3.5.5. Grassland Resources Assessment

Grasslands and savannas cover nearly one third of the earth surface, providing livelihoods for nearly 800 million people, along with forage for livestock, wildlife habitat, carbon and water storage. Conservation of grasslands/ savannas has become major concern due to their rapid degradation, in terms of reduction in productivity, invasion of weeds and land cover changes. In case of India, it is very critical that 80% of Indian grasslands/pasture are considered as very poor in their productive potential. As the milk production increased rapidly over the years (from 21 MT in 1968 to 78MT in 2001), the pastures on the other hand, has not increased, instead they were getting reduced or degraded. This has created a wide gap between the availability of fodder and demand for it, which in turn will have wide ranging consequences on the balance of the ecosystem.

Hence, it is very important to monitor and assess the state of grasslands and grazing resources. Considering the large area covered by the grasslands, (~2 Mha In India), it would be very difficult to assess them by ground-based methods. In this regard, Satellite Remote Sensing offers an effective tool to monitor and assess them periodically in time and cost effective manner. In view of this, a study had been undertaken for mapping (1:50,000 scale) of grasslands/ grazing resources using IRS LISS-III data for which 3 different bio-climatic regions namely, Western Himalayas (humid tropics), Gujarat (semi-arid) (Figure 3.11) and Tamil Nadu (tropical) were chosen.

3.5.6. Species level mapping as potential information as Bioresource

The economically and medicinally important species like Teak, Sal, Dipterocarpus (Plywood) and medicinally important species like Hippophae, which grows in large extents as single species dominated formations can be identified and mapped using remote sensing sensors like IRS LISS-III. Sal forests cover 9 Mha of Indian forests and serve as bioresource in terms of wood, fodder, NTFPs etc. and are almost mapped for the entire part of the country. The spatial information on the distribution of these species could be used as source to prepare scientific assessments on quantification, extraction and conservation systems. In addition, high resolution satellite data like IRS-LISS-IV and Cartosat could be used to map assemblage of species which can give the relative abundance of a species.

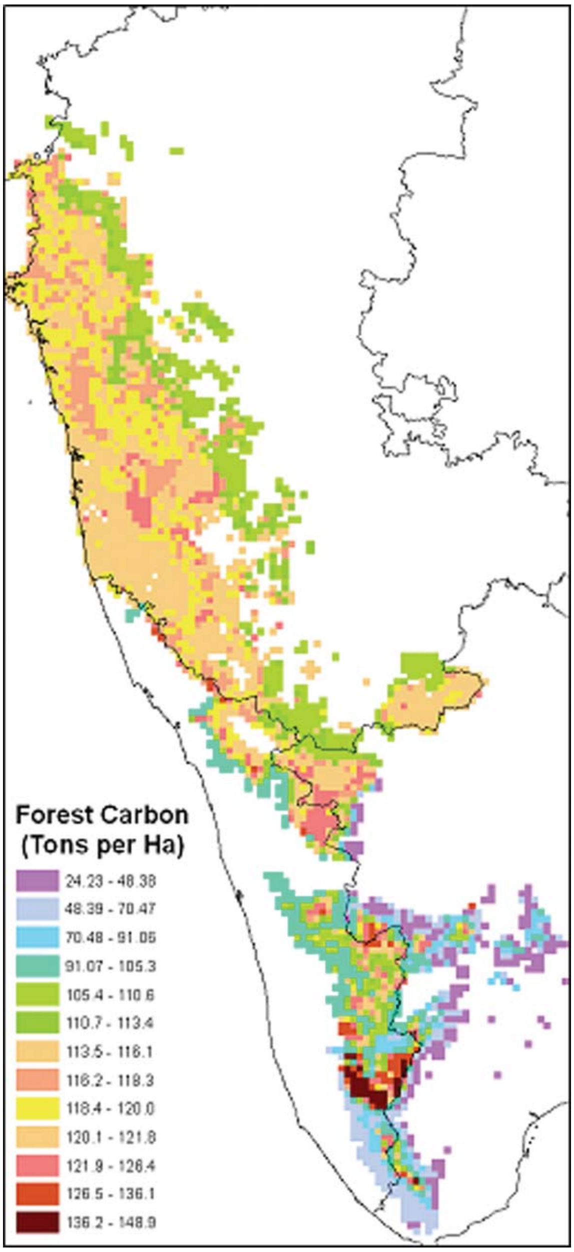

Figure 3.12: Above ground forest carbon – South Western Ghats

3.5.7. Biomass assessment as fodder, fuel and carbon stock

India has enormous biomass potential contained in different ecosystems. 65.7 M ha of forests has about 2400 M T biomass. 12 M ha of grassland / scrub has 30 M T biomass. 224 M ha of cultivable non forest area has ~11 trees/ha. 170 M ha of cultivated land contributes large biomass of crop residue. An accurate and precise measurement of carbon sequestered and released is very critical in terms of increasing population demand for biomass and to understand the role of carbon cycle on global climate change. Assessment of forest carbon is complex due to spatial variability and heterogeneity of vegetation, composition, underground growth, annual increment and extractions. As part of ISRO-GBP programme, Indian National Carbon Accounting System is initiated to address these issues. Forest carbon estimated over 5x5 km grid using basic database on vegetation type and land cover using 6000 point based biomass data for south Western Ghats is shown in Figure 3.12. In addition satellite remote sensing technique is used to estimate the fodder biomass, fuel wood availability enabling to understand the supply demand gaps and identify appropriate measures.

3.5.8. Community Forest management – Sustainable use of Bioresources

In India, a population of 226 million depends on forest energy resources. 26 M ha open forest areas are linked with 1,70,000 villages. 96% of rural households use biofuel. Still a gap of 184 M T/annum of firewood and 125 M T/annum of green fodder exists. In view of this, reliable accounting of forest resources and sustainable resources extraction has become critical and a new paradigm of "Forest Management" with rural participation has evolved. Several joint forest management and community forest management programmes are launched in different states. RS & GIS based approaches provide means to assess potential biomass, NTFP resources, perspective planning and monitoring. In this scenario the sustainable resources extraction has become critical. A new paradigm "Joint Forest Management (JFM)" with rural participation has evolved and launched over 25 M ha forest area. It has been implemented in the many states as West Bengal, Andhra Pradesh, Orissa and Madhya Pradesh. JFM activities are monitored and evaluated using Remote sensing data. JFM activities involve active participation and involvement of the rural people in developing plantation on marginal and degraded lands, regulating of forest structure, building water and soil conservation structures as bunds on barren lands, fire control, weed removal and overall forest protection. Rural communities in turn share the benefits accrued from these activities. Satellite remote sensing helps in site identification, resources assessment, monitoring and evaluation. Site identification includes delineation of degraded forests over suitable slopes/terrains and accessibility.

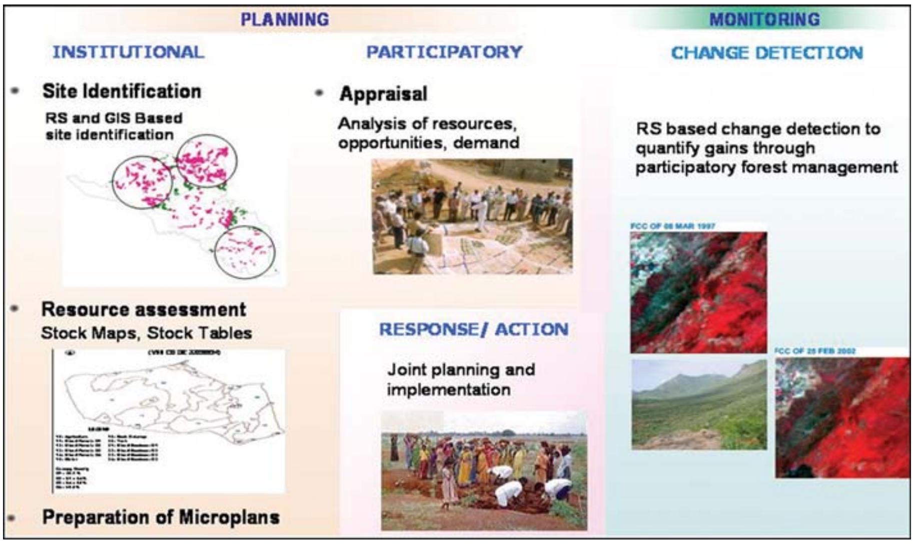

Figure 3.13: Community Forest Management in India

Satellite remote sensing data also helps in monitoring and evaluation in terms of changes in greenness, crown closure improvements, mono species formations (Weeds/Bamboo/plantation) (Figure 3.13).

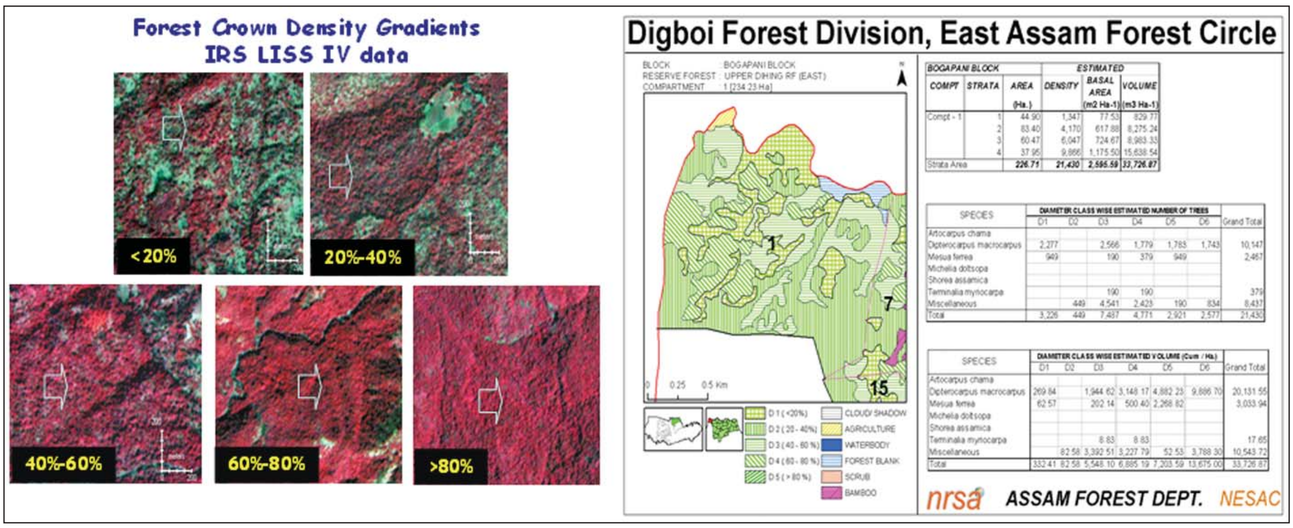

Figure 3.14: Forest Working Plan Preparation

3.5.9. Commercial Timber Resource Assessment

In India management plans of 750 forest divisions need updation every 10 years. The management plan preparation requires detailed stock maps which show the type of standing forest crop and its timber volume. Ground based conventional methods take 4-5 years with ~5% ground sampling intensity. High resolution satellite data used for forest canopy and type stratification optimizes ground sampling intensity and proper distribution of sample points. Hence, using RS and GIS inputs work is accomplished in 2 years with 0.01-0.1% sampling. Several state forest departments are adopting these approaches. National Forest Working Plan code committee envisaged the use of RS & GIS in Forest Working Plan. A sample output provided in terms of stands tables (number of trees distributed across different species and diameter classes), stock tables (total timber volume across species and diameter classes) and stock map is shown in Figure 3.14. These inputs are used by forest departments to make operational plans for suitable harvest and conservation scenarios.

3.5.10. Protected Areas and Conservation

With increasing pressure on the primary forest ecosystems, the concept of "Protected Areas" has been introduced in the country under the Wildlife Protection Act (1972). Around 500 wildlife sanctuaries, 90 National Parks constituting 15.6 Mha of the forests exist. National mission to generate spatial databases on vegetation type (1:25,000) using IRS LISS IV data and large mammal density distribution launched for all protected areas under the aegis of Standing Committee on Bioresources. Satellite Remote sensing provides inputs in terms of vegetation type, habitat maps, water holes, management zonation prepared using rule based criteria 3-D view of the Vegetation type map prepared using IRS LISS III data and management plan map indicating core, buffer, rehabilitation and tourism zones prepared using rule based criteria for Kudremukh National Park in Karnataka are shown in Figure 3.15.

3.5.11. Web-Enabled Information System

In order to disseminate databases to wider community, effective querying, relational analysis and decision making, web enabled information systems are developed to address biodiversity, Land Use and Land Cover (LULC) changes, Forest Fire related issues.

3.5.11.1. Biodiversity Information System

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. A web enabled information system provides distributed but available information in one sharable framework. 'Biodiversity Information system' is developed to serve the databases and decision support system based on the databases developed as part of the project entitled "Biodiversity Characterization at Landscape Level using

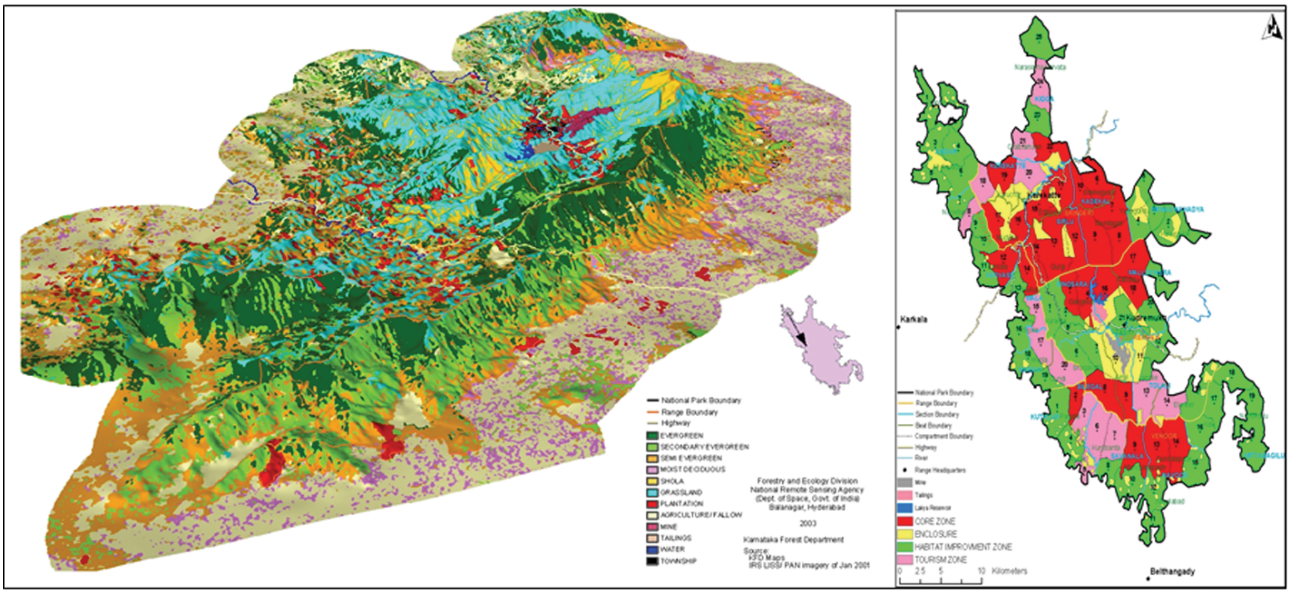

Figure 3.15: Protected Area Management

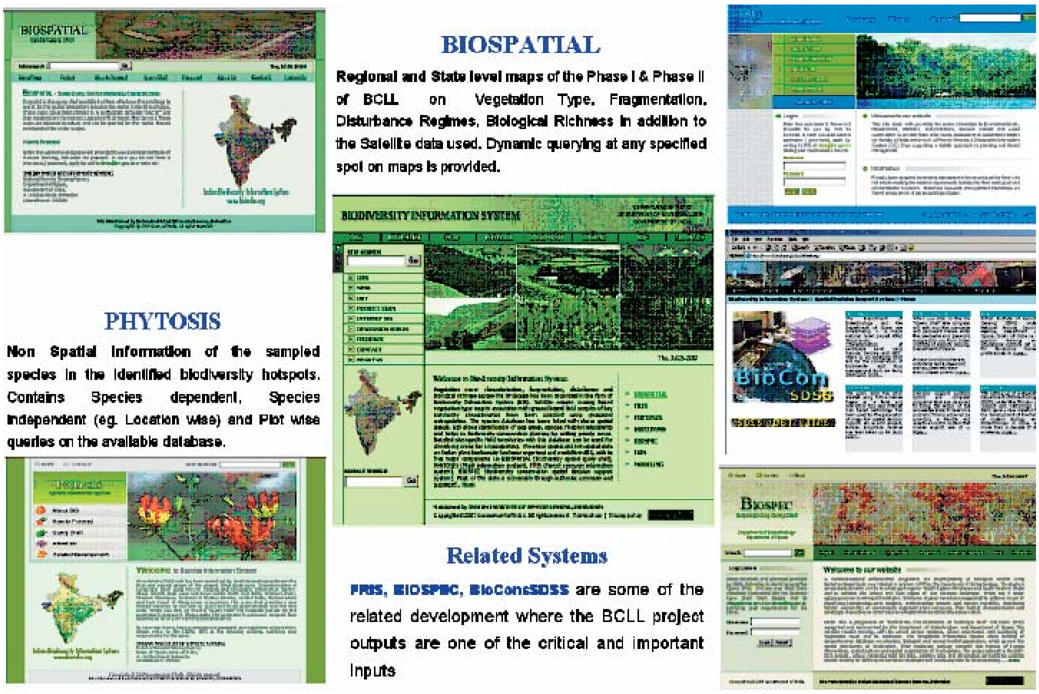

Figure 3.16: Components of Biodiversity Information System (www.bisindia.org)

Satellite Remote Sensing and Geographic Information System" of the Department of Biotechnology and Department of Space, Government of India and DBT network organizations.

The Biodiversity Information system is available on internet domain under www.bisindia.org. The components of BIS are BioSPATIAL, Biospec, PhytoSIS, FRIS and BioConsSDSS (Figure 3.16). Individually all these components focus on separate but related issues of biodiversity and natural resources management. All the components are scalable and upgradable. The information system provides sharable framework with metadata, quality evaluation procedures and their standardization. The entire database is organized in object oriented relational database management system using Oracle as back end and application development by using ASP and .NET technology as front end. The web enabling part comes through uploading the entire spatial and non-spatial data at a common platform using spatial database engine and Internet map server. This information system would allow the sharing and dissemination of biological resources in a conceptual spatial framework. It involves the basic framework of concept, selection and aggregation of fundamental and processed data.

The spatial characterization of landscape structures and its linkages with attribute information on the floristic composition, economic valuation, and endemism are presented in Biodiversity Information System in a sharable environment. The basic objective of biodiversity information system is to give access to meaningful information about biological diversity, which is key to mobilizing resources for the conservation as well as sustainable use of these resources. The use of Biodiversity Information System in particular would help the ecologists of being informed about what species and ecosystems should be targeted for protection, where these occur, and how we should protect and manage these resources, and the areas that sustain them, for the benefit of present and future generations.

3.5.11.2. Indian Bioresource Information Network (IBIN)

Department of Biotechnology (DBT), Government of India, launched a national level programme to develop a digital database of the bioresource of the country. IBIN is uniquely placed as a single portal data provider on India's bioresource - plant, animal, marine, spatial data and microbial resources. The data sets collated here are the result of the research of over four hundred scientists, working in over 150 institutions. For the first time ever, an electronic database has been developed using an indigenously developed software application for data access and query on spatial data, plant, animal, marine and microbial resources of the country. All the digital databases were developed with a common basic structure such that they could all be eventually compiled on to a single servicing platform. There arose a need to offer these non-spatial data (attribute data) sets on a wide

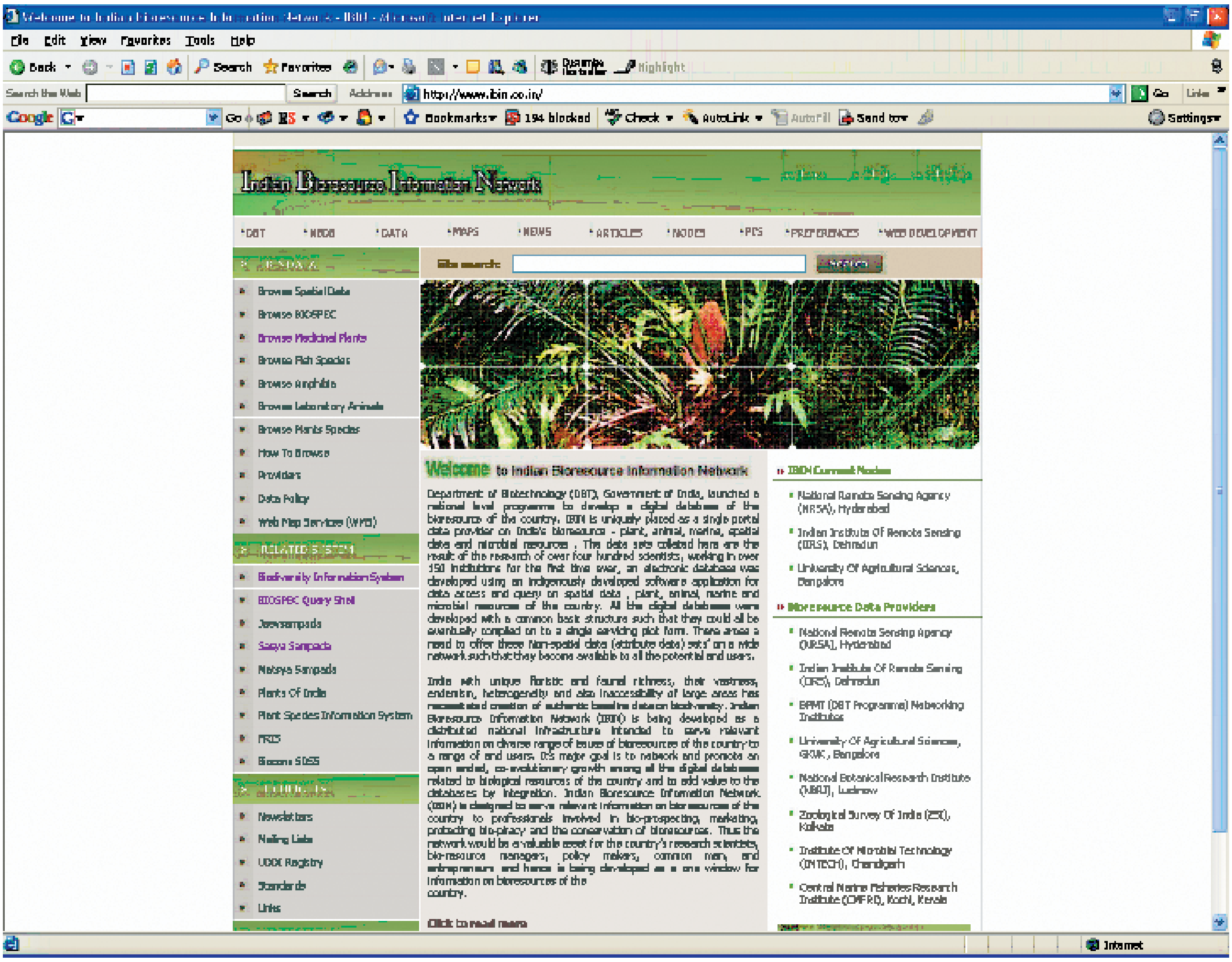

Figure 3.17: Home Page of Indian Bioresources Information Network (www.ibin.co.in)

network such that they become available to all the potential end users. India with unique floristic and faunal richness, their vastness, endemism, heterogeneity and also inaccessibility of large areas has necessitated creation of authentic baseline data on biodiversity.

Indian Bioresource Information Network (IBIN) is being developed as a distributed national infrastructure, intended to serve relevant information on diverse range of issues of bioresources of the country to a range of end users(Figure 3.17). The Indian Biodiversity Information Network is available on internet domain under www.ibin.co.in. Its major goal is to network and promote an open ended, co-evolutionary growth among all the digital databases related to biological resources of the country and to add value to the databases by integration. Indian Bioresource Information Network (IBIN) is designed to serve relevant information on bioresources

of the country to professionals involved in bio-prospecting, marketing, protecting bio-piracy and the conservation of bioresources. Thus the network would be a valuable asset for the country's research scientists, bio-resource managers, policy makers, common man, and entrepreneurs and hence is being developed as a one window for information on bioresources of the country.

Major highlights of IBIN spatial node: The outputs of DOS-DBT project on Biodiversity characterization at landscape level using Remote Sensing and GIS are important inputs for IBIN spatial node. Since the DOS-DBT outputs are generated in 1:50,000 and 1:250,000 scale in restricted coordinate system therefore as per map policy and guidelines the same can not be made available in public domain as it is. NRSC has developed a mechanism to share this information in public domain after certain downscaling. The field sample plant species data is also linked with spatial data for further querying and downloading. The main highlights of the IBIN spatial node are:

- The map layers available in IBIN spatial node are: Vegetation type map. Fragmentation, Disturbance Index, Biological richness, IBIN spatial grid, DOS-DBT sample grid, District Boundary and State Boundary
- All the spatial data is available in LCC projection and WGS84 datum
- The DOS-DBT outputs are available on 1:1M scale after certain degradation in original map quality

- All the spatial datasets are converted into uniform grids (3.75' x 3,75' minutes (approx. equivalent of ¼th of 1:25000 SOI topo-sheet area) with WGS84 datum considering the data sharing policy of Ministry of Defense. The size of the individual grid is 6.75 km (approx.) (1'=1.8 km (approx) and 3.75' = 6.75 km (approx.) These spatial blocks are made after the thematic generalization in order to retain the spatial patterns. The plant inventory details such as listing of plant species is available for each block wherever DOS-DBT field sampling is carried out
- The query on DOS-DBT sample grid provides a list of plant species collected and recorded during DOS-DBT field sampling with location information. The user can download and save same at client end
- The IBIN spatial node provides a dynamic Internet GIS base map viewer with basic GIS tools like dynamic legend display, zooming, panning, navigation, zoom to scale, identify, querying, searching, map output generation (in PDF, JPG, PNG and GeoTIFF format), sending outputs through email etc.
- The spatial data downloading utility is available in GeoTIFF format. IBIN spatial node also provides a detailed document and help file to download and use map outputs
- The spatial data is available as OGC compliant web map service (WMS)
- The spatial outputs are also available as static map for download on 1:1M scale and
- The entire software development and web map publishing for IBIN spatial node is done using open source software/languages by NRSC as indigenous in-house development

3.5.11.3. Global change studies – Need for LULC databases

During the next 50 years, demand for food by a wealthier and 50% of larger global population will be the major driver of global environmental change. With the business as usual scenario of global environmental impacts of agriculture on human population and consumption continue, 109 hectares of natural ecosystems would be converted to agriculture by 2050 representing the worldwide loss of natural ecosystems larger than the United States (Scole, 2007). In India while the Net Sown Area is stabilized around 140 Mha, for ensuring food security, India needs to produce about 100 million tones of additional food grains by 2020. Towards realizing this goal, an additional 38 Mha of watersheds are targeted to be treated in the rain fed regions.

The forest cover of 68 M ha in India is largely disturbed due to the increasing rate of fragmentation, deforestation and unsustainable extraction of timber, fuel wood and fodder, forest fires and forestland conversions. The studies conducted by National Remote Sensing Center have reported that around 35% of the Indian forests are subjected to higher levels of fragmentation, fire and invasion and 1 Mha due to shifting cultivation which have larger impact on climate change (NRSC, 2005, 2008).

Ecosystem changes associated with land-use and land-cover change are complex, involving a number of feedbacks (Lepers *et al.*, 2005). For example, conversion of natural vegetation to agricultural land drives climate change by altering regional albedo and latent heat flux, causing additional summer warming in key regions in the boreal and Amazon regions, and winter cooling in the Asian boreal zone (Chapin *et al.*, 2005b; Feddema *et al.*, 2005), by releasing CO_2 via losses of biomass and soil carbon and through a 'land-use amplifier effect' (Gitz and Ciais, 2003). India has experienced the urban expansion of 14% over last 20 years and expected to increase by 7% during next 10 years effecting the total LULC system and landscape patterns.
In contrast, afforestation, reforestation, and other land-use or land-management changes such as modifications of agricultural practices, can work to mitigate climate change through carbon sequestration (Nabuurs *et al.*, 2007). This mitigation potential is probably limited to reducing the ultimate atmospheric CO_2 increase by 2100 by between 40 and 70 ppm (House *et al.*, 2002), and by approximately a century-long time lags until mature forests are established. In India 11 M ha of open forests and 27 M ha of unutilized culturalable lands are being subjected to amelioration and improvement of biomass development which could serve as effective climate change mitigation strategy towards enhancing the carbon sink potential.

Realising the importance of role of LULC in regulation of climate, productivity and biodiversity, the need for developing reliable LULC databases over India is considered as one of the critical task towards understanding climate and non climate driven changes. In view of the several limitations of coarse scale available global LULC databases (Schmidt *et al.*, 2008), heterogeneous and fragmented landscapes of India, an effort has been made to develop LULC databases using multitemporal IRS AWiFS satellite data.
LULC Databases of India : LULC system in India exhibits high degree of spatial and temporal variability due to the influence of climate and local land use practices on agriculture, compositional and phenological variability of natural vegetated systems like forests, grasslands. In order to precisely capture these variabilities multi-temporal

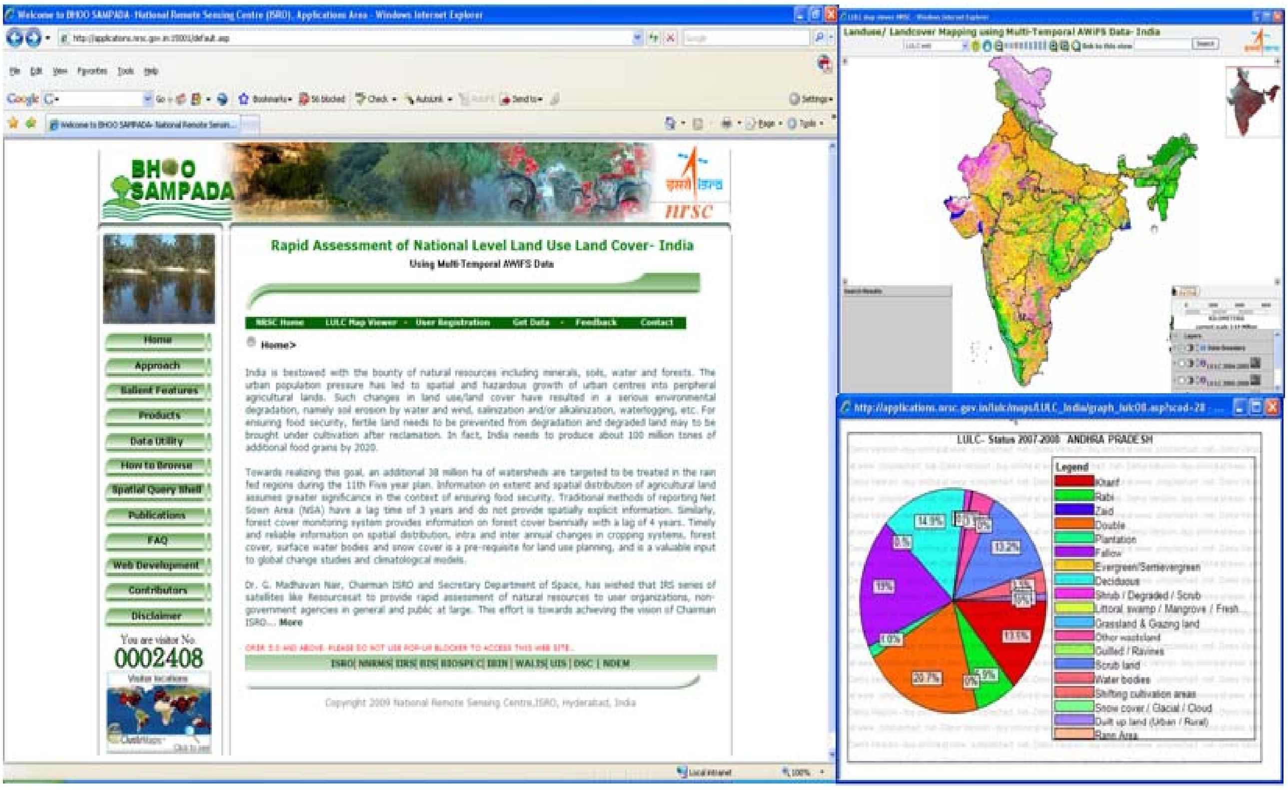

Figure 3.18: BHOOSAMPADA-Land use/Land cover information system using multi-temporal AWiFS data. (http:// applications.nrsc.gov.in:15001)

Resourcesat-1 Advanced Wide Field Sensor (AWiFS) data acquired during August- May of each crop calendar year (kharif, rabi, and zaid seasons) were used. LULC classification scheme (legend) amenable to digital classification was adopted in order to generate LULC maps rapidly. Hierarchical decision tree, maximum likelihood and interactive classification techniques were adopted for classification of the data.

The study developed annual LULC databases for 2005, 2006, 2007, 2008 and databases for 2009 are in progress. Study has brought out based on spectral and temporal signatures delineation of 19 LULC classes compatible at 1:250,000 scale. The database provides both intra and inters annual LULC changes which could be used critical inputs for different ecological studies. The detailed results of the different cycles are available under official web portal of the project at (http:// applications.nrsc.gov.in :15001).The study would continue for another 5 cycles to understand the LULC trends on long term basis.

BHOOSAMPADA - Web GIS LULC Information System : The web based information system based on national level programme on Rapid Assessments of land use/ land cover changes of India using AWiFS data has been developed as BHOOSAMPADA web portal which is accessible through web URL-http:// applications.nrsc.gov.in:15001 as an operational service of ISRO (Figure 3.17). BHOOSAMPADA provides a multi-user cross platform to access, query and analysis geo-spatial data in a simple web browser environment without having any specific GIS/ image processing software installed at user end. Various GIS tools and functionalities are available to its users for geo-spatial querying, analysis and spatial output generation. The web portal serves its data and information as web service format which is an industry standard mechanism to share and distribute data and information to its user without physical transfer of the data. Few sample screens of Bhoosampada portal are shown in figure 3.18.

The tools and technology used in development of BHOOSAMPADA incorporates open source as well commercial GIS solutions. The spatial data is disseminated under two important categories i.e., 1:1 M scale for general users and 1:250K scale for registered users. The map viewer for 1:1M scale data is developed using open source GIS solutions with limited functionalities whereas to enable registered users with more GIS functionalities and query utilities, the 1:250,000 map viewer has been developed using COTS package. At present all four cycles LULC database, seasonal snow and water are organized in a central server system with ancillary information on roads, settlements and socioeconomics.

Data under BHOOSAMPADA is meant to be utilized only for scientific, research and educational purposes. Data use or issues related to any commercial and legal purposes will not be entertained and any related responsibility is thus disowned. The data under 1:1M scale map viewer is provided in public domain for wider use as a primary information product and the data and information under 1:250,000 scale map viewer viz., maps and statistics are provided upon registration. Digital databases are provided only for authorized users to facilitate advanced analysis and integration. Users should invariably acknowledge the data source and its use. Users are encouraged to provide feedback and suggestions for overall improvement of the product.

LULC Data Utilisation : Database facilitates monitoring and assessment of NSA under rainfed and irrigated conditions in conjunction with climate, socioeconomics and other factors. It provides baseline and facilitates monitoring fallows. The database also proved to be useful for rapid monitoring of dynamic land covers like surface water, forest, waste lands etc. It works as potential database for planning and developmental activities, regional EIAs, stands as inputs for global environmental studies.

National LULC databases developed are being used as baseline to study LULC changes over last 3 decades as inputs for assessment for trace gas emissions due to Land use Land cover Change and Forestry (LULCEF), ecological studies of all major river basins, inputs for regional climate models, afforestation /reforestation studies as part climate change mitigation programs, species loss and biodiversity change models. The databases would also work as potential inputs for to study and validation of Dynamic Global Vegetation Models (DGVMs). For more detail on Bhoosampada data, services and its utilizations, please visit-http://applications.nrsc.gov.in:15001.

3.5.11.4. Forest Fire Management

Fifty five per cent of Indian Forests are prone to recurrent fires annually affecting ecological and economic damage. INR 440 crores is the reported economic loss due to fire. Conventional approach of the State Forest Dept. for fire protection through an elaborate network of fire lines, fire watch towers and manual fire control system has been far from adequate. The existing facility need to be augmented with effective and fast response tools like RS & GIS based fire detection, monitoring and damage assessment in conjunction with ground data. As part of Disaster Support Center of NRSC, services on Fire management are provided using multi-resolution, multi-temporal satellite data. Active forest fire locations for the entire country on daily basis to facilitate fire control operations using MODIS and DMSP data is provided as part of Indian Forest Fire Response and Assessment System (INFFRAS) that is operationally started to provide these services through NRSC web site (Figure 16.8 at page 363).

3.6. Gap Areas

Digital retrieval of forest parameters using high resolution and hyperspectral data, optimal sampling designs for forest volume estimation, automated forest cover retrieval and change assessment, species exploration and niche modeling, biodiversity monitoring and change modeling, vegetation stress analysis, disease detection, forest ecosystem responses to climate change and anthropogenic impacts, ecological foot printing analysis for sustainable development, forest vulnerability and change assessment are a few important R&D areas need to be addressed .

IRS series of satellites which have been functioning as main work horse for the last two decades have limitation due to spatial, spectral and temporal resolutions, persistent cloud cover over certain areas and lack of atmospheric corrections to address natural resource monitoring, vegetation stress detection, biophysical and geophysical parameter retrievals. The fragmented forests and vegetation communities have been found to be a major limitation. Therefore satellite sensors with high repetivity and high spatial resolution would strengthen these observational gaps. The land surface characteristics such as biomass, canopy moisture regimes, canopy roughness etc., are more sensitive in their reflection properties in the microwave regions. The inclusion of air and satellite borne microwave sensors in the IRS programme is very much required to fill this gap. Non availability of thermal data also limits temperature estimation which is needed for ocean and land applications. On the other hand to assess the vegetation stress, biogeochemistry, mineral regimes the existing spectral resolution in terms of number of spectral channels and channel width is inadequate. This calls for hyper spectral sensors providing spectral information at high spatial and spectral resolutions. In the context of infrastructure development, the existing satellite sensor resolutions need to be further enhanced to provide information on 1:1000 scale.

These advanced land and ocean observation sensors would ameliorate the low availability of geophysical/biophysical products, viz., Land Surface Temperature, Insolation, Surface Radiation, Albedo, Precipitation, Vegetation Fraction, LAI, fAPAR, NPP.

3.7. Summary and Conclusions

In the last decade, there has been significant progress in the application of Remote Sensing GIS for forestry and ecological monitoring. The newer sensors, the hardware and software technologies have helped the scientists and all concerned to understand the various paradigms of structure and processes of biosphere. However, in the light of newer challenges set by IPCC fourth assessment report, CBD, MDC goals, UNFCC and various other national and international conventions that have addressed the climate change and its constraints that is likely to impact the human as well as living system in general, still lot remains to be done such as availability of high repeat cycle, hyperspectral data of fine resolution etc. There is urgent need to progress on the establishment of proper linkages on the ecosystem models with RS monitoring data.

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