Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 1177-1186
Received: 25-11-2018
Accepted: 27-12-2018

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Assessment of bio diversity conservation using geospatial models

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Abstract
Landscape changes as well as the distribution of biodiversity are phenomena with strong spatial correlates. Since India is identified as one of the 12-mega biodiversity countries in the world, this task is of great significance. In this respect the Biodiveristy Characterization at Landscape Level for India is a milestone in biodiversity study. A spatial model incorporating ground based biodiversity attributes of the landscape elements, land use change patterns, disturbance regimes of the landscape and terrain complexity have been used to delineate the spatial pattern of biological richness. Recent developments in remote-sensing (RS) technology, Geographic Information Systems (GIS) and the Multicriteria Spatial Decision Support System (MC-SDSS) allow the use of a landscape ecology and spatial analysis approach to the problem of deforestation and biodiversity conservation in India. It includes analyses of land-cover and land use change; estimation of deforestation rates and rates of forest fragmentation; modelling of deforestation (GEOMOD2); analysis of the consequences of land-cover and land-use change in the form of climate change and change in distribution of biodiversity; gap analysis of the effectiveness of the protected area network in conserving areas of importance for biodiversity conservation; and conservation planning.
The study highlighted the usefulness of geospatial approach for decision making and implementation of biodiversity conservation and thereby to achieve sustainable development of natural resources. This approach will facilitate conservation prioritization, systematic inventory and continuous monitoring.

Keywords: Biodiversity, RS, GIS, landscape ecology, deforestation, modelling

Introduction
The term biodiversity was first used by Dalesman (1968) [9], it was only in the 1980s that the term came into common usage in science and environmental policy. The term biodiversity in its present form was coined by W.G. Rosen in 1985 (Wilson 1988). Biodiversity is the variety of living organisms considered at all levels of organization, from gene through species, to higher taxonomic levels, including the variety of habitats and ecosystems, as well as the processes occurring therein. Biodiversity is expressed at different levels – genetic, species and landscape level (Roy 2011; Fig. 1) [39].
Biodiversity is the biological diversity which includes the variety of the whole species present on earth. It includes different animals, plants, micro-organisms and their genes, water ecosystems, terrestrial, and marine ecosystems in which they all are present. India is recognized as one of the mega bio diversity nations and support 3 of 34 biodiversity hotspots of the world. The diverse habitats in India are the repository of rich biological diversity, providing all organism unparalleled ecological resources. These resources are intricately linked to society through traditional knowledge about medicine and other life support systems.The anthropogenic drivers of change such as land use, nutrient loading, CO_2 enrichment and climate change to name a few are leading to a deleterious effect on the biological diversity either singly or in combination (Sala *et al.*, 2000; IPCC, 2007). The fragmentation of natural landscapes by human activities is a major threat to biodiversity world wide (Saunders *et al.*, 1991).

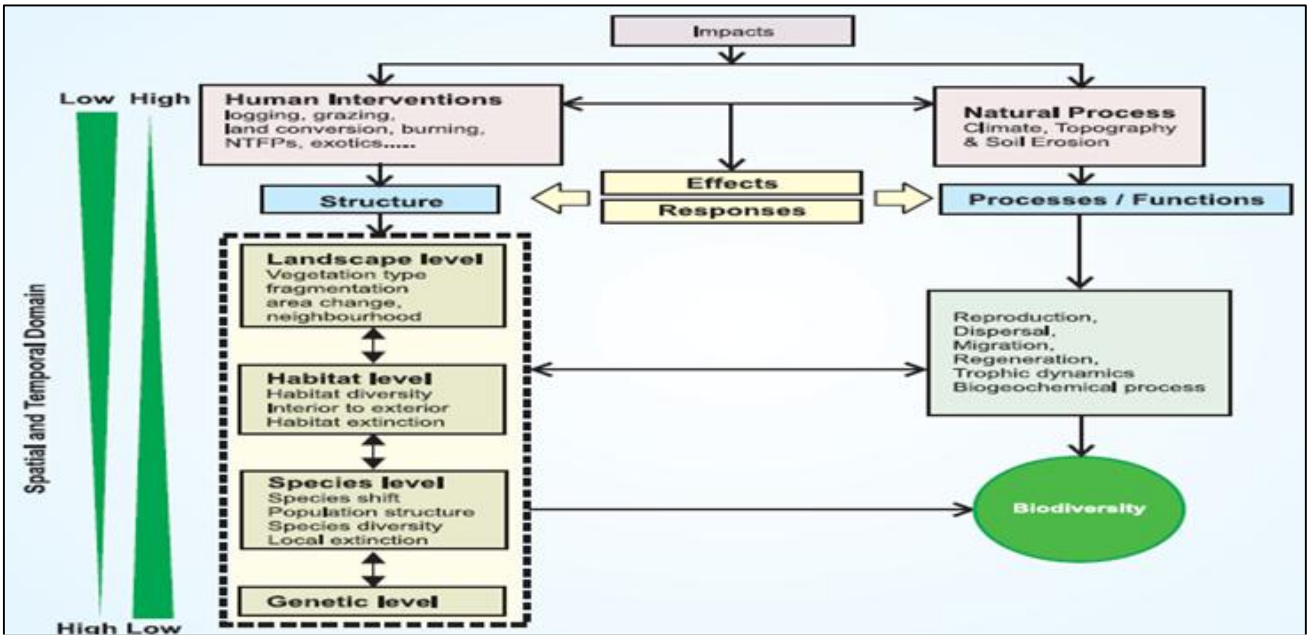

Fig 1: Components of biodiversity assessment (Roy, 2011) [39].

The current rate of tropical forest loss and disturbances has resulted in 5-10% loss of all forest species in one decade during the last quarter of the century (Roy *et al.,* 2001). Human actions must be considered as an integral part of ecological, environmental and evolutionary processes (Robertson and Hull, 2001) [34]. Proper documentation of biological diversity is essential for conservation and sustainable use of this natural wealth for the benefit of mankind (Tangeley 1990). In-situ conservation strategies emphasize the protection of ecosystems for conservation of the overall diversity of communities, populations, species, and genes and ecological processes, which are crucial to ecosystem services (Gupta *et al.,* 2003) [10]. Conservation of biological resource is of paramount importance for the economic development and sustenance of life support system not only for humans but also other organisms. It is a critical issue that the gene pool rich Indian subcontinent in general and India in particular are highly threatened due to the impact of globalization, climate change, and species loss. There is a need for a robust and quality database of the biological diversity at the species, community, ecosystem, and landscape levels for identification of the vulnerable ecosystems and risks to species (Roy *et al.,* 2012). Biodiversity and disturbance are hierarchical concept. A few studies were done in India towards establishing the relationship between disturbance and the biodiversity without (Pandey and Shukla, 1999) and with (Roy and Tomar, 2000) [35] landscape analysis. The patch characterization along with landscape parameters enables one to identify disturbance regimes. Besides, the biodiversity characterization of landscapes provides very important inputs for the prioritization of sustainable bioprospecting (Murthy *et al.,* 2006) [18]. The understanding of the priorities of biodiversity conservation and management has resulted in a shift of approach from conservation of a single species to habitats through interactive network of species at landscape level (Orians, 1993). [27] Vegetation types or ecological habitats possess spatial, physical, social, phytosociological, ecological and economical attributes (Behera *et al*., 2005) [6], and the information content of vegetation can be measured using species diversity (Burton *et al*., 1992) [5].

The Convention on Biological Diversity under its article has stressed that the signatories shall, as far as possible and as appropriate, identify components of biodiversity important for conservation and sustainable use, and monitor them. Various approaches and strategies have been suggested for the measurement of biodiversity at different levels and scales (Singh *et al.,* 1994) [6]. One of the approaches is assessing the pattern diversity and mosaic diversity at landscape level (Scheiner, 1992) [46]. There is also a need for identifying hotspots of change in the natural habitats of India. This will require revisiting the sample plots and recording the changes in the species frequency, density, abundance, IVI, etc. A national biodiversity monitoring protocol has to be evolved for this purpose. The biological richness and fragmentation map generated as part of the project Biodiversity characterization at landscape level (BCLL) will act as baseline data baseline database in identifying target areas and monitoring changes in Hotspot. Geospatial presentation of habitat status has become a key issue for planning conservation. Biodiversity characters of the habitat provide the basis of prioritizing the sites in conservation effort. Various methods viz., empirical, statistical and computational are now available for modelling wider spatial distribution patterns from the point records that field samples represent, but their reliability is also at least partly a function of the degree of spatial bias for the biodiversity conservation and monitoring. A paradigm shift in our approach to biodiversity quantification and documentation is required which would call for the amalgamation of landscape level (top down) and species level (bottom up) approaches (Roy *et al.,* 2012 Fig.2)

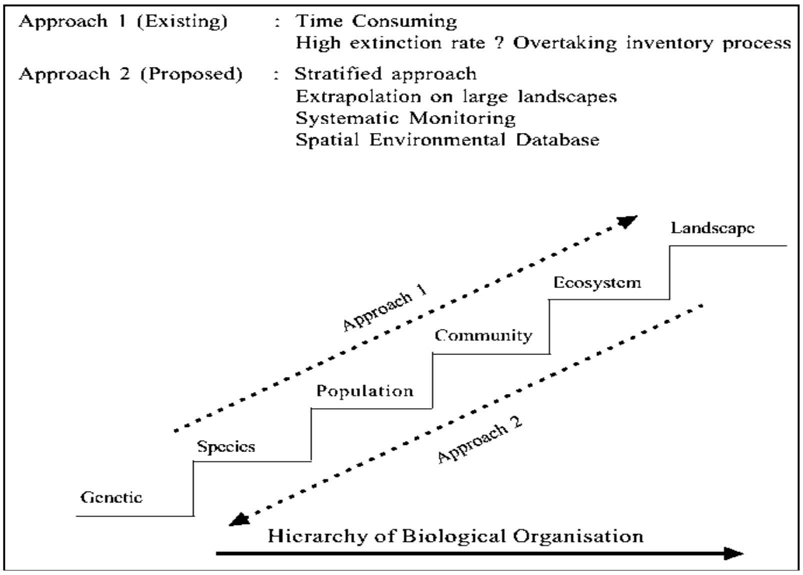

Fig 2: Approaches to study the biodiversity at different levels of biological organization (Roy *et al.,* 2012).

The need to preserve and sustain biodiversity for future generations will remain a significant challenge in the coming years. Biodiversity remains under threat throughout the world. Natural resources are being steadily depleted and ecosystems are under threat. In addition to the extinction of species, the degradation of local biodiversity also constitutes a threat to our well-being, economic growth, sustainable development and security in the short term. Dutch policy will therefore focus more than ever on preserving the goods and services that ecosystems provide and promoting their sustainable use.

Biodiversity conservation

Landscape ecology approach

The landscape approach for biodiversity characterization also addresses some of the limitations of ground based point inventory. The understanding of the priorities of biodiversity conservation and management has resulted in a shift on approach from conservation of a single species to habitats through interactive network of species at landscape level (Edwards *et al.,* 1994). Landscape ecology sought to understand the ecological functions of larger areas (Forman and Godron, 1986). In landscape ecology, biodiversity is considered an integral part of the broader concept of landscape heterogeneity for management and conservation. The landscape model calculates the Biological Richness (BR) and Disturbance Index (DI) (Karnatak *et al.,* 2007; Eq.1, 2). Biological Richness (BR) = ∫ {Ecosystem uniqueness, species richness or diversity, biodiversity value, terrain complexity and disturbance index}

$$BR = \sum_{i=1}^{n} (DI_i \times Wt_{i1} + TC_i \times Wt_{i2} + SR_i \times Wt_{i3} + BV_i \times Wt_{i4} + EU_i \times Wt_{i5}) \quad \text{Eq.1}$$

Where DI=Disturbance Index, BR=Biological Richness, TC=Terrain Complexity SR= Species Richness, BV=Biological Values, EU=Ecosystem Uniqueness, Wt=Weight.

$$DI = \sum_{i=1}^{n} (Frag_i \times Wt_{i1} + Por_{i} \times Wt_{i2} + Int_i \times Wt_{i3} + BD_i \times Wt_{i4} + Jux_i \times Wt_{i5}), \quad \text{Eq.2}$$

Where, DI = Disturbance Index, Frag = Fragmentation, Por = Porosity Int = Interspersion, BD = Biotic Disturbance, Jux = Juxtaposition Wt = Weights

In an effort to save biodiversity, several protected areas (Biosphere Reserves, National Parks and Wildlife Sanctuaries) have been earmarked. The landscape ecology approach departs from traditional approaches by focusing on the structure, function, and spatial patterns of landscape elements and on changes in the landscape mosaic through time. Fragmentation of ecological units have been well documented at landscape level using patch size, shape, abundance and forest matrix characteristics (Skole and Tucker, 1993) [47]. In landscape ecology approach, bio-diversity is considered as an integral part of the border concept of landscape heterogeneity for management and conservation. Furthermore, this approach has numerous applications to conservation planning because the total area, patchiness, and connectivity of ecosystems and habitats, and their representation in the protected area network are all important for biodiversity conservation. Daniels (1996) has demonstrated an application of the principles of landscape ecology to the conservation of birds in the heterogeneous and human altered landscape matrix of the Western Ghats.

Remote sensing Studies

The digital nature of land cover information from the satellite imageries allows us to analyze the landscape matrices and provides information at various spatio-temporal scales. Joshi *et al.,* (2006) [18] reveals that nearly 78–80% of plant species in Nubra are restricted to the valley bottoms and aspects of bioprospecting and conservation of valuable species used the IRS – 1D LISS III digital data set (path/row 96/45). Menon and Bawa (1997) [24] have discussed the role of remote sensing, GIS, and landscape analysis for biodiversity conservation in Western Ghats using land cover modelling approach. On-screen visual interpretation approach based on IRS LISS-III and Landsat TM data sets was used to delineate the vegetation communities. The landscape parameters, viz., fragmentation and disturbance index, clearly indicate that Nicobar Islands are less disturbed compared to Andaman. The plant communities of Andaman show high plant diversity in terms of number of species (523 species) and more heterogeneity compared to those of Nicobar (347 species). The community structure analysis revealed that the tropical forests in the islands are repository of many endemic, rare and threatened species with 523 (tree = 264, shrubs = 77, Herb = 107, epiphytes = 16 and climber = 79) vascular species recorded from Andaman Islands and 347 species in Nicobar Islands (Roy *et al.*, 2005; Table 1) [17].

Table 1: The distribution of unique (endemic, rare and threatened) species in the vegetation types in Andaman (AN) and Nicobar (NI) Islands

Vegetation types.	Number of species					
	Endemic		Rare		Threatened	
	AN	NI	AN	NI	AN	NI
Evergreen forest	64	36	25	7	1	-
Mixed evergreen forest	-	21	-	5	-	-
Seml-evergreen forest	48	-	22	-	3	
Moist deciduous forest	49	-	11	-	-	-
Lowland swamp forest	-	14		5	-	-
Windrows	5	5	5	2	-	
Littoral forest	10	22	2	3	-	-
Grassland	-	S	-	2	-	-

Source: Roy *et al.*, 2005 Eq.2 [17]

In their paper, (Roy, 2011) [17] forecast applications to biodiversity conservation as one of the areas in which remote sensing will play an important role in the future. Prasad *et al.* (1996) [28] used remotely sensed data and digital elevation and terrain data from the Mehao Wildlife Sanctuary in northeast India, to generate 3-D visualization of pheasant and taking habitats, hot spots of plant diversity, and areas vulnerable to human-induced changes. Sudhakar *et al., (2015)* [51] attempt has been made to prioritize areas of Biodiversity rich areas and rehabilitated RET (Rare, Endangered, Thread) species in Gudem-Saparla hilly tract in Visakhapatnam district, Andhra Pradesh (India) through geo-informatic techniques(Satellite data of Landsat MSS 1973 and IRS-1D LISS III of 2003) Integration of satellite data coupled with field data has resulted in generating Biodiversity Conservation Priority Zone Map (CPZM) for the entire area for identifying and delineate large continuous patch within the CPZM for management for decision making and implementation of Biodiversity conservation and rehabilitation programs in R V Nagar Forest Range, Visakhapatnam (Vizag) in Andaman Island Sharma *et al.*, 2001 [36].The recent advancement in the fields of Remote Sensing & Geographic Information System, mobile computing, GPS technology, wireless connectivity, and internet has enabled accurate and uniform documentation of biological diversity with revisit capability helping in identification of the hotspots of biodiversity and the gaps in biodiversity exploration. Biodiversity characterization at landscape level using satellite remote sensing (RS) and Geographical Information System (GIS) has been undertaken by the Department of Biotechnology (DBT) and the Department of Space (DOS) as an important initiative to develop baseline database with Patch size stratification of important landscapes The Eastern Ghats in India (Murthy *et al.*, 2008, Fig. 3) [16].

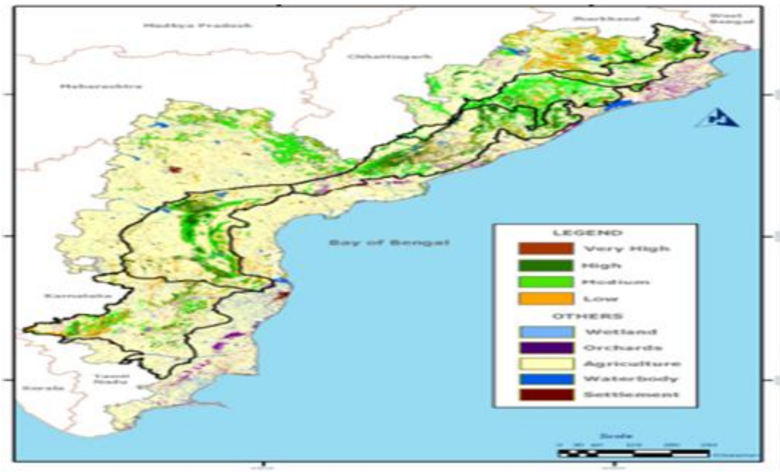

Fig 3: Biological Richness Map of Eastern Ghats, India (Murthy *et al.*, 2008) [16].

RS in conjunction with GIS technology can play a vital role in the monitoring and planning of mangrove forests, by multitemporal interpretation of satellite data in Bhitarkanika Wildlife Sanctuary. The land-cover system undergoes significant change according to the changes in socio-economic and natural conditions of the people. Agricultural practice is gradually increasing from 32,346 (1973) to 33,501 ha (1988) and reached 34,782 ha in 2004. A net change of 2436 ha area was observed due to conversion of dense and open mangrove forests to agricultural field by the surrounding villagers (Reddy *et al.*, 2007) [8].

Multicriteria Spatial Decision Support System (MC-SDSS)

MC-SDSS Multicriteria decision making (MCDM) and a wide range of related analytical techniques offer a variety of decision making processes to expose and integrate choices with available MCDM methods in order to solve “real-world” GIS-based planning and management problems. Multicriteria spatial decision support systems are part of a broader field of spatial decision support systems (SDSS). Several application specific frameworks for designing MCSDSS have been proposed (Jankowski *et al.*, 1997).A database structure and standard for Indian biodiversity database is designed, which can be used for the development of SDSS or related information systems. The developed web based SDSS, i.e., Biocons SDSS, provides an interactive GIS environment in thin as well as thick client for basic GIS operations and querying. The Multicriteria Spatial Decision Support System (MC-SDSS) software development uses AHP, ASP, Arc IMS 9.0, ArcSDE9.0 and Oracle 9i data server in the web GIS environment system has been demonstrated for biodiversity conservation and priorities by the following spatial layers have been taken as criteria maps in the present study Ecosystem uniqueness, Terrain complexity, Species richness, Disturbance Index, Biodiversity value, (Karnatak *et al.,* 2007, Fig. 4).

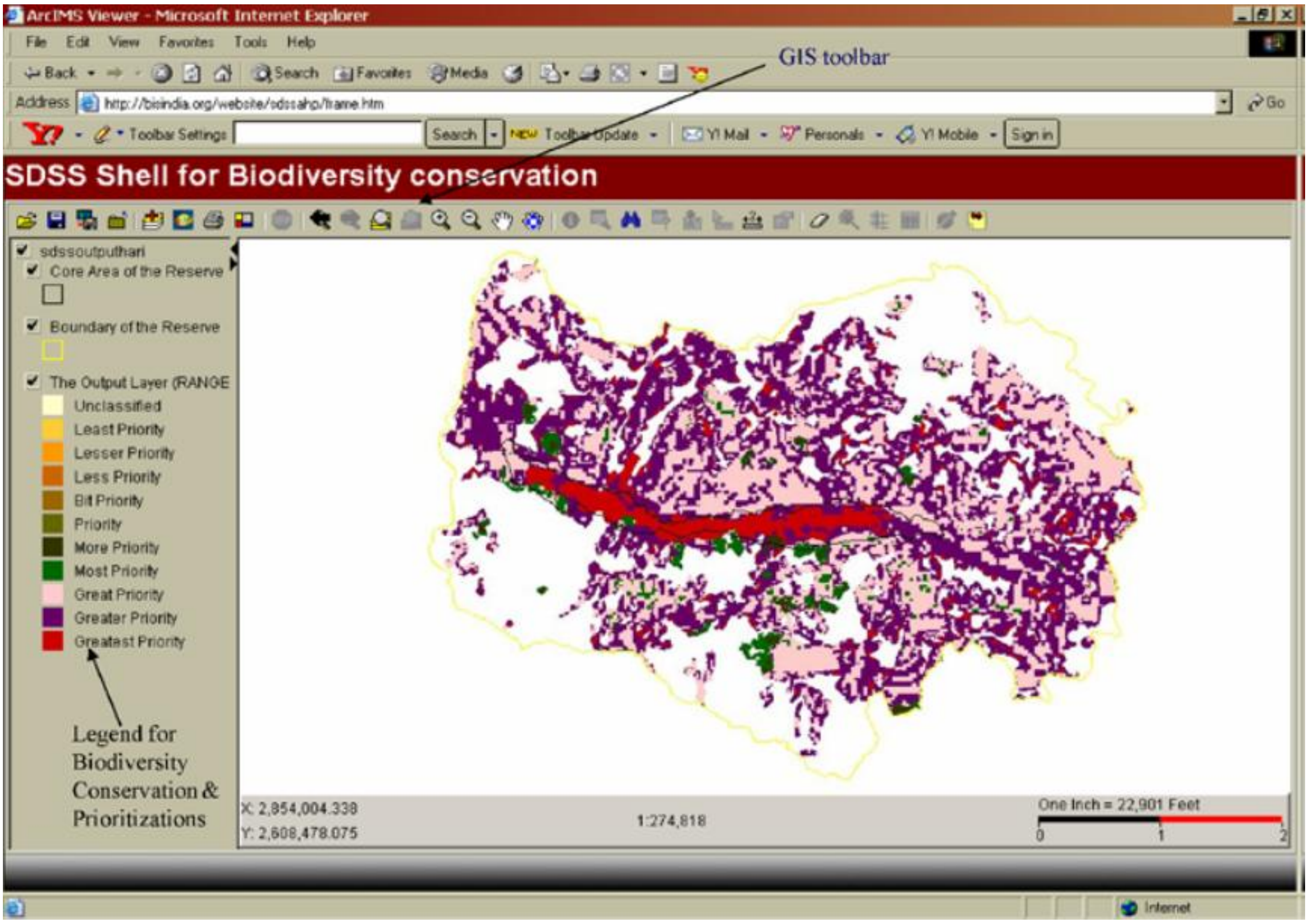

Fig 4: SDSS map (derived) with legend (Karnatak *et al.*, 2007).

The developed Web-SDSS is an integration of the landscape model developed by (Roy and Tomar, 2000) [35] and multicriteria decision analysis technique AHP (Saaty, 1980) to address the semi-structured problem with various degrees of uncertainty on biodiversity with the various parameters viz. patch shape, patch size, number of patches, porosity, fragmentation and juxtaposition calculation was based on subjective judgement. Multicriteria spatial decision support system (named Biocons SDSS) is demonstrated for small areas, i.e., Nokrek Biosphere reserve forest of Meghalaya State of Northeast India, but can be implemented for other areas.

Biodiversity Information System (BIS)

The Biodiversity Information System aims to provide user level information regarding the Biodiversity hotspots. However, it was felt that in addition to Biodiversity Characterization information it should also cater to decision making, monitoring and management of various resources (Roy and Saran, 2004). The components are described as follows:

- BIOSPATIAL (Biodiversity Characterization at Landscape Level)
- BIOSPEC (Bioprospecting and Molecular Taxonomy Programme: Bioprospecting Query Shell)
- BIOCON (Spatial Decision Support System)
- FRIS (Forest Resource Information System)
- Phyto-SIS (Plant Species Information System)
- Online decision support OLAP (online analytical processing)

Roy and Saran (2004) [23] present an approach to organize spatial and non-spatial data into a Biodiversity Information System (BIS) for North East India using multicriteria analysis in web GIS. Landscape analysis for determining the parameters like fragmentation, porosity, proximity, and other patch characteristics, have been used to derive disturbance index using proximity from settlements and roads. It is a step to evolve with new a mechanism to conserve biological diversity at local, regional and national level.

Modelling deforestation

GEOMOD2 is a spatially explicit model which simulates future land-use change based on either a statistical analysis of how people have used land in the past or alternative hypotheses of how people will use land in the future (Hall *et al.*, 1995). The model uses maps of land-cover and land use types along with a set of driver maps (elevation, aspect, slope, precipitation, soil, transportation network, rivers, biogeographic zone, and protected areas). GEOMOD2 is calibrated using the land use map from one point in time.Mechanistic modeling mainly deals with terrestrial ecosystem structure and function. These models are based on current understanding of energy, biomass, carbon, nutrient and water relations, and their interacting dynamics with and among species from projections of future vegetation structure (Fischlin *et al.*, 2007) [12]. Extrapolated to global scale, these are termed Dynamic Global Vegetation Models (DGVMs). Giriraj (2008) [16] showed the distribution of endemic and edge species, land cover heterogeneity and continuity of patches in these clusters and these were evaluated to understand the degree of disturbance at the landscape scale by GEOMOD S/W predicted for year 2020 using the current disturbance scenario in Kalakad- Mundanthurai Tiger Reserve (KMTR), Southern Western Ghats (India).

Spatial Landscape Analysis Modelling (SPLAM)

SPLAM is a program generated for the analysis of porosity, interspersion, fragmentation, juxtaposition, terrain complexity, disturbance index and biological richness. SPLAM is developed over ARC/INFO GIS and provides facilities for display, overlay, integration, analysis, statistics and landscape modelling. It is a unique bundle of three major components, viz., landscape analysis, predictive modelling and conservation prioritization, whereas the initial version had only landscape analysis (Chandrashekhar *et al.*, 2003) [7]. In SPLAM, user-friendly graphic user interface (GUI) has been provided which helps the user to execute the functions of data handling and management. It provides options for certain basic querying on the processed layers, a viewer with display option, statistics and management of displayed files. (Roy and Tomar 2000) [35] using spatial landscape analysis modelling (SPLAM) to assess biodiversity characterisation at landscape level (BCLL). Roy *et al.*, (2013) [6] used Cloud-free IRS 1C, 1D and P6 LISS-III satellite data (spatial resolution 23.5 m) and moving window approach to identify potential areas of forest fragmentation in the Indian landscape using customised software, SPALM for the purpose (Roy *et al.*, 2005) [18]. Thus development appears to act in conflict with bio diversity conservation and other patch characteristics. It can also be used to identify the core areas of a forest for conservation. Reddy *et al.*, (2008) [16] using SPALM with geospatial techniques provides insight into the disturbance status and biological richness of forest of SBR, Orissa, which is useful for forest management and biodiversity conservation. The results show that the high disturbance regimes cover 14.75% of the total forest area, whereas 39.12% of the area comes under low biological richness area (Fig.5).

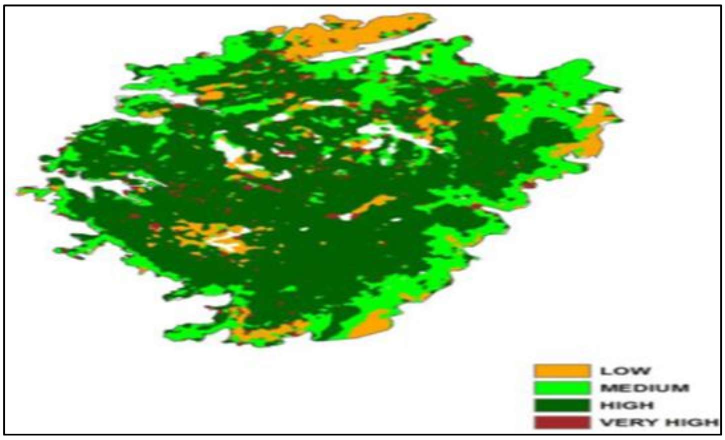

Fig 5: Biological richness map of SBR, Odisha (Reddy *et al.*, 2008) [16]

Roy *et al.*, (2013) first attempt by SPLAM which resulted in spatial database information (disturbance Index, fragmentation, Biological Richness) on vegetation types, porosity, patchiness, interspersion, juxtaposition, fragmentation, disturbance regimes, ecosystem uniqueness, terrain complexity and the species richness for biodiversity conservation. The range of the biological richness index is 0-100 and have been categorized as low (17-33), medium (34-49), high (50-69), and very high (70-91). Models are used in several ways to understand the dynamics of hierarchically structured, heterogeneous landscape systems. Simulated (neutral) landscape models (Gardner *et al*., 1987) [14] have been used to investigate the role of patch-scale and landscape-scale variables using ecosystem patterns and processes. William *et al*., (1998) [54] developed core area models to study the edge and core dynamics. Spatial Landscape Modeling has been developed (Roy *et al*., 2006) [18] to study landscape level disturbance and biological richness, and ecological niche models to decipher species level potential niche patterns (Pearson *et al*., 2004). Recently macro ecological (Gaston, 2000) and metabolic theory models (Allen *et al*., 2006) [3] have been developed to study regional and global patterns of environment and species richness.

Future Challenge

Metabolic Theory of Ecology (MTE) comprising global biodiversity, biochemical kinetics and the energetic equivalence rules is being developed to predict various aspects of the structure and functioning of ecological systems (Allen *et al*., 2002) [1]. Several concepts and models addressing the above aspects of species richness and ecosystem processes are at an experimental stage. Environment richness regression models, based on macro ecological diversity theory are found making reliable spatial predictions of diversity patterns. If these empirical theories capture true functional relationships between environment and diversity, then they should make consistent predictions through time as well as space and could complement individual species-based predictions (Adam *et al*., 2009) [4].

Importance in Conservation and sustainable management

Globally, efforts are being made in this direction through various conventions and the formulation of a strategy for sustainable development. In the recent past, many nations and regions have been involved in developing their own biodiversity strategies and action plans. The database contributes to biodiversity conservation planning and to identifying vulnerable areas of economically important species for effective protection. The database created in the GIS domain is versatile in that it can be updated and compatible with future inventory programs. This database could also support the gene to landscape approach of conservation (CBD, 2010; Fig.6) [8].

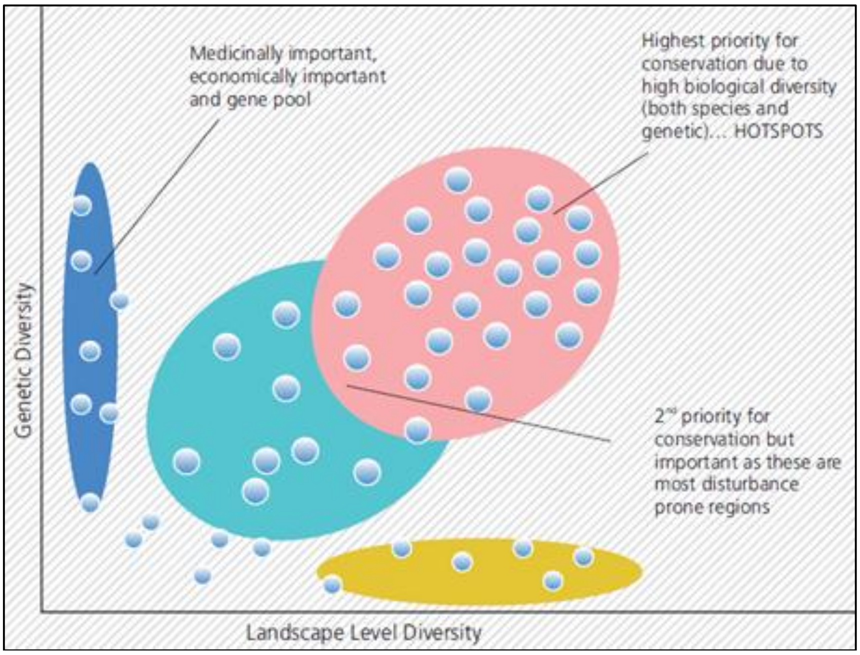

Fig 6: Approach to conservation prioritization (gene to ecosystem), (CBD, 2010) [8]

The database also has the potential to be used to identify potential habitats or potential niches of endemic and threatened species (Irfan-Ullah *et al.*, 2006) [18]. The database of the type of map, along with the fragmentation and biological richness maps, will give a clear idea about the areas where future botanical exploration should be carried out (Reddy *et al.*, 2008; Fig. 7) [8].

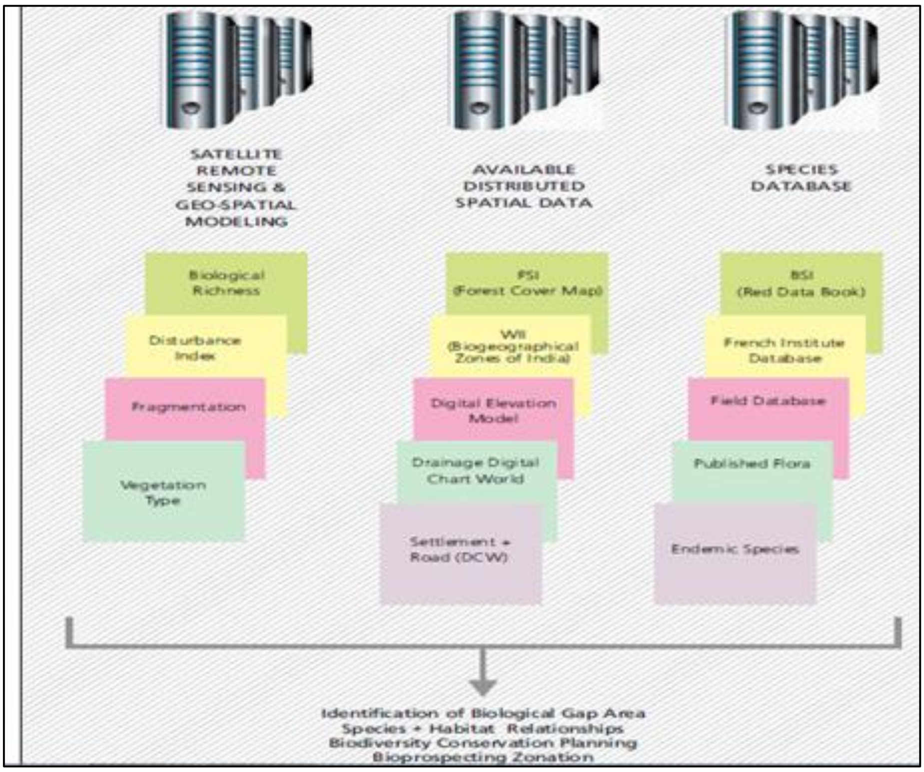

Fig 7: Geospatial framework for monitoring and conservation (Reddy *et al.*, 2008) [8]

The approach 'from gene to ecosystem' was initiated as a Research Agenda for Biodiversity, IUBS/SCOPE/UNESCO, Paris (Solbrig, 1991) [44]. The agreed upon text of the CBD was adopted by 101 governments in Nairobi in May 1992, signed by 159 governments and the European Union at the United Nations Conference on Environment and Development (UNCED) held at Rio de Janeiro in June 1992. At present, 174 governments are parties to this convention. The priorities address the needs of the CBD and of many conservation programmes aimed at protecting biodiversity, as well as focusing on many national research programmes dedicated to developing biodiversity science (Walther *et al.*, DIVERSITAS, 2011).There is an important emerging effort to supply just such a system of book keeping of the status of our natural capital, this is the proposed Global Observation System of Systems in the task area of biodiversity (GEO-BON), (Scholes *et al*., 2008; Fig. 8)

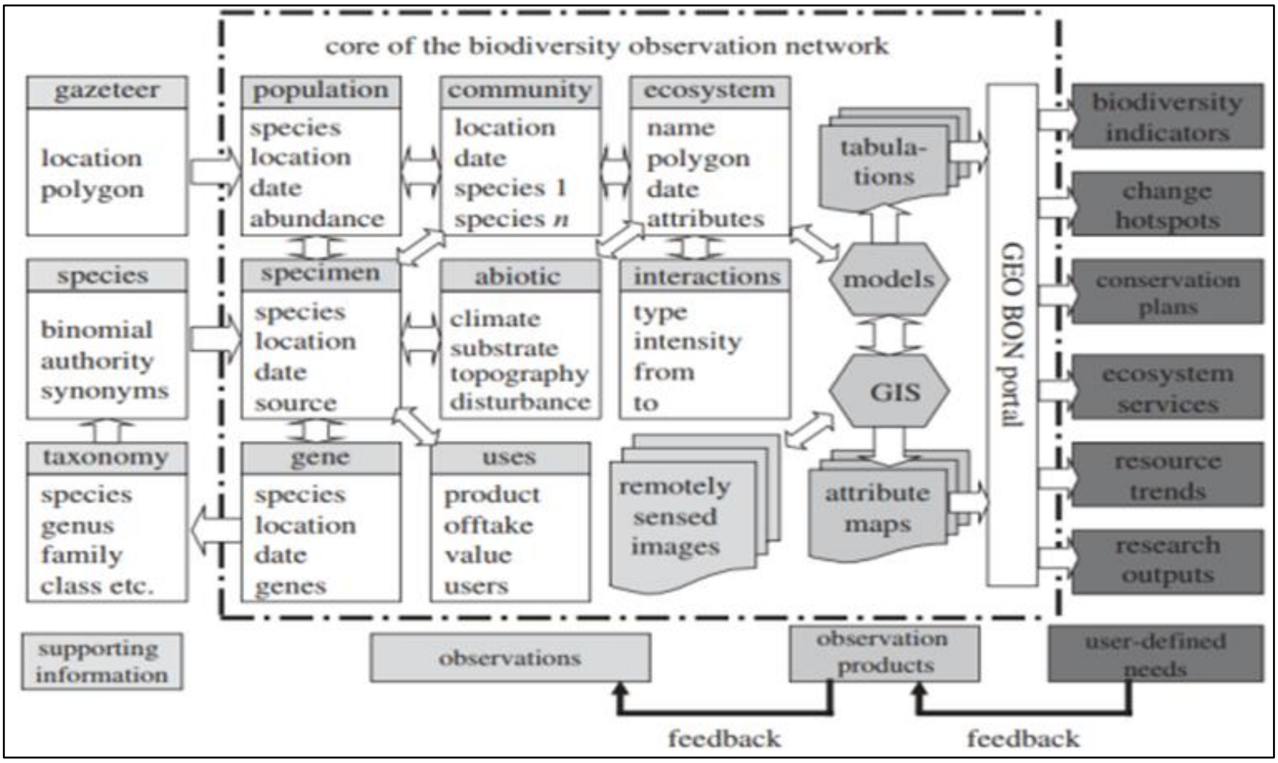

Fig 8: The structure of a proposed Global Biodiversity Observation System (Scholes *et al.,* 2008).

The complexity priority setting varies considerably due to complexity of biodiversity and the number of ways of valuing it. Among the biological criteria are richness (the number of species or ecosystems in given area), rarity, threat degree of harm or danger), distinctiveness (how much a species differs from its nearest relative), representiveness (how closely an area represents a defined ecosystem) and function (the degree to which a species or ecosystem affects the ability of other species or ecosystems to persist).utility, the most common non bio-logical criteria, points to biodervisity elements of known or potential use to humankind.

Conclusion

Biodiversity is a natural wealth of a nation, for which accounting and auditing is of paramount importance for intellectual property characterization and its conservation. Proper documentation of biological diversity is essential for conservation and sustainable use of this natural wealth for the benefit of mankind. Wide dissemination and an open software environment for further value addition by integration with other data set available with knowledge institutions service. RS and GIS can be used to managed this limited resources in an effective and efficient manner. Geospatial data are effective in the analysis and determination of factors that affect the utilization of these resources. In the coming decades, dissemination of this archived information, along with its associated knowledge base, will help in conservation and sustainable use of biological resources for the benefit of mankind. The database created in the nation-wide project on Biodiversity Characterisation at Landscape Level will act as a surrogate for the conservation and sustainable management of the natural resources. It may be finally concluded that the adopted methodology is a rapid and predictive approach for efficient biodiversity assessment and monitoring.

Thus, with the understanding of these factors, sound decisions can be arrived at that will ensure the sustainable use natural resources to meet the needs of the present generation as well as future generations.

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