE / LAND COVER CHANGE DETECTION

11.1Classification of Landsat MSS data of 1977:

The Landsat MSS satellite image of 1977 was downloaded from the internet (www.glcf.org) and the image was geometrically and rediometrically corrected using ERDAS Imagine 9.0 version software. The Barnadi WLS boundary was superimposed over the image and a subset was done for the sanctuary area. The 60 mt. pixel size image was resampled to 23.5 mt pixel size and sub pixel accuracy was achieved in geometric correction. The reference image for geometric correction was survey of India topographical sheets. A supervised classification approach using maximum likelihood parametric rules was used to get the six major land use / land cover classes of Barnadi WLS. These land use classes were verified in the ground to see the changing pattern of land use / land cover in Barnadi WLS. Necessary rectifications were made after ground verification and final land use / land cover database of 1977 was prepared for Barnadi WLS. The following table 3 shows the land use / land cover status of Barnadi WLS in 1977.

Table 3 – Land use / Land cover of 1977

Land Use/ Land Cover	Area in Sq. km
Woodland	10.46
High Density Grassla	6.39
Degraded Forest	2.71
Low Density Grass	3.57
River Sand	0.85
Scrub Forest	2.24
Total Area of Sanctuary	26.22

11.2 Classification of Landsat TM data of 1990:

The Landsat TM satellite image of 1990 was downloaded from the internet (www.glcf.org) and the image was geometrically and radiometrically corrected using ERDAS Imagine 9.0 version software. The Barnadi WLS boundary was superimposed over the image and a subset was done for the sanctuary area. The 30 mt. pixel size image was resampled to 23.5 mt pixel size and sub pixel accuracy was achieved in geometric correction. An image to mage geometric correction approach was adopted, the reference image was Landsat MSS image of 1977. A supervised classification approach using maximum likelihood parametric rules was used to get the six major land use / land cover classes of Barnadi WLS. These land use classes were verified in the ground to see the changing pattern of land use / land cover in Barnadi WLS. Necessary rectifications were made after ground verification and final land use / land cover database of 1990 was prepared for Barnadi WLS. The following table 4 shows the land use / land cover status of Barnadi WLS in 1990.

Table 4 Land use / Land cover of 1990

Land Use/ Land Cover	Area in Sq. km
Woodland	**13.91**
High Density Grassla	**3.12**
Degraded Forest	**3.98**
Low Density Grass	**2.58**
River Sand	**1.19**
Scrub Forest	**1.44**
Total Area of Sanctuary	**26.22**

11.3 Classification of IRS 1 D LISS III data of 2002:

The IRS 1D LISS III satellite image of 2002 was procured from the National Remote Sensing Agency, Hyderabad and the image was geometrically and rediometrically corrected using ERDAS Imagine 9.0 version software. The Barnadi WLS boundary was superimposed over the image and a subset was done for the sanctuary area. A sub pixel accuracy was achieved in geometric correction. An image to mage geometric correction approach was adopted, the reference image was Landsat TM image of 1990. A supervised classification approach using maximum likelihood parametric rules was used to get the six major land use / land cover classes of Barnadi WLS. These land use classes were verified in the ground to see the changing pattern of land use / land cover in Barnadi WLS. Necessary rectifications were made after ground verification and final land use / land cover database of 2002 was prepared for Barnadi WLS. The following table 5 shows the land use / land cover status of Barnadi WLS in 2002.

Table 5. Land use / Land cover of 2002

Land Use/ Land Cover	Area in Sq. km
Woodland	13.23
High Density Grassla	4.26
Degraded Forest	4.01
Low Density Grass	1.03
River Sand	0.43
Scrub Forest	3.26
Total Area of Sanctuary	26.22

11.4 Classification of IRS 1D LISS III data of 2006:

The IRS P6 LISS III satellite image of 2006 was procured from the National Remote Sensing Agency, Hyderabad and the image was geometrically and rediometrically corrected using ERDAS Imagine 9.0 version software. The Barnadi WLS boundary was superimposed over the image and a subset was done for the sanctuary area. A sub pixel accuracy was achieved in geometric correction. An image to mage geometric correction approach was adopted, the reference image was IRS 1D LISS III image of 2002. A supervised classification approach using maximum likelihood parametric rules was used to get the six major land use / land cover classes of Barnadi WLS. These land use classes were verified in the ground to see the changing pattern of land use / land cover in Barnadi WLS. Necessary rectifications were made after ground verification and final land use / land cover database of 2006 was prepared for Barnadi WLS. The following table 6 shows the land use / land cover status of Barnadi WLS in 2006.

Table 6 Land use / Land cover of 2006

Land Use/ Land Cover	Area in Sq. km
Woodland	11.95
High Density Grassla	7.27
Degraded Forest	4.01
Low Density Grass	0.5
River Sand	0.96
Scrub Forest	1.53
Total Area of Sanctuary	26.22

11.5 Land use / land cover change detection analysis:

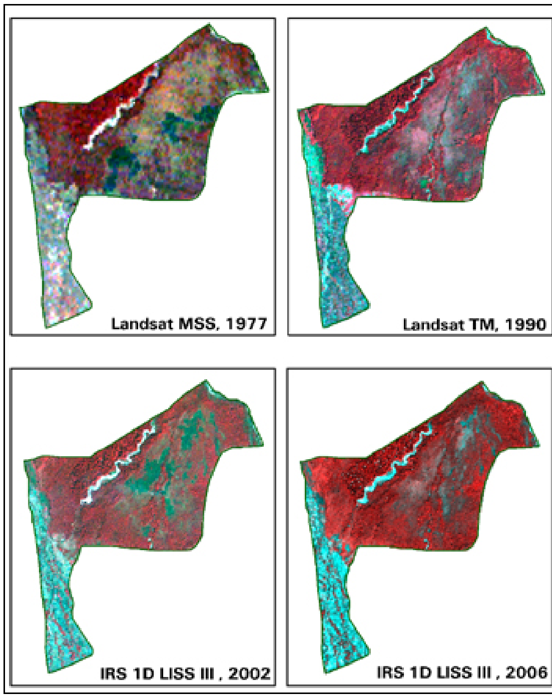
It was already mentioned in the satellite image processing sub-chapter (6.2), the method of change detection applied here in this study was the post classification comparison. This method consist in overlaying, using a cross operation, the two images to be compared, previously classified. The cross operation allows the analyst to know the extent and nature of the changes observed; in other word, the transition between different land use / land cover classes and the corresponding areas of change.

Applying this method finally the land use / land cover change analysis of Barnadi WLS was done. The images of 1977, 1990, 2002 and 2004 were used to do the change analysis. The table 3 shows the changes in land use / land cover in Barnadi WLS.

Table 7 Land use / land cover change in Barnadi WLS from 1977 to 2006

Land Use Classes	Years				Net change		
	1977	1990	2002	2006	1977 to 1990	1990 to 2002	2002 to 2006
Woodland	10.46	13.91	13.23	11.95	3.45	-0.68	-1.28
High Density Grassla	6.39	3.12	4.26	7.27	-3.27	1.14	3.01
Degraded Forest	2.71	3.98	4.01	4.01	1.27	0.03	0
Low Density Grass	3.57	2.58	1.03	0.5	-0.99	-1.55	-0.53
River Sand	0.85	1.19	0.43	0.96	0.34	-0.76	0.53
Scrub Forest	2.24	1.44	3.26	1.53	-0.8	1.82	-1.73

From the above table we find that the woodland of the sanctuary increased from 10.46 sq.km in the year 1977 to 13.91 sq.km. in the year 2002, but there was substantial decrease of woodland from 13.91 sq.km. in year 2002 to 11.95 sq.km. in the year 2006. The main reason we found in the field was the extensive illegal activities of tree felling that was occurred in the 2002 and it was continued till 2003 last. Similarly high density grassland was increased from 6.39sq. km in the year 1977 to 7.27sq. km in the year 2006. This indicates the natural succession rate as well as improper management of grassland. The low density grassland decreased from 3.57sq. km in the year 1977 to 0.50sq. km in the year 2006. This indicates that the low density grassland areas are gradually converting to high density grassland. Similarly in case of river sand there was a increase from 0.85sq. km in the year 1977 to 1.19sq. km in the year 1990 and again it decreased to 0.96 in the year 2006. This change in river sand is mainly due to the erosion and deposition process of the rivers. The carrying capacity of the river suddenly decrease in the bhabar belt due to the low water holding capacity of the soil so the amount of sediment carries by a river, deposited extensively in the river bed. Similarly the erosion done by a river in the upstream depends upon the run off which the river received from its catchments and it varies from year to year depending upon rainfall and snowmelt. Therefore, the river sand is always dynamic in nature. From the change analysis it was found the scrub forest of Barnadi WLS is also decreased from 2.24sq. km in the year 1977 to 1.53 sq. km. in the year 2006. The figure 26 and 27 shows the change of land use / land cover in Barnadi WLS.



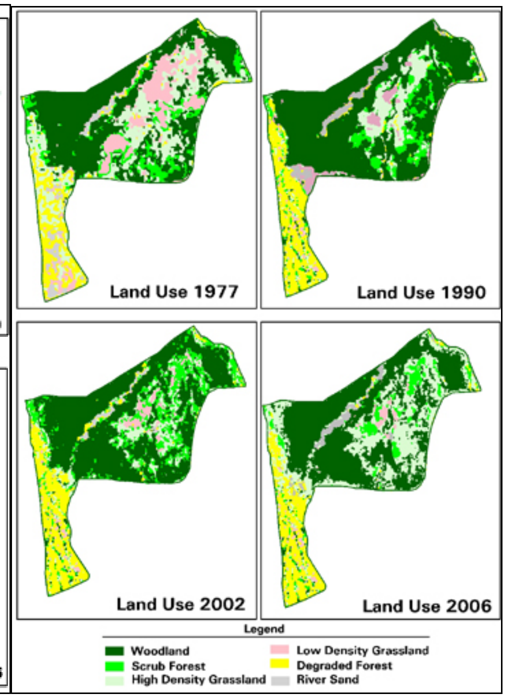


Fig. 28 – Satellite images of Barnadi WLS **Fig. 29 – Classified maps of Barnadi WLS**

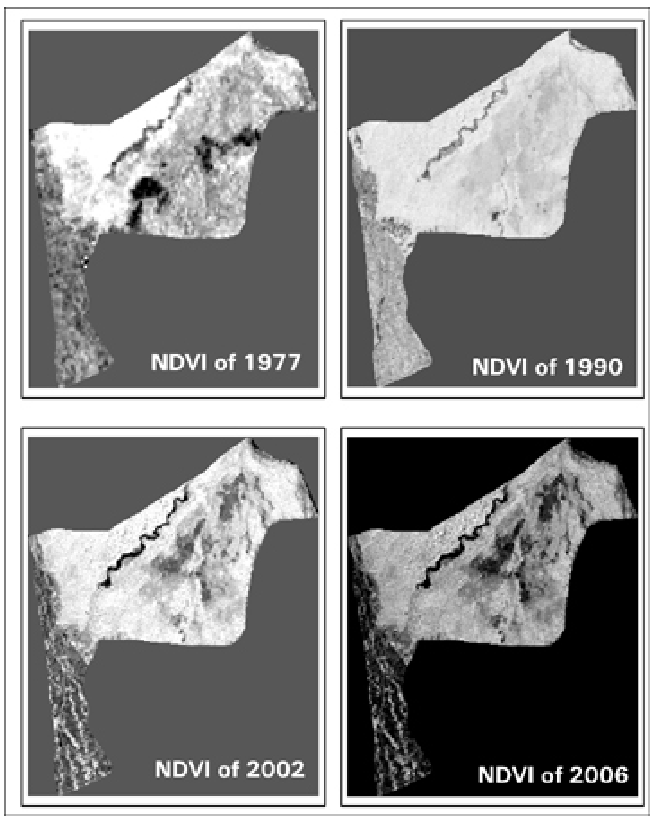


Fig. 30 – NDVI maps of Barnadi WLS

NDVI Analysis:

NDVI means **Normalized Difference Vegetation Index**. The main purpose of NDVI analysis is to see the status of vegetation cover. The algorithm to get the NDVI values from a FCC is **band 4 (near infrared band) – band 3 (red band) / band 4 (near infrared band) + band 3 (red band)**. The value of NDVI ranges in between 0 to 1. The 0 value indicates low vegetation cover and also low vegetation growth and in the other hand 1 indicates excellent vegetation cover and growth. The final out put of NDVI image come in black and white color and complete black indicates no vegetation cover and the complete white indicates excellent vegetation cover. Here in this study NDVI analysis was done to see the forest cover change in Barnadi WLS. The output of the analysis is shown in the figure 28.

CHAPTER IV

12 LIMITATIONS OF THE RESEARCH:

Every research has its own set of limitations, and this is particularly true for a research conducted within a short period of time. Whatever their nature, it is very important to be aware of and have into account those limitations, in order to better evaluation and discuss the results of the research. The most relevant limitations encountered during this study are described in the following paragraphs.

One group of limitations that should be referred is related with the primary data collection during the fieldwork: the dimension of the study area, the accessibility within the same area and the time available for data collection.

The result of the primary data collection, both in terms of number of samples and location, was strongly influenced by these limiting factors. Still in relation to the primary data collection it should be noted that the quality of vegetation survey, in particular the consistency of the cover estimation (of different layers or species), is highly dependent on the skill and experience of the people involved. In this case the survey was made of four persons which had very little knowledge on vegetation types at species level.

The duration of the secondary data collection was also very limited, and the possibility of getting more information about the vegetation cover existent in the area, in the past, was not sufficiently explored.

13 CONCLUSIONS:

As a result of the work developed in this report, it was concluded that geospatial technology has immense potentiality to work in biodiversity conservation in North East India in general and Assam in particular. Spatial decision support system, developed using geospatial technology helps not only in planning process of the conservation of biological diversity but also helps the protected area managers to protect the biodiversity rich areas in scientific manner. This project is a model for the entire biodiversity rich areas of Assam and other states of North East India. Here in this study all the objectives were successfully achieved using multi source data, GIS and extensive filed survey.

14 RCOMMENDATIONS

Since the problem that motivated the current research is not directly related to any specific environmental or social problem, the recommendations presented in this chapter refer essentially to what can be done in terms of future research, in line with the work developed in this report. The result of this study suggests replication of similar works in other protected ecosystems in North East India to develop such kind of decision support system that would tremendously help achieve biodiversity conservation goal in a scientific manner.

15 PHOTO SESSION

Photo 1- High density grassland

Photo 2 – Low density grassland surrounded by woodland

Photo 3- River sand, low density grassland and woodland

Photo 4- Field assistant with forest department staff

Photo 5 – Ground verification using satellite image

Photo 6- Observing a hog nest.

Photo 7- Habitat mapping

Photo 8 – Tiger scat and pugmark collected from the filed

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