

DEVELOPMENT OF BIODIVERSITY INFORMATION SYSTEM FOR NORTH EAST INDIA USING INTERNET GIS

P. S. Roy, Sameer Saran, Suddhasheel Ghosh, Nupoor Prasad, Harish Karnatak and Gautam Talukdar
 Indian Institute of Remote Sensing, 4, Kalidas Road, Dehradun (Uttanchal), INDIA
 dean@iirs.gov.in

Commission IV, WG IV/4

KEYWORDS: Biodiversity Information System, Internet GIS, Landscape Ecology, Conservation planning

ABSTRACT

Conservation of Biological Diversity will be major challenge for the ecologist in the forthcoming century. In-situ conservation, biotechnology tools for conservation and prospecting, understanding genetic variability, species habitat relationship and allowing evolutionary process of speciation are some of the challenges. India is one of the mega biodiversity centers and is also known for its traditional knowledge of conservation. The varied regions of the country, with unique floristic and faunal richness, their vastness, endemism, heterogeneity and also inaccessibility of large areas have necessitated creation of authentic baseline data on biodiversity. This information system is essential to monitor, analyze and plan action oriented programs for conserving and preserving our biological wealth. North Eastern India is one of the three mega diversity hotspots in the country. The region is referred as a cradle of flowering plants as it lies in the region of conjunction of biogeographical zones of India viz. Indo-China, Indo-Malayan and Gondwana land masses. The spatial characterization of landscape structures and its linkage with attribute information on the floristic composition, economic valuation, endemism has been developed in the form of Biodiversity Information System (BIS) on sharable environment. The BIS is integration of large databases using a concept of Internet based Geographical Information System commonly known as Internet GIS. The development of BIS involves the basic framework of concept, selection, and aggregation of fundamental and processed data. The information generated as a part of project entitled "Biodiversity Characterization at Landscape Level using Remote Sensing and Geographic Information System" of the Department of Biotechnology and the Department of Space, Government of India has information on vegetation type/ land use, disturbance regimes, biological richness, ancillary information from different sources and non spatial attribute database on plant species (field sample and flora). The database has been organized under the sharable framework with metadata, quality evaluation procedures and their standardization. The different database structure created on different formats/platforms comes as an input to the information system for standardization that is they are converted into the same format. The non-spatial species database is converted into a relational database structure and the geospatial data is converted to a uniform spatial projection. The conversion of data from the various available formats also constituted reverse engineering of the databases using Visual Basic, Oracle and the database format software and Open Data Base Connectivity (ODBC). The web enabling part comes through uploading the entire spatial and the non-spatial data at a common platform using the concept of Internet GIS. We use ArcSDE, ArcInfo, Oracle at the backend, ArcIMS as the Internet Map Server and Microsoft Internet Information Server 4.0 as the web server.

1. INTRODUCTION

Since the late nineties the world has been experiencing a great boom in information dissemination and communication technologies. This recent boom in the technological capabilities has enabled humankind to bring education and information right at its doorstep. In a scenario where ecological imbalance is at its heights and forest covers are depleting at an exponential rate day by day, important studies to conserve such resources should not remain restricted only to paper maps and higher authorities. In order to implement suggested strategies under a study it is very important to use the current information and communication technologies to its best. It is therefore felt that the results of such studies should be projected onto the Internet wherein monitoring of such resources and respective conservation issues be handled.

Acquisition of images of earth from space has opened new frontiers in mapping. The multispectral satellite images provide definitions of vegetation patches, which are related to phonological types, gregarious formations and communities occurring in unique environmental setup. The temporal images help in monitoring all back processes a landscape has experienced (Delcourt and Delcourt, 1988). The images also provide digital mosaic of spatial landcover and vegetation types amenable to computer processing

(Coulson *et al.* 1990 and Chuvieco, 1999). Biophysical spectral modeling techniques allow to stratify vegetation types based on the canopy closure (Roy *et al.* 1996). Such an approach allows mapping and monitoring the forest condition and degradation processes.

2. WHY A BIODIVERSITY INFORMATION SYSTEM?

Biological diversity is a part of our daily life and livelihood for it constitutes resources upon which humanity depends. From time immemorial man and animal have been using this diversity in harmony for their sustenance, but this harmony is getting disturbed owing to natural as well as human action of late. This leads to loss or extinction of plants and animals. This again may be either due to the inability of the species to evolve and adapt to the newer conditions or falling prey to the human greed. Sustainable management of natural resources has become a key issue for survival of planet earth. This is an urgent need to conserve gene pool *in situ* before it is lost forever because a large percentage of biological wealth and its importance is still unknown to us.

The north east India – a bowl of plant diversity is a part of the biodiversity *hot spot* in Eastern Himalayas. The latter is the meeting point of temperate east Himalayan flora, palaeo – arctic of Tibetan high land and wet evergreen flora of south-east Asia and Yunan. The region is well known for

its unique flora and fauna, high endemism and rare plants. At the same time, the region is experiencing alarming rate of deforestation and degradation, causing threat to the world's well known *hot spot*. Conservation of bioresources has become essential in view of the loss of species, both flora and fauna. There has been loss biodiversity due to shrinkage and/or loss of habitats and fragmentation of forests.

The goals and scales of inventorying and monitoring programmes may change with time. Hence the baseline data at landscape level should be sufficiently robust to accommodate changes. It should be based on robust samples enabling calibration for future Rapid Biodiversity Assessment. Landscapes contain all levels of the biological hierarchy, from ecosystem to species and genes that are targeted from diversity inventories and conservation. The project titled 'Biodiversity Characterization at Landscape Level using satellite remote sensing and GIS' first of its kind at national level. Though attempts have been to identify the gaps in biodiversity management, this is the first attempt to quantify species richness, biodiversity valuation and phytosociological analysis and use these themes to characterize biodiversity in conjunction with other ecological parameters. In this project methodology has been developed to analyze and prioritize the different ecosystems for conservation by using the existing knowledge and assessing the disturbance impacts/regimes by way of investigating and inventorying biological richness of the areas. Once biologically rich sites/areas are identified then detailed study can be taken up for possible potential areas for bioprospecting. The present effort to characterize vegetation cover, fragmentation, disturbance and biological richness across the landscape is organized in the form of Biodiversity Information System. The field samples of key ecological characters have been used for geospatial extrapolation. The

project are to identify the bio-rich areas, to evaluate the forest types for their value, to provide locational information of the economically important species for bioprospecting. The outcome of this project will assist the forest managers, decision makers and the national lead institutes involved in the genetic diversity and bioprospecting.

This multi institutional project is being participated by various lead organizations like Botanical Survey of India, Forest Survey of India, Wildlife Institute of India, G. B. Pant Institute of Himalayan Environment and Development, French Institute, Pondicherry and various specialized remote sensing centers in Department of Space.

In this paper we present an approach to organize spatial and non spatial data into a Biodiversity Information System (BIS) for the north east India in web-enabled environment. The spatial information on biodiversity character of landscape have been developed using multicriteria analysis in GIS and facilitates the following:

- Rapid Assessment of monitoring biodiversity loss and/or gain;
- Assess nature of habitat and disturbance regimes;
- Evolve species—habitat relationship;
- Mapping biological richness and gap analysis; and
- Prioritizing conservation and bioprospecting sites

3. ARCHITECTURE OF THE WEB ENABLED BIODIVERSITY INFORMATION SYSTEM

As given in the diagram, the following software components exist in the Web Enabled Biodiversity Information System.

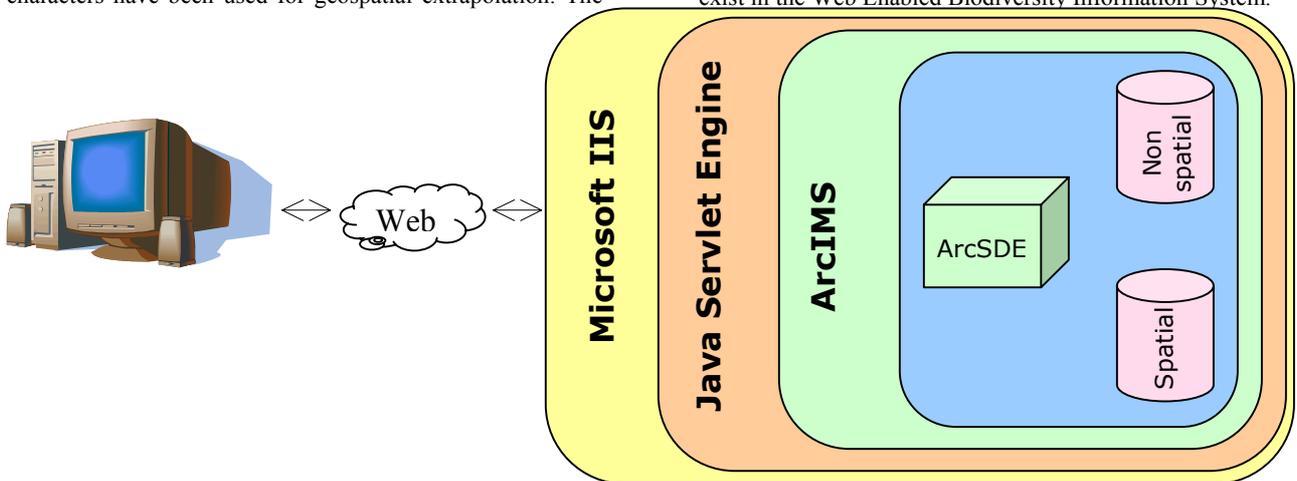


Fig 1: Architecture of the Biodiversity Information System

species data base has been linked with above spatial details. The Biodiversity Information System allows the user to identify gap areas, species/habitat relationship and helps in biodiversity conservation planning by setting priority areas. Such database coupled with detailed site specific field inventories helps in identifying areas for bioprospecting.

The Department of Biotechnology (DBT) and Department of Space (DOS) have joined hands to undertake study on biodiversity characterization. The main objectives of this

3.1 Operating System

Operating system is the basic requirement for any system to function. In our case we chose for the Microsoft Windows NT Server 4.0 as a standard server.

3.2 Web Server

In order to serve pages to the net a basic requirement is a web server. As we opted for a Microsoft designed operating

system, we also chose to use Microsoft's Internet Information Server 4.0

3.3 Java Servlet Engine

We planned to display dynamic and interactive maps through the software ArcIMS. It is a prerequisite for ArcIMS that a Java Servlet Engine be installed on the system in addition to a web server. As per ESRI's recommendations, we installed New Atlanta ServletExec ISAPI 4.1 as the Java Servlet Engine.

3.4 Internet GIS Software

In order to display interactive maps through the net, we require a map server. We chose to use ESRI's Arc Internet Map Server (ArcIMS). As mentioned earlier, ArcIMS runs on a Java Servlet Engine and the web server.

3.5 GIS Software

ArcGIS 8.1 was installed on the server so as to import the entire spatial database generated.

3.6 Spatial Database Engine

All the imported maps were now to be directed to ArcIMS for which the Arc Spatial Database Engine 8.2 was required. The Arc Spatial Database Engine (ArcSDE) support various RDBMS platforms like DB2, SQL Server, Oracle 8, Oracle 9i etc. It is to be noted that the previous version of ArcSDE that is ArcSDE 8.1 did not have support for Oracle 9i and ESRI released the new version with support for Oracle 9i on May 9, 2002.

3.7 Non spatial database engine

The entire non-spatial database which consisted of data of sample points, species database, tables regarding the economic, medicinal and ecological importance. In addition to these, tables containing ecological parameters like Shannon Weiner indices, Similarity indices etc were also added.

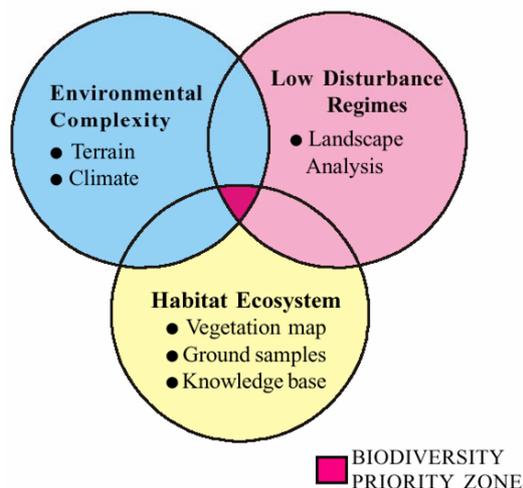
The web server hardware taken was a high end server. In addition to this a 256 kbps leased line Internet connectivity was taken from Videsh Sanchar Nigam Limited (VSNL). Leased line connectivity is required to handle the high Internet traffic and to quickly serve pages and results to the net.

4. Data

The data which comes as an input to this information system is the result of all the work which had been carried out at Phase I of the DOS-DBT project (Anonymous, 2002). The mapping task has been done by Indian Institute of Remote Sensing (Arunachal, Assam and Meghalaya), Regional Remote Sensing Service Centre, Dehradun (Mizoram and

Tripura) and Regional Remote Sensing Service Centre, Kharagpur (Manipur, Nagaland and Sikkim).

Thematic spatial data are generated using satellite remote sensing data through digital classification. In addition to that spatial and non-spatial data from other ancillary data sources is collected. Database is created/generated in a GIS domain and analysed. Finally biological richness has been assessed using ground based data on ecosystem uniqueness, species richness, biodiversity value, terrain complexity, diversity index etc. (Roy and Tomar, 2000)



4.1 Field Data Collection

Stratified random sampling method has been used to do the sampling in all the vegetation types. For trees 20m x 20m / 32 m x 32 m, for shrubs 5m x 5m or one 10m x 10m and for herbs 1m x 1m sample plots were laid. In all more than 1750 sample plots have been laid in various types of vegetation. For shrubs and herbs nested sampling approach was followed. Geographical position of these points has been recorded. All the plant species and life forms occurring in the plot were enumerated. For test areas classification accuracy has been tested and over all it is more than 85%.

4.2 Vegetation Map

The North Eastern region is very rich and varied and fosters vegetation from tropical forests in Assam to Alpine in Arunachal Pradesh and Sikkim. About 45 land cover and land use classes have been delineated using satellite data. And for the sake of uniformity Level II vegetation classification was attempted. The task of classification has been accomplished by doing reconnaissance survey and collecting ground truth using False Color Composite (FCC) on 1:250,000 in combination with 1:50,000 scale where ever required.

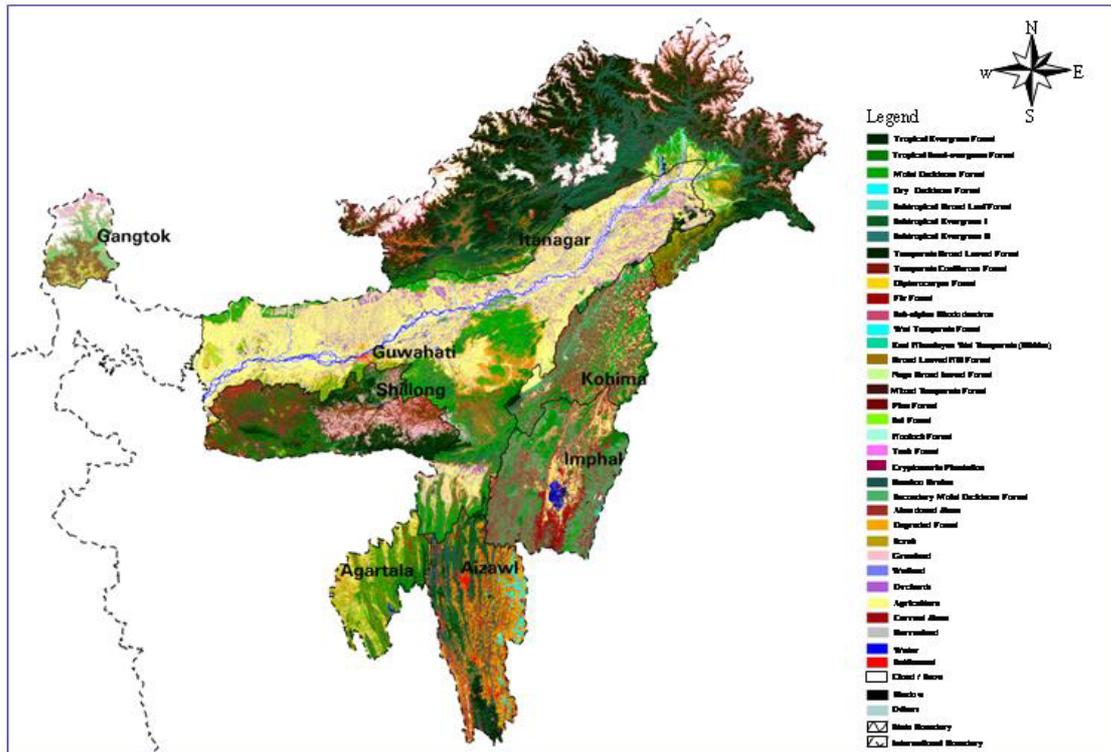


Fig 2: Vegetation Type Map of North East India

4.3 Fragmentation Map

Fragmentation is the number of patches of forest and non – forest type per unit area. The forest type map was reclassified into two patches, viz. forest and non-forest resulting in a new spatial data layer. This layer was convolved with a grid cell of $n \times n$ (e.g. $n = 500m$) with a criterion of deriving the number of forest patches within the grid cell. An output layer is derived. To this a look up table is generated which keeps the normalized data of the patches per cell in the range of 0 to 10.

4.4 Disturbance Regimes

In nature various factors affect the richness of biodiversity. Topographic variations, micro-climatic conditions, biotic factors and land itself control the distribution of plant communities. Thus coexistence of plants or animals is the result of interactions. Studies have revealed that there exists a relationship among various communities forming patches and the occurrence of species. Discontinuities in the vegetation as a whole and forests in particular are the result of such disturbances and can be explained through patch characterization. Various landscape ecological parameters like fragmentation, porosity (number of patches in primary vegetation types per unit area), patchiness (number of patches of all vegetation types per unit area), interspersion (intermixing of the vegetation types) and juxtaposition (adjacency of vegetation types) and the disturbances from the road and settlements etc have been used for characterizing the disturbance. Since biotic pressure is most significant and influences the population and diversity, disturbance regimes have been established for the entire north eastern region.

The Disturbance Index Map is computed as a linear combination of the defined parameters on the basis of probabilistic weightages. The final spatial data is rescaled to a range of (0-100) for final preparation.

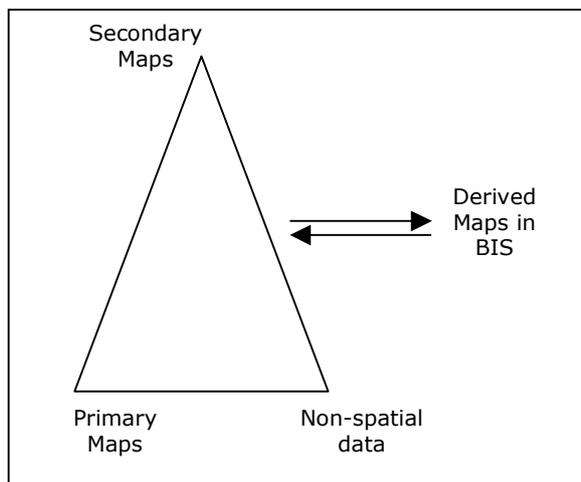
4.5 Biological Richness Estimation

North eastern region is endowed with high floristic richness and has been rightly called as the ‘cradle of flowering plants’. The region has 4 micro – endemic centres out of the 26 such centres in India. More than 5000 plant species have been reported from this region. The region is also famous for orchids and ferns. About 500 species of orchids occurring in wide variety of conditions are reported from here. The region has about 132 wild relatives of crop plants out of the 686 reported from Indian sub continent. This is important for genetic engineering and bioprospecting. This information has been incorporated while characterizing the biodiversity from the field observations. More than 1750 sample plots were laid and analysed to determine the total number of species, endemic species, economic species (more than 2000) has been reported from Arunachal Pradesh. Occurrence, frequency and abundance of the species is governed by the climatic and biotic factors.

The biological richness at landscape level is determined as function of ecosystem uniqueness, species diversity, biodiversity value, and terrain complexity and disturbance index. The main parameters like ecosystem uniqueness, species richness, Biological values *etc.* come from ground based observation. Various vegetation types available in the terrain are evaluated. It is also dependent on localized information. The final integration of landscape parameters, disturbance regimes, habitat & their attributes and terrain complexity was made. The output BR spatial layer is scaled to (0 - 100) for final presentation.

The additional data sets which were used directly or indirectly were the following:

- Digital elevation models
- Digital Chart of world (DCW) for village location, road network, drainage information
- Survey of India topo-sheets on 1:250,000 and 1:50,000 scales
- Biogeographical digital maps available from Wildlife Institute of India, Dehradun (Rodgers and Panwar, 1988)
- Climatic maps of NATMO on 1:1 million and agroclimatic maps for entire country available with National Bureau of Soil and Landuse Survey, Nagpur, India
- Socio economic data of national census 1991
- Protected Area Network map available with the Wildlife Institute of India, Dehradun, India
- Forest Vegetation Maps 1:250,000 scale available with Forest survey of India
- Administrative boundaries available from Survey of India, Dehradun, India



In addition to these databases, the result of the extensive field sampling has resulted in the generation of a huge species database, which can be used as a tool to measure and monitor the biodiversity of the area.

Another species database from the Bioprospecting and Molecular Taxonomy Programme of the Department of Biotechnology has also been used. Under the Bioprospecting and Molecular Taxonomy Programme (BPMT), some environmentally / medicinally / economically important plant species are being studied and a good amount of data has been generated. It was also planned to integrate this database with the species database of the North East India in order to correlate forest types, ecological parameters and molecular level studies.

5. METHODOLOGY

5.1 Uniformity of Data

Since the project is a collaborative one, the various results received from different institutions were obtained in different formats. When it was considered that the whole data be projected in a single platform, it was decided that the entire

data should be recast into a uniform format. We chose the projection given by Survey of India, Dehradun, India as a standard. We then registered all maps as per this norm.

The non-spatial data consists of a huge species database, which contains information regarding species, importance values, photographs, ecological parameters etc. A common format of the data was worked out using the field sampling form used in this project using the RDBMS concept.

The non-spatial data from the BPMT programme was organized in a format agreed upon jointly between the personnel of Department of Biotechnology and the Department of Space

5.2 Data Organization Plan

The spatial data and the non spatial data were then imported into ArcSDE, ArcIMS and Oracle 9i using various tools. As mentioned earlier, the structure of the non-spatial data was made according to an RDBMS concept. The data was entered into Oracle 9i using the methodo

5.3 Reverse Engineering of Data

The non-spatial data too was supplied in different formats by different collaborative agencies. A uniform format was worked out using the field data collection form. A program was made in Visual Basic using ODBC and all data was converted into SQL statements. These SQL statements were run directly into Oracle 9i's SQL* Plus mode and thus the data entry was done.

5.4 Metadata

Metadata information has been keyed using the ArcGIS 8.1 package. This information provides details regarding all the layers used in the Information System. The format for this data has been formulated using directives of National Spatial Data Infrastructures (NSDI)

5.5 Scripting Techniques

It was planned that access to the Biodiversity Information System should be through a user name and password. Further the users would have different levels of access to the maps. In order to handle such requirement coding through Active Server Pages (ASP) was done at server side and Javascript at client Side.

6. RESULTS

This is the first attempt in the north east region to generate baseline information on vegetation types, floristic composition of forest types and various other parameters like their value and uniqueness. In all 21 vegetation cover types have been identified and mapped using satellite data. A total of 45 land cover and land use classes have been mapped at 1:250,000 scale. Further information on the endemic, economic and ecologically important species in each of the forest types has been compiled.

Arunachal Pradesh still has original or virgin forests. Many areas like Namdapha Biosphere Reserve and adjacent areas in Chhanglang and Lohit districts, Mehao Wildlife Sanctuary, upper reaches of Debang Valley district

beyond Anini on the west etc. still are botanist's paradise. Well known tropical evergreen forests of *Dipterocarpus macrocarpus* have been mapped in Chhanglang and Lohit districts of Arunachal Pradesh and eastern districts of Assam (Tinsukhia, North Cachar Hill etc.). Similarly North District of Sikkim specially the Kanchanjunga Biosphere Reserve, Zemu and Lhonak valleys, areas around Djongri are repository of the excellent flora. Temperate forests of Sikkim are moist and humid and support unique plants of Sino-Tibetan are well known for the Rhododendrons, Primulas, Asters etc. Alpine vegetation of Sikkim is moist and humid and support unique plants of Sino-Tibetan region. In Arunachal Pradesh two prominent subtropical evergreen vegetation types with different species composition have been mapped. More than 1750 sample plots have been laid in all the vegetation types and field sampling has been conducted. Forest cover vegetation occupies about 37.04% in the region. It is estimated that about 7.65% of the landscape is under abandoned shifting cultivation. Open bamboo brakes 3.62%. The secondary forest developed as degraded forests formations with scattered trees occupy 5.79%. Results indicate that temperate broad leaf forest occupy the highest area which is followed by subtropical evergreen forest, moist deciduous, tropical semi-evergreen and tropical evergreen forests. Tropical evergreen forests of Barak valley dominated by *Dipterocarpus turbinatus* - *Palaquium polyanthum* are unique in the region and indicator of high rainfall. Large areas have Pine Forests, like *Pinus insularis* in Meghalaya and Nagaland, *Pinus merkusii* in Lohit District of Arunachal Pradesh and other species Pines in Sikkim and western Arunachal Pradesh.

Assam has largest area of man-made landscape and followed by Tripura. The land usually after one or two years of cropping and the process is repeated for another new forested site. The practice of jhumming is rampant in Karbiang long and the North Cachar hill of Assam. In addition to jhum large chunk of *Dipterocarpus* dominated area are being converted into open degraded forest resulting in the loss of rich biodiversity. It is observed that only 22.07% of the total forested area is intact and it indicates that only 7.39% of the forest is under high to medium richness. As discussed earlier the disturbance is caused by several factors. Mizoram has largest area under disturbance because of large scale shifting cultivation spread throughout the state and re-growth of bamboo. Meghalaya is one among most developed states in the region and its plateau been subjected to intensive shifting cultivation and higher settlements and road network resulting fragmentation of habitats. Khasi and Jaintea hills are highly disturbed. Nagaland also has very high disturbance, but for some areas towards Myanmar border and Assam border remaining areas fall under very high and high categories of disturbance. Tripura has large areas under disturbance. Arunachal Pradesh and Sikkim have less area under disturbance zone. Tirap district of Arunachal Pradesh has shifting cultivation and degraded forest represent low biodiversity.

Arunachal Pradesh tops the list among the high biorich area. The state still has intact and high biodiversity region from tropical to sub-alpine zone. Tropical evergreen forest of *Dipterocarpus* are unique ecosystems and grow in Chhanglang and Lohit districts. Sub-tropical forests Kameng, Subansiri, Siang etc. are very rich. The state has less population as compared to all other states in the region and therefore the upper reaches harbor excellent biodiversity. Sikkim has high biodiversity throughout and reason could be

the permanent terrace cultivation and protection given by the communities in the form of sacred groves. North district has varied climatic condition and is extremely valuable for bioprospecting as it has several medicinal plants. Garo hills and some areas of Jaintea hills of Meghalaya have high Biodiversity. North Cachar hills district of Assam has good forest cover and has high biorich area. Inner line reserve forest of Barak valley has some pockets of good primary forests of *Dipterocarpus turbinatus* - *Palaquium polyanthum*. States like Mizoram, Manipur, Nagaland and Tripura have less areas under high biorichness.

About 0.45 million families in this region annually cultivate 10,000 km² of forests whereas total area affected by Jhumming is believed to be 44,000 km². Anthropogenic factors are leading to the erosion in biodiversity and therefore there is need to study and protect before it is too late. Mapping is the first step for any resource planning and management and remote sensing technology has been providing special details about the vegetation or a landscape and provides answer to several questions asked by the resource management.

As is well known biodiversity is governed by several biotic, abiotic and climatic factors, therefore the need to understand their ecological relationships has been considered as most important for their *in situ* conservation. Relationship of biodiversity with that of fragmentation tested in Arunachal Pradesh indicates the increased fragmentation has resulted in smaller patches and edge effect which in turn has resulted in reduced biodiversity. Fragmentation was found inversely proportional to the biodiversity. Species richness analysis along with disturbance gradients indicates increase in Biodiversity as one moved away from the source of biotic pressures.

The study has resulted in characterization of biodiversity and formation of database for biodiversity conservation as well as for bioprospecting for all the eight states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Database in the form of layers of land cover and land use, fragmentation, disturbance and biorich areas has been generated as a part of Biodiversity Information System for better planning management and decision making. These biodiversity rich or biorich areas have categorized into very high, high, moderate and low richness areas.

The Biodiversity Information System has been developed for faster retrieval and visualization of the information. The following results were obtained as a result of integration of ArcIMS, ArcGIS and ArcSDE. The first picture is the homepage of the Biodiversity Information System which was generated using the ASP and Javascript coding techniques.

The Biodiversity Information System comprises of three sub-information systems:

- Bioprospecting and Molecular Taxonomy Programme (BPMT)
- Species Information System (SIS)
- Forest Resource Information System



Fig: Front Page Screens of Biodiversity Information System



Fig: 3. BPMT Non – spatial query Results

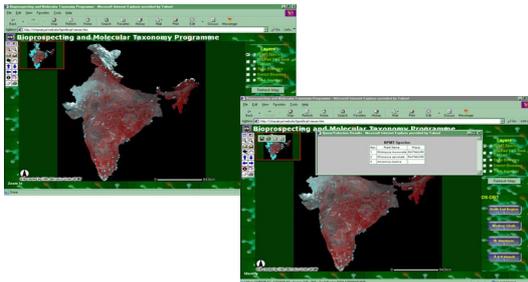


Fig 4. BPMT Spatial Query Shell using Internet



Fig 5. Displays of Vegetation, Fragmentation, Disturbance Regimes and Biological Richness Maps

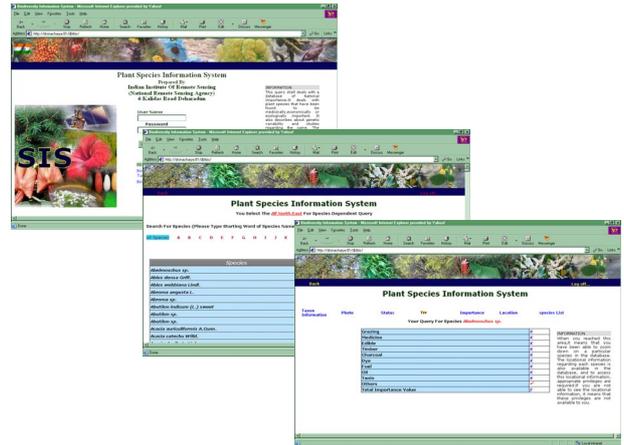


Fig 6: SIS – Display of species query shell

6.1 Using the Biodiversity Information System

It was decided that the access to the Biodiversity Information System be divided into three categories. The category of users will have access to all information and updation privileges. The second category of users will have right to browse all information on the site. Further this user will be able to see interactive maps. The interactive maps in the information system have various tools like zoom-in, zoom-out, query, info, pan etc. The user can interactively query and view more layers like state boundary, district boundary and taluk boundary. The third category of users will be able to access static maps through the web and will not be able to see or query dynamic maps.

7. DISCUSSION

Biologically Rich areas are those habitats where landscape ecological conditions are favourable for natural speciation and evolutionary process. These areas can be expected to be in equilibrium where species can occur, grow and evolve in natural conditions. Biological Richness Indices (BR) map asserts the areas, which should be treated on priority in decision making and management level for conservation of biodiversity. The 'Gap Analysis' carried out on these maps will guide management and decision making for bioprospecting.

All plant species have a basic requirement of its ecological optima in particular habitat or niche within range of tolerance and requirement. Habitat identification and economic importance of the species can be useful input for bioprospecting and biodiversity conservation. Each species requires a specific ecological niche (minimum/optimum area for its survival, evolution, gene exchange). Analysis of landscape parameters like, habitat fragmentation, patchiness, interspersions and juxtaposition have shown impact on the definition of the limits in different habitats. The greater the variety of types of habitat, the greater the diversity of the species. Diversity also increases with expanding architectural complexity of the physical habitat. Most of the species growing in the natural conditions have some sociological association with the species–environment complex and in general have fairly well defined niches. Similar ecological conditions in different geographical location bear similar biodiversity if not the same. But they will have differences at genetic level. The vegetation cover types, their composition,

association, latitude, altitude, fragmentation levels, inferences on possible corridors and species database complements the information needs.

Management of contagious (large), intact and juxtaposed patches of high diversity in any landscape should draw first attention for conservation. The ground inventories on species/ genetic diversity should further decide on priorities. The patches having higher biological diversity at landscape level will be subjected for more intensive ground inventories for assessing species/genetic diversity. The patches with genetic and species diversity should draw first attention followed by patches of high species or genetic diversity.

Bibliography

- Abbey M, Corey M and Abramson I, Oracle 9i, A beginner's guide, Oracle Press, USA, 2001
- Anonymous, Biodiversity Characterization at Landscape Level in North East India using Satellite Remote sensing and Geographic Information System, Project Report – Phase I, Indian Institute of Remote Sensing, Department of Space, Government of India, 2002
- Anonymous, Oracle Magazine, Oracle Press, USA, 2002
- Chuvieco, E. 1999. Measuring changes in landscape pattern from satellite images: short-term effects of fire on spatial diversity, *Int. J. of Remote Sensing*, 20(12): 2331-2346.
- Coulson, R.N., Lovelady, C.N., Flamm, R.O., Spradling, S.L. and Saunders, M.C. 1990. Intelligent geographic information systems for natural resource management. In: M.G. Turner and R.H. Gardner, (eds.), *Quantitative Methods in Landscape Ecology*, Ecological studies 82 New York: Springer-Verlag. pp 153-172.
- Delcourt, H.R. and Delcourt, P.A. 1988. Quaternary Landscape ecology: relevant scales in space and time. *Landscape Ecology* 2: 23-44.
- <http://www.asp101.com/articles/carvin/dataaccess/default.asp>
- <http://msdn.microsoft.com/library/default.asp?URL=/library/devprods/vs6/vbasic/vbcon98/vbstartpage.htm>
- <http://www.vb-bookmark.com>
- Rodgers W. A. and H. S. Panwar, 1988, Biogeographical classification of India, WII, Dehradun
- Roy, P. S. and S. Ravan, 1996, Biomass estimation using satellite remote sensing data – an investigation on possible approaches for natural forest, *Journal of Biosciences*, 21(4): 535-561.
- Roy, P. S. and Sanjay Tomar, 2000, Biodiversity characterization at landscape level using geospatial modeling technique, *Biological Conservation*, 95 (1): 95-109.
- Siler B and J. Spotts, Using Visual Basic 6: Special Edition, Que Publishing, USA
- Urman S., Oracle 9i PL/SQL Programming, Oracle Press, USA, 2001