India's plant diversity database at landscape level on geospatial platform: prospects and utility in today's changing climate

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Characterization, quantification and monitoring of biodiversity have been among the major challenges in biodiversity conservation. Until recently, spatial ecological database in India was almost non-existent. There is need of a robust and quality database of the biological diversity at species, community, ecosystem and landscape levels for identification of vulnerable ecosystems and risk species. In order to have a national level database on the spatial distribution of biological diversity, a nationwide project on the biodiversity characterization at landscape level was implemented and studies were carried out between 1998 and 2010 to characterize and map the flowering plants richness in the forested landscapes. The spatial database on vegetation types generated from temporal IRS LISS-III satellite imagery, road/rail network and settlements from topomaps and high-resolution satellite images, and species richness from field sampling were used to generate the spatially explicit species distribution maps and statistics. This study has resulted in the creation of a large baseline spatial database on vegetation types, porosity, patchiness, interspersion, juxtaposition, fragmentation, disturbance regimes, ecosystem uniqueness, terrain complexity and biological richness.

Keywords: Biodiversity characterization, landscape analysis, remote sensing, spatial database.

Introduction

TRADITIONALLY, biodiversity assessment has primarily been carried out by different botanical, zoological and anthropological survey organizations at international and national levels. Organizations like Royal Botanical Gardens, Kew; Smithsonian National Museum of Natural History, USA and Botanical and Zoological Survey of India, Kolkata, have been documenting biological diversity at species level since their existence. Although the documentation procedure followed by these organizations is quite elaborate and effective in many respects, they are not user-friendly and suffer from integration and extrapolation for interdisciplinary and multidisciplinary studies. The current pace of documentation appears to be slower than the rate of species loss. A combination of top-down, i.e. landscape to species level and bottom-up, i.e. exploratory approach for inventory and documentation needs to be adopted for biodiversity studies that can ensure speedy documentation of all existing species along with their locational information and habitat characteristics.

In India, the existing biodiversity databases are discrete, localized and rarely provide a complete picture of the extent and distribution of species in the entire country. Efforts are being made by various institutes to study and document the bio-resource data in digital form (Table 1). Some of the national databases are the Indian Biodiversity Portal by PADAP of the National Botanical Research Institute (NBRI), Lucknow, Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, under the National Knowledge Commission and *Jeeva Sampada* by GKVK, Bangalore. At the global level, there are more than 300 digital databases of various kinds containing information on the plant resources and diversity on national, regional or continental scale, of which few are mentioned in Table 1. Such comprehensive databases are relatively scarce in Asian and African countries. Some of the important spatial biodiversity databases available at the global level are Global Assessment of Endemism[1] and Global Centres of Vascular Plant Diversity[2], Global Patterns of Plant Diversity and Floristic Knowledge[3] and Map of Potential Species Diversity of Vascular Plants[4]. In 2001, the Global Biodiversity Information Facility (GBIF)[5] was created to develop a portal for free and open access to primary biodiversity data. Primary data provide information on the location of animals or plants at a particular time and are useful for understanding the drivers of biodiversity loss, such as invasive species. As of July 2009, about 177 million primary biodiversity records covering more than a million species have been published through this portal. However, the records are mainly from North America and Europe, with 42% coming from USA, 15% from Sweden and 13% from the UK. Although Africa, Asia and Oceania (lands in the Pacific Ocean) have high levels of biodiversity, they are grossly under-represented due to non-availability of information on these continents.

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Table 1. List of available biodiversity database

Database	Description	Organization
Global database		
Thailand National Biodiversity Database System	GPS-tagged biodiversity data in geospatial environment	NBIDS, Thailand
North American Environmental Atlas	Identifies priority areas to conserve biodiversity, and to predict the spread of invasive species	Commission for Environmental Cooperation
Biodiversity Information System for Europe	Land-use and land-cover maps, species and habitat database for conservation areas	European Commission and the European Environment Agency (EEA)
Atrium Biodiversity Information System	Virtual herbarium, vegetation surveys, geospatial data repository, weather and field data	The Botanical Research Institute of Texas, USA
BioGIS – Israel Biodiversity Information System	National database of the flora and fauna of Israel. Provides, advanced tools for querying, analysing, modelling and visualizing patterns of species distribution in Israel	Israel National Parks Authority, Hebrew University, Tel-Aviv University, Society for Protection of Nature and Israeli Gene Bank for Crops
National database		
PADAP	Web-enabled database containing taxonomic and biodiversity information on algae, bryophytes, lichens, pteridophytes, gymnosperms and selected flowering plant taxa	NBRI (CSIR), Lucknow
National Wildlife and Zoo Database	Geographic distribution of wildlife across the country	WII, Dehradun
Jeeva Sampada	Compilation of data on bio-resources such as plants, animals, marine and microbial resources	GKVK, Bangalore
Indian Biodiversity Portal – ATREE	A repository of information designed to harness and disseminate collective intelligence on the biodiversity of the Indian subcontinent	ATREE, Bangalore
BISINDIA (the present one)	Geospatial database on plant diversity of India	IIRS, DoS–DBT

Database creation and organization in the web portal

The maiden national vegetation cover type map of India prepared using dry and wet season IRS LISS-III data accommodated 121 different classes having variation in their diversity content (Figure 1 *a*). It provides spatial information on the vegetation types consisting of natural, semi-natural and managed formations (forest plantations). The satellite image elements were correlated on ground with the sampling intensity varying from 0.002% to 0.005%, depending upon the vegetation heterogeneity (Figure 1 *b*). Details of the study methodology, sampling technique and biological richness modelling have been published[6–16]. The non-spatial database includes phytosociological data collected from 16,578 field sample plots with 7596 plant species, wherein 648 species are endemic, 23 are endangered, rare or threatened (ERT), 1879 medicinally important and 2803 are economically important species.

The website www.bisindia.org has 87.5 thousand visitors so far, and the request for 1 : 50,000 scale map data is increasing day by day (Figure 2). The species database has been linked with the above spatial details. Biodiversity information system (BIS) allows identification of gap areas, species/habitat relationships and helps in biodiversity conservation planning by setting up priority areas. Detailed site-specific field inventories with this database can be used for identifying areas for bio-prospecting. The entire spatial and non-spatial data on Indian plant biodiversity have been organized and are available in BIS, with the five major components, viz. *BIOSPATIAL* for biodiversity spatial query shell, *PHYTOSIS* for plant species information system, *FRIS* for database related to forest resources from various sources, *BIOSPEC* for bioprospecting and molecular taxonomy, and *BioConsSDSS* for biodiversity conservation spatial decision support system. *BioConsSDSS* is a unique application in the web GIS environment which addresses the semi-structured problem with various degrees of uncertainty on biodiversity, where computer-based models can interact directly with the biodiversity experts to generate a knowledge base for biodiversity conservation and prioritization[16]. It provides multi-criteria geospatial decision analysis for biodiversity conservation in the web GIS environment. The information services implemented using OGC WMS under BIS

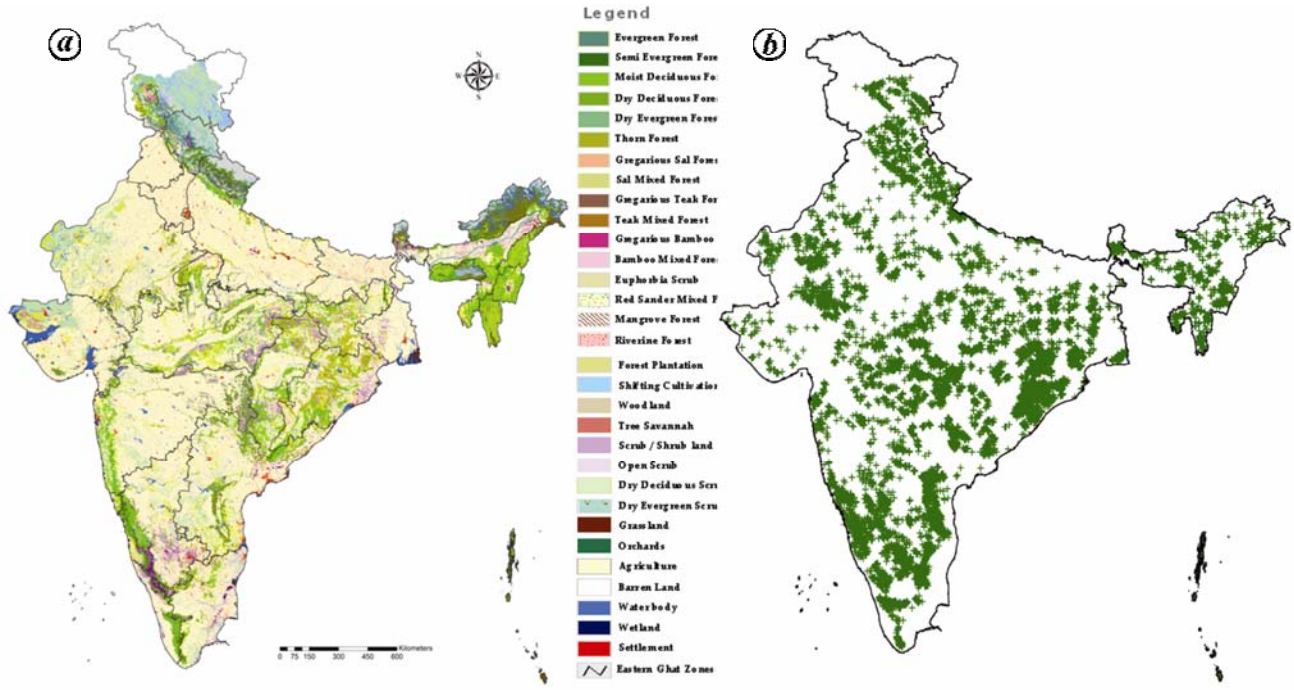

Figure 1. Vegetation cover type and land-use map of India (***a***), overlaid with field sample plots (***b***).

are freely accessible by the users after formal registration, and the digital spatial data are shared with user organizations for further value-addition and scientific studies. The World Wide Web and high-speed network access have given a new dimension to the geospatial domain; thereby larger datasets are processed with more complex models and analysis for decision-making through better display and visualization. These technological advancements through geospatial technologies have provided the biodiversity information system (BISINDIA) an unparalleled boost. The database of BISINDIA forms an important component of the Indian Bioresource Information Network (IBIN) of the Department of Biotechnology, Government of India (Figure 3). IBIN (www.ibin.co.in) is being developed as a distributed national network infrastructure using open source software solutions to provide relevant information on diverse themes and of issues related to the country's bioresources to a wide range of end-users in an interoperable environment.

Data dissemination and utilization

The data have become immensely useful in varied areas of research and policy-making processes, namely climate change, conservation, prioritization, identifying gaps in research, etc. and identification of potential ecological and wildlife corridors, development of international monitoring protocols and forest management. It has been disseminated to a large number of central and state departments, research institutes, universities and individuals for their own scientific use. Several states such as Karnataka, Odisha, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and many other State Forest Departments have used the data in growing stock assessment and working plan preparation, NTFP. Protected area managers and researchers have used spatial data for species conservation planning and management. The Zoological Survey of India (ZSI), Kolkata has requested the Indian Institute of Remote Sensing (IIRS), Dehradun, to help create a similar database for animal species. Table 2 provides a list of organizations that have utilized the database for various scientific and management purposes.

Inputs for conservation prioritization and monitoring

The database on the vegetation type, fragmentation, disturbance index and biological richness can effectively help in the identification and prioritization of areas under threat[17,18]. Spatial information generated on vegetation types and disturbance regimes stands as the baseline data for habitat suitability assessment, prioritization for microscale habitat studies, corridor connectivity[19] and landscape planning. Identification of species-rich areas, distribute towards conservation methods for protection of rare species and ecologically sensitive areas. The database can identify the potential habitat or niche of the endemic and threatened species[20].

Identification of gap areas in botanical exploration

It has been seen that most of the field-based botanical explorations are only concentrated in some select areas in the country. This is because many of the collections are carried out in the vicinity of the major botanical

Figure 2. Biodiversity Information System (BIS), the web-interface. The site has received over 87,000 visitors till mid-December 2011.

institutes/universities. The database created of the type map along with the fragmentation and biological richness will give a clear idea about the area where the future botanical exploration should be carried out[20].

Inputs to climate change study

Most of the climate change studies take a relatively coarse resolution vegetation database for calibrating the various climate forcings, which sometimes gives erroneous results especially in the Indian region due to varied factors like orography[21]. The digital database on vegetation type distribution, a systematically organized database developed in India, is a basic input for identifying species habitat. This database can be utilized in future climate change-related studies, be it species or habitat transitions[22], loss or tree-line shifts and the dynamics of the various natural and anthropogenic forcings.

Identification of areas prone to biological invasion

The results are also useful for monitoring invasive species and gap analysis. The key requirement in invasive species mapping is delineation of the spatial extent of invasion to understand its severity. The data from inventory as well as modelled output of fragmentation and disturbance index are essential for prioritizing initiatives for invasive species control, monitoring rate of species spread and evaluation[23].

Management and policy applications

Few critical areas where databases have been effectively utilized are in forest working plan preparation, protected area management, people's biodiversity registers, bioprospecting, species niche modelling, prioritization of local habitats for studies using high-resolution databases, biodiversity change analysis, economic evaluation and inputs for international protocols like CBD. New initiatives have been taken up by the Department of Space to adopt the databases for these varied adaptation strategies as part of the National Action Plan on Climate Change (NAPCC) of the Government of India[24].

Conclusions

India being one of the mega biodiversity countries is also one of the most densely populated regions of the world.

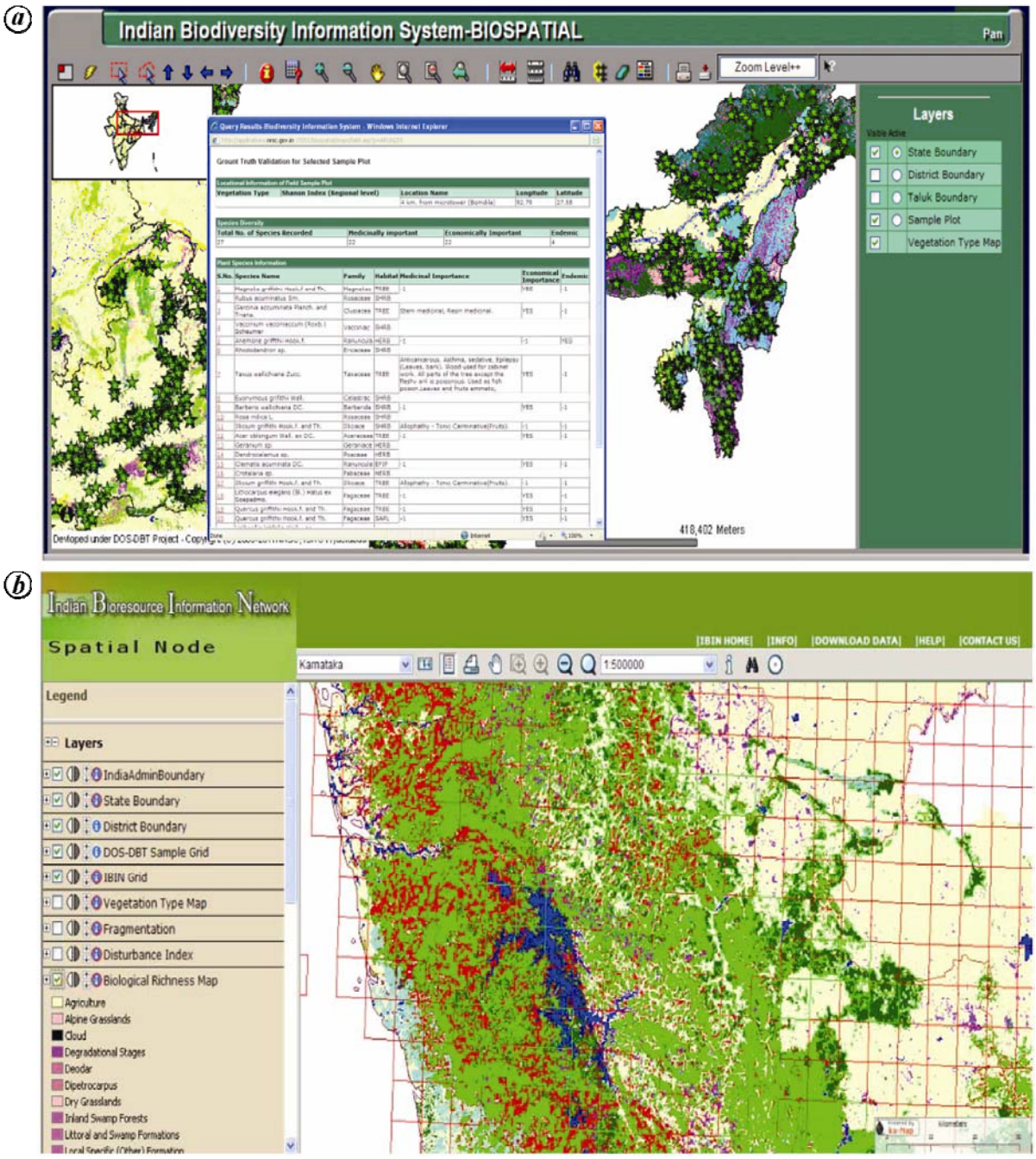

Figure 3. Geo-visualization and query provision in BIS (***a***) and grid-wise data sharing and dissemination in IBIN (***b***).

The country harbours two of the 38 global biodiversity hotspots: the Indo-Malayan which includes the eastern Himalayas, NE India and Andaman Islands, and the Western Ghats. These regions harbour some of the important gene-pools of medicinal plants, wild varieties of cultivable crops and other species of economic importance as well as innumerable endemic and RET plant species. Conservation of this national wealth is of paramount importance in the face of increasing pressure on the plant diversity in the form of land-use and land-cover change, invasive species, global warming, nutrient deposition and climate change. There is an urgent need of a quality database of the biological diversity at species, community, ecosystem and landscape level.

The outcome of the nationwide study on biodiversity characterization at the landscape level has generated a wall-to-wall holistic database on the key inputs describing the quality and quantity of the vegetation and biodiversity at different spatial levels. Although there are a few biodiversity databases in many parts of the world in the public domain, none covers the complete gamut of spatial databases starting from vegetation type, fragmen-

Table 2. BCLL data dissemination and utilization

Usage	Organization	Media	Application
NTFP abundance	Andhra Pradesh, Tamil Nadu, Jharkhand, Punjab and Odisha State Forest Departments (SFDs)	Reports, digital maps and inventory in digital form	NTFP spp. maps with spatial distribution of its qualitative abundance
Forest working plan preparation	Odisha, Tamil Nadu, Punjab, Jharkhand, Andhra Pradesh, West Bengal, Uttarakhand and Andaman and Nicobar Islands	Reports, digital maps and inventory in digital form	For the preparation of working circles, inventory design, and inputs for chapters on biodiversity and disturbance
Protected area management	Andhra Pradesh, Punjab, Meghalaya and Odisha SFDs, Wildlife Institute	Digital map data for spatial analysis	Corridor analysis for joining protected areas. 'Nomination of suitable sites in Western Ghats under UNESCO's Natural World Heritage List'
Biodiversity registers	Biodiversity boards of states and NGOs, viz. Kalpavriksh, ATREE	Reports, digital maps and inventory in digital form	For documentation of the local biodiversity wealth
Bioprospecting of chemical principles	Regional Research Laboratory, Bhubaneshwar	Reports, maps and inventory in digital form	Screening and bioprospecting the plant for high-value chemical extraction
Niche modelling and local habitat description	Department of Space R&D projects; research organizations; FMR–CDF, Chennai (NGO)	Reports, digital maps and inventory in digital form	For mapping the potential niche of the important or key species
Biodiversity change and fragmentation studies	Uttar Pradesh, Madhya Pradesh and West Bengal, SFDs and Andhra Pradesh Biodiversity Board; SACON; MS Swaminathan Research Foundation (MSSRF), Chennai	Reports, digital maps and inventory in digital form	For mapping the size class distribution of forest fragmentation patches for prioritization for conservation as well as baseline data for future; biodiversity monitoring; Impact of climate change on lichen biodiversity
Economic evaluation	SFDs	BCLL reports	Economic evaluation inputs for working plans
Policy, planning and monitoring	State Biodiversity Boards, SFDs and MoEF, GoI; Forest Survey of India; Environment and Wildlife Management Department – Sikkim; Wildlife Research and Conservation Society (WRCS), Pune	Reports, digital maps and inventory in digital form	For compliance to the communications to be made to CBD for 2010 and for conservation and prioritization, Green India Mission, Sikkim; Biodiversity conservation and forest management project, conservation, wildlife management.

tation and biological richness coupled with geospatially tagged field-plot data. This is a baseline database on vegetation type, fragmentation status and biological richness of the Indian landscape, which is the key to biodiversity conservation planning and development of future management strategies for conservation efforts and climate change studies. Using the spatially linked species database across the country in association with spatial ecological data, risk species and habitats under potential species loss risk can be identified using statistical modelling. The wider dissemination and an open software environment for further value-addition by integration of other available datasets with knowledge institutions have been achieved by development of the web GIS-based central and distributed information services. In the coming decades this information archived and disseminated along with its associated knowledge base would help in conservation and sustainable use of the biological resources for the benefit of mankind.

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