Geoinformatics for Landscape Ecology and Biodiversity Research

Giriraj Amarnath[1, 2*], Birendra Bajracharya[2] and Basanta Shrestha[2]

[1]*International Water Management Institute (IWMI), Colombo, Sri Lanka*

[2]*International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal*

Abstract

This review paper evaluates the potential of remote sensing for assessing landscape and species diversity in mountainous terrain. Understanding the complex mechanism of biodiversity necessitate its spatial and temporal dynamics and synergetic adoption of measurement approaches with long-term plot inventories. In view of this, importance of geoinformatics - which can be seen as a combination of integrating tools such as Geographic Information System (GIS), satellite remote sensing, Global Positioning System (GPS), and information and communication technologies, are realized as complimentary systems to ground-based studies. This paper addresses how wide range of geospatial tools can be used in monitoring and assessment of biodiversity. Further discussions are made on the wide variety of landscape ecological application tools, and the required data from broad spatial extents that cannot be collected through field-based methods. Remote sensing data and techniques address these needs, which include identifying and detailing the biophysical characteristics of species' habitats, predicting the distribution of species and spatial variability in species richness, and detecting natural and human-caused changes at scales ranging from individual landscapes to the entire world.

Key words: Remote Sensing, GIS, Biodiversity, Landscape Ecology.

1. Introduction

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. Global Biodiversity Assessment (Heywood *et al*., 1995; Gaston 2000) estimates the total number of animal and plant species to be between 13 and 14 million. It further records that so far only 1.75 million species have been described and studied (Heywood *et al*., 1995). Incidentally, many of the species are getting extinct even without being recognized their presence and importance in the ecosystem.

For many of the conservation ecologists, question remains unclear to estimate species richness, as there is rapid decline in species diversity. Scientifically sound environmental management requires frequent and spatially detailed assessments of the species diversity and distribution. Such information can be prohibitively expensive to collect directly. Measuring the distribution and status of biodiversity remotely, with airborne or satellite sensors, seems to be an ideal way to gather these crucial data (Gross *et al*. 2009; Menon and Bawa, 1997; Noss, 1990; Tuner *et al*., 2003). This remote sensing based information on vegetation and land cover provides a potential spatial framework and works as one of the vital input layers in assessing and monitoring biodiversity (Table 1). The major issues taken in consideration in the present review paper includes: (i) How far remote

©2012 AARS, All rights reserved.

* Corresponding author: a.giriraj@cgiar.org; gudugiri@gmail.com
Phone: +94-11-2880000 Fax: +94-11-2786854

Table 1. General framework for assessing and monitoring biodiversity using geospatial techniques

Potential areas	Scale and type of measurement	Examples
Changes in vegetation and land use type, landscape transformation	Landscape (remote sensing) and stand (direct measurement)	Tropical rain forest conversion to transition forest, agriculture
Stratification for optimal ground sampling and assessment of diversity	Direct stand-level measurements for most indicators; remote sensing for some (e.g. gaps)	Systematic monitoring of plots for biodiversity conservation
Landscape analysis for forest fragmentation and neighborhood analysis	Landscape-scale direct measurement using remote sensing with limited ground-truthing	Landscape analysis as a tool for the scientific management of biodiversity
Delineation of broader vegetation types and analysis of species assemblages along with ancillary data	Landscape and habitat-scale measurements using remote sensing; surveys for identification of ecologically important species	Feasible way to monitor habitats with limited ground measurements
Identification of homogenous and threatened species and inputs for species habitat models	Habitat-scale and measurements using ground-truthing for model distribution trend	Potential areas for habitat restoration
Spatial delineation of biological rich area	Landscape-scale (remote sensing) and stand-level measurements; survey of endemic species	Helps to identify biodiversity conservation corridors

sensing data is being considered as an effective tool in monitoring and conserving biodiversity? (ii) Is it possible to detect individual species or extent of habitat that are necessary to estimate the distribution of species, levels of species richness, or the structure of ecological communities?

2. Geoinformatics for Biodiversity Assessment

Geoinformatics combines geospatial analysis and modeling, development of geospatial database and information systems using satellite remote sensing, GIS, in-situ and models. The holistic understanding of the complex mechanisms that control biodiversity, as well as their spatial and temporal dynamics, requires synergetic adoption of measurement approaches, sampling designs and technologies (Gross *et al*. 2009; Menon and Bawa, 1997; Murthy *et al*., 2003, 2006; Tuner *et al*., 2003). These technologies include Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning System (GPS). The wide range of remote sensing satellite data having different spatial and temporal resolutions in generating inputs for assessing the biodiversity are given in Table 2 and Figure. 1. It is very clear for managing and conserving biodiversity that the data requirements are both of spatial and non-spatial nature and also of various time scales. The list of various parameters required for biodiversity assessment and their amenability for measurements by geospatial techniques is given in Table 2. Key task of geoinformatics applications are spatial inventory and modeling, natural resources and environmental management and biodiversity conservation. A comprehensive review of RS and GIS applications in biodiversity conservation was compiled by Gross *et al*. (2009), Joshi *et al*. (2009) and Roy (2003).

Giriraj *et al*. (2008) and Phillips and Dudik (2008) employed GIS and ecological niche modeling tool to predict species distributions with presence-only data. Giriraj *et al*. (2009) and Nagendra and Gadgil (1999) used GIS methods to integrate biodiversity information and the vegetation maps with existing spatial environmental data to establish priority areas for biodiversity conservation of the Western Ghats, India. The method provided a novel cooperative mechanism to aid spatial knowledge management and building consensus between remote sensing inputs and field observation on biodiversity conservation. Similarly, Chettri *et al*. (2007) used satellite remote sensing and GIS to identify conservation corridors in the protected area system of Eastern Himalaya region. The results addressed the conservation issue by promoting participatory reforestation and development of trans-boundary landscape corridors, which helps in conserving biodiversity with sustainable use of resources by local communities. On global to local scales, the only feasible way to monitor the Earth's surface is to prioritize and assess the success of conservation efforts through remote sensing (Murthy *et al*., 2003). Currently a suite of remote sensing satellites, having various resolutions, is available to generate spatial information on vegetation and land cover from global to local level (Table 3 and Figure. 1).

2.1 Remote Sensing and GIS for Landscape Analysis

The landscape analysis combines satellite remote sensing data along with GIS and *in-situ* observation in the study of management, and conservation of natural resources. Habitat loss and forest fragmentation strongly influence biodiversity conservation in landscapes that has intense land use changes.

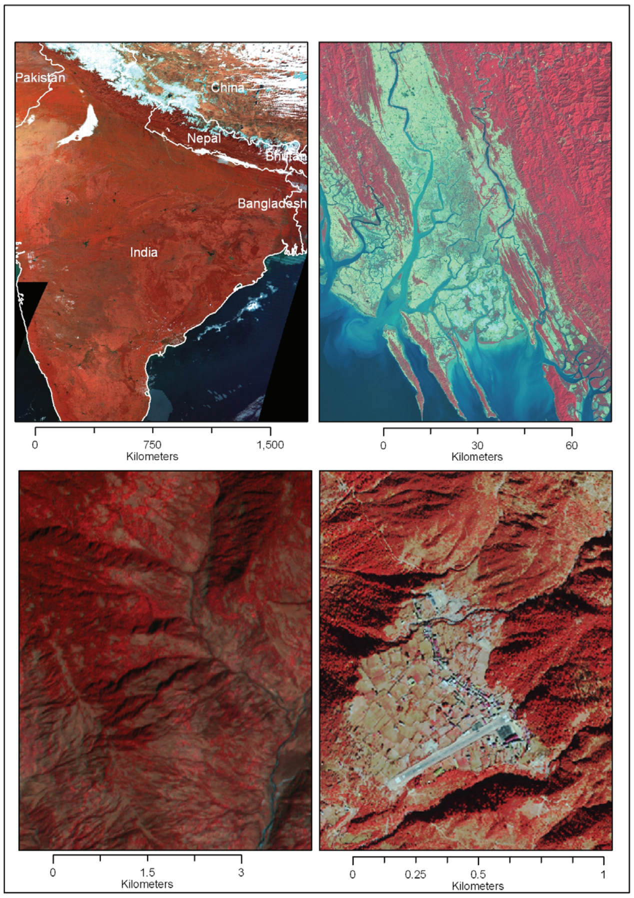

Figure 1. Satellite sensors using false colour composite image in the Hindu Kush-Himalayan region. a) MODIS Terra coarse resolution data showing wide-range of ecosystems b) LANDSAT medium resolution image for the Chittagong hill tracts, south-eastern Bangladesh c) ASTER high resolution image in the north-east of Jiri, Nepal showing mosaic of grassland and vegetation types d) IKONOS very high resolution image for the Lukla airport and surrounded by Pine and Juniper tree species with grass and shrubs

Several attempts have been made to use landscape structure metrics to quantify the independent and joint effects of these processes (Barbaro *et al*., 2007; Torras *et al*., 2008). There is a strong relationship between landscape structure and ecological processes; objectively quantifying spatial landscape structure remains an important aspect of landscape ecology (Turner, 1989). A large number of metrics and indices have been developed to characterize landscape composition and configuration based on categorical map patterns (McGarigal *et al*., 1995). These metrics are used to analyze landscape structure for a wide variety of applications, including quantifying landscape change over time (O'Neill *et al*., 1997), relating landscape structure to ecosystem (Wickham *et al*., 2000), population and meta-population processes (Fahrig, 2002; Kareiva and Wennergren, 1995). Arguably the major application of landscape structure metrics has been assessing effects of habitat loss and fragmentation on landscape connectivity (Neel *et al*., 2005).

2.2 Forest Fragmentation

Forest fragmentation is considered as one of the greatest threats to global biodiversity because the forests are the most species-rich of terrestrial ecosystems (Armenteras *et al*., 2003; Chai *et al*. 2009; Soulé, 1986; Steininger *et al*. 2001;). The complex process of fragmentation and forest loss is a common phenomenon in tropical and temperate forests, and apart from forest degradation it also brings about several physical and biological changes in the forest environment (Cordeiro and Howe, 2003; Giriraj *et al*., 2010; Jha *et al*., 2005; Skole and Tucker, 1993). These two processes may have negative effects on biodiversity, increasing isolation of habitats, endangering species, modifying species' population dynamics, and expanding at the expense of interior habitat (Giriraj *et al*., 2009) and with the increased rate of deforestation, timber extraction and encroachment had exposed catchments to flash floods and landslides. As an example in Khola watershed of the Dolakha district of Nepal (Figure. 2) figure explains clearance of forest degradation

Table 2. Components of biodiversity addressed using geoinformatics tools and ground measurements (modified from Murthy *et al*., 2003)

	Parameters	Remote sensing	Ground Measurement / GPS	GIS (Derived / Integrated Spatial layer)
A	**Human interventions**			
	Logging and Grazing		✔	✔
	Wildfires	✔	✔	✔
	Natural resources extraction		✔	✔
	Agriculture / Plantation	✔		
	Encoarchment / Clearances	✔	✔	
B	**Natural Process**			
	Climate		✔	✔
	Erosion	✔	✔	✔
	Topography	✔	✔	✔
	Soil	✔	✔	✔
C	**Structure and Function**			
	Vertical stratification	✔	✔	✔
	Canopy gap and profile	✔	✔	✔
	Stand density and Volume		✔	
	Standing and fallen dead wood		✔	
	Trophic dynamics		✔	
D	**Landscape level**			
	Vegetation type and extent	✔		
	Landscape diversity	✔		✔
	Species diversity		✔	✔
	Patch characterization	✔		✔
E	**Habitat level**			
	Species assemblages	✔	✔	✔
	Species diversity		✔	✔
	Interior to exterior habitat	✔	✔	✔
	Habitat extinction		✔	✔
F	**Species level**			
	Potential distribution	✔	✔	✔
	Reproduction		✔	
	Dispersal		✔	
	Regeneration		✔	
	Migration		✔	
	Local extinction		✔	

Presence of ticks in single, two, all columns indicate individual and synergistic approaches

Table 3. Satellite data (sensors, revisit time, spatial resolution) for the utility biodiversity assessment. Table also describes for wide range of biodiversity application necessary mapping scale and costs is suggested (modified from Turner *et al*. 2003)

Ecological Variables	**Sensors Space (S) / Airborne (A)***	**Spatial resolution**	**Revisit time**	**Spectral resolution**	**Description**	**Coverage**	**Mapping scale**	**Monitoring cost**
Approach : Direct								
Species composition	ALI (S); HYPERION (S); ASTER (S); IKONOS (S); IRS-LISS-IV (S); Quickbird (S); AVIRIS (A); CASI (A)	<1-30m	16 days (ETM, ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird); 5 days (IRS) N/A for aircraft	V/NIR, SWIR, ASTER also has TIR	These sensors can be used to map individual or homogenous speecies, measure canopy structure and density, generated species spectral signature, adds input to species modeling system	Landscape to local scale	1: 1000 scale	Very high
Land Cover	MODIS (S); TM/ETM+ (S); ASTER (S); ALI (S); IKONOS (S); Quickbird (S); IRS P6 LISS-III, AWiFS; RISAT; MERIS	1–1000 m	1–2 days (MODIS); 16 days (TM/ETM +); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODIS and ASTER also have TIR	Can discriminate different land surfaces at various resolutions; land cover classification is considered a first-order analysis for species occurrence	Global or regional level	1:5000 to 1:1 M scale	Low to High
Approach: Indirect								
Primary Productivity								
ChlorophyII	SeaWIFS (S); MODIS (S); ASTER (S); TM/ETM + (S); ALI (S); Hyperion (S); IKONOS (S); Quickbird (S); AVIRIS (A); CASI (A); MERSI	1–1000 m	1 day (SeaWiFS); 1–2 days (MODIS); 4–16 days (ASTER); 16 days (TM/ETM +, ALI, Hyperion); 2–5 days (IKONOS); 2–4 days (Quickbird); N/A (AVIRIS, CASI)	V/NIR, SWIR, MODIS and ASTER also have TIR	Applications involving global and regional mean chlorophyll biomass mapping and estimation for productivity assessment, measure reflectance to assess presence/absence of vegetation and enabling detection of ocean and land surface chlorophyll	Global or regional level	1: 50,000 to 1: 1 M scale	Low to High
Ocean Color and Circulation	TOPEX/Poseidon (S); AVHRR (S); MODIS (S); SeaWiFS (S); IRS P3 OCM	1-10km	10 days (TOPEX/Poseidon); 1 day (AVHRR); 1–2 days (MODIS); 1 day (SeaWIFS)	TOPEX/Poseidon; (microwave) AVHRR; MODIS, SeaWiFS; (V/NIR, SWIR) MODIS and AVHRR also have TIR	Circulation patterns can be inferred from changes in ocean color, sea surface height, and ocean temperature, important for understanding larval transport and movement of pathogens and sediment	Global or regional level	1: 1 M scale	Low
Climate								
Rainfall	CERES (S); AMSR-E (S); RADARSAT; TRMM; NOAA Rainfall Estimates	20-56km	1–2 days	Microwave	Enable detection of precipitation and surface moisture at coarse resolutions; such data parameterize models of species occurrence based on drought tolerance	Global or regional level	1: 1 M scale	Low
Soil Moisture	AMSR-E (S)	5.4–56 km	1-2 days	Microwave	Can be estimated over rel. large areas; data parameterize models of species occurrence based on moisture requirements	Global or regional level	1: 1 M scale	Low
Phenology	MODIS (S); TM/ETM + (S); ASTER (S); ALI (S); HYPERION (S); IKONOS (S); Quickbird (S)	1–1000 m	1–2 days (MODIS); 16 days (TM/ETM + ; ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODISand ASTERalso have TIR	Global mapping of phenology for monitoring vegetation response to climate change. Provides for identification of species tied to certain phenological events	All levels	1:5000 to 1:1 M scale	Low to High
Habitat Structure								
Topography	SRTM (S); ATM (A); ASTER (S); IKONOS (S); SLICER (A); LVIS (A); Cartosat I & II	90 m SRTM;30 m/15 m ASTER;1–1 5 m IKONOS,SLICER, LVIS	N/A (SRTM);4–16 days (ASTER);2–5 days (IKONOS);N/A (SLICER, LVIS)	Microwave SRTM;V/NIR and SWIRfor others	Digital elevation models derived from radar signals via interferometry (SRTM); image stereo pairs (ASTER / Cartostat) or discrete-return (usually) LIDAR signals. Many species are constrained by microhabitats resulting from changes in altitude; elevation also determines watershed flows	All levels	1:5000 to 1:1 M scale	Medium
Vertical canopy structure	SLICER (A); LVIS (A)	1–10 m	N/A (SLICER, LVIS)	V/NIR	Provides 3D measurements via laser pulses; provides biomass estimates and information about vegetation structure	Landscape to local scale	1:1000 Scale	High

and fragmentation which will have direct consequences on adjacent forest patches and the composition of habitats. The ecological consequences of fragmentation may differ depending on the patterns of spatial configuration imposed on a landscape and how it varies both temporally and spatially (Armenteras *et al*., 2003). Therefore, an understanding of the relationship between landscape patterns and the ecological processes influencing the distribution of species is required by resource managers to provide a basis for making land-use decisions.

Land use and land cover is a fundamental variable that impacts forest fragmentation and isolation of habitats, which is being linked with human and physical environments. While the importance of human activities is widely recognized, the relative influence of human activities on environmental factors is less understood. Remote sensing is the only feasible way to map forest fragmentation from regional to global scales. Improvements in technology and availability of imagery are rapidly increasing the importance of the field in many areas including forest ecosystem monitoring. However, land cover maps indicate only the location and type of vegetation, and further processing is needed to quantify and map forest fragmentation. These attributes can be quantified in the form of mathematical descriptors, referred to as metrics (Gustafson, 1998). Riitters *et al*., (2000) provided a useful mathematical summary of 55 such metrics. In addition, a public-domain software packages like FRAGSTATS (McGarigal *et al*., 1995), BioCAP (BioCAP, 1999), UTOOLS (McGaughey and Ager, 1997), ATtILA (Ebert and Wade, 2004) are available for computation of numerous metrics and have been extensively used by the landscape ecology community. Several authors have used these tools to provide reliable means of ecosystem monitoring and biodiversity conservation (Giriraj *et al*., 2009; Günlü *et al*., 2009; Neel *et al*., 2004; O'Neill *et al*., 1995; Roy and Joshi, 2002; Wickham *et al*., 2007). Finally, for the fragmentation assessment of a landscape, it requires incorporation of landscape metrics using satellite analysis of land-cover changes and the processes driving the changes. In addition, the direct linkage of geographical information system (GIS) technologies with remote sensing and

Figure 2. Forest degradation and fragmentation at landscape level in the Mid-hills of Nepal (left top); steep slopes in Yarsha Khola landscape, where forest areas are cleared for agricultural practices (left below) and the high-resolution satellite imagery from Google Earth showing large-scale forest fragmentation observed for northeast region of India

landscape ecology research allows us to integrate spatial land-cover patterns and ecological processes in a manner which is essential for the understanding of processes of change (Forman, 1995; Turner, 1990).

2.3 Remote Sensing for Habitat Analysis

Remote sensing based habitat maps in conjunction with information on species–habitat associations are generally being used to derive information on the distribution of species, although a few exceptions may exist. The degree of correspondence between habitat maps and species distributions depends on the degree of habitat map generalization, and this could be optimized to get maximum information of species diversity (Coops and Catling, 1997; Stoms, 1992). Habitat maps appear to be capable of providing information on the distribution of large numbers of species in a wide variety of areas; however, this is restricted to the spatial scale to tens of square kilometers. In smaller, local areas with limited species diversity, direct mapping can provide detailed information on the distribution of certain canopy tree species or associations. Satellite datasets from IRS, Landsat, SPOT and ASTER have been used effectively in mapping the homogenous plant colonies with prior knowledge of their occurrence, and the vegetation types of the area using remote sensing techniques (Roy *et al*., 2001; Wabnitz *et al*., 2008). Studies have reported on the use of hyper spectral image data for differentiation of species (Hirano *et al*., 2003) as well as discrimination within conifer species (Gong *et al*., 1997) and several tropical species (Cochrane, 2000).

Mapping habitats requires information on species composition and indicators that include canopy cover, stand density, topography, soil type and reflectance properties of vegetation type to characterize individual species or homogenous system using satellite remote sensing data are a complex process. In areas where vegetation structure varies greatly, species differences may predominate in imagery (Giriraj *et al*. 2009). The remote sensing data may then prove less suitable for determining species composition and delineation of specific vegetation types and habitats. Patterns of species distribution on the ground have been shown to be associated with the distribution of environmental variables, such as topography, precipitation, soil and geomorphology type, and levels of disturbance. In such cases, a GIS model based on elevation, slope, aspect, and proximity to water source, etc., in conjunction with ground-based species databases, and broad vegetation types derived from RS, will help in identifying the spatial pattern of the species assemblages and habitats (Figure. 3).

With the detail information on species occurrences and its environmental condition it is possible to identify potential plant and animal distribution for conservation planning, when primary information is lacking. Association of a particular species with specific environmental conditions has long been documented, but quantitative analyses have been

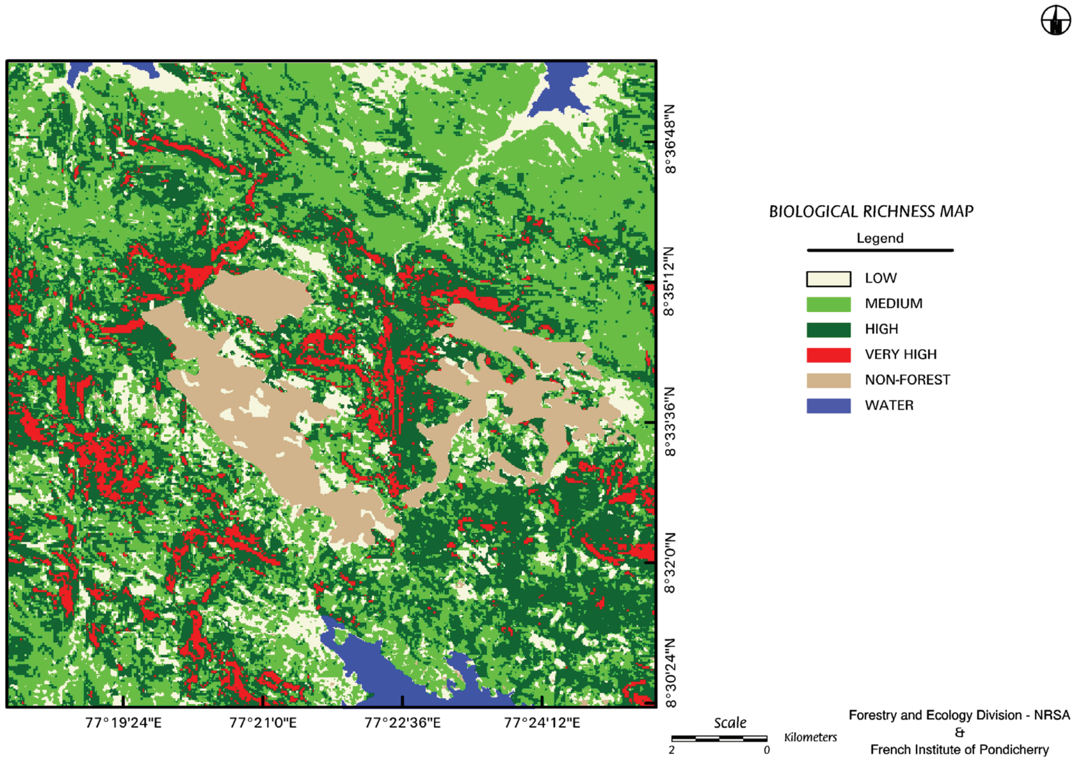

Figure 3. Biological richness map based on fragmentation, disturbance level and ground inventory for the part of Kalakad-Mundanthurai Tiger Reserve, Southern Western Ghats (Tamil Nadu), southern India (Giriraj *et al*. 2009)

possible only recently with the advent of new tools, as well as availability of continuous spatial data on various environmental parameters. Ideally, for modeling potential distribution of species, environmental data at an appropriate scale (i.e. precipitation and temperature) and precise geo-coordinates are required (Figure. 4). Today wide range of satellite and climate data sets is available freely to model potential plant and animal distribution using modeling tools like Open Modeler GARP, Maxent, Biomapper, Diva-GIS. Globally studies carried out using these tools can be found, for example in Western Ghats (India) are Ganeshaiah *et al*., 2003; Giriraj *et al*., 2008; Irfan-Ullah *et al*., 2007; in tropical America examples from Carstens and Richards (2007); de Siqueira *et al*. 2009; Peterson *et al*. (2004) Phillips and Dudik, 2008). Outputs that provide robust and reliable predictions of geographic distribution and its ecological conditions of the species are important measures for monitoring threatened species, spread of invasive species, potential sites for habitat restoration and biodiversity conservation.

2.4 Identification Areas for Conservation Measures

Landscape level spatial data of disturbance and intensity using earth observation satellites are important for tracking responses of the biosphere to climate change and for improved resource management. Remote sensing satellite data (NOAA, MODIS, SPOT Vegetation) are highly efficient to monitor and understand major disturbance events and their historical regimes more at a regional to global scale. Certain combination of satellite data derived vegetation parameters like Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Leaf Area Index (LAI), Net Primary Productivity (NPP) and land properties such as Land Surface Temperature (LST), Emissivity and Albedo can be correlated to understand uncertainties in ecosystem recovering or changes in energy balance. For e.g. coupling of LST and NDVI was found to substantially improve land cover characterization for regional and continental scale land cover classification (Coops and Catling, 1997; Coops *et al*., 2009; Mildrexler *et al*., 2007; Nemani and Running, 1997). Nemani and Running (1997) explained LST-NDVI space, an energy exchange trajectory results, where decreasing vegetation density is coupled with increasing LST can be identified as disturbed areas and increasing trends in vegetation density and decreased LST can be identified as reforestation or irrigated lands.

Some of the examples on the application of remote sensing derivative products for regular monitoring and assessment of earth systems are: applications of NDVI and EVI derived products from coarse and medium resolution satellite data to identify dynamics of crop vegetation status, crop progress, areas of drought and areas cleared by deforestations (Tao *et al*., 2008). LAI derived from remote sensing data can be used a variable in crop growth models, estimation of different crops and its changes, forest canopy density and index can be used to categorize different ecosystems, input for biogeochemical cycle modeling, carbon flux studies and NPP estimations (Sasai *et al*., 2007). Other key products like burned area, land surface temperature, chlorophyll mapping and many others can be used an end product for conservation and monitoring of ecosystems.

At landscape level disturbed areas can be identified using combination of land cover maps and landscape metrics to calculate disturbance index (DI). DI along with biodiversity information (species diversity and richness, endemism, invasiveness) and degree of terrain complexity can spatially identify areas of biological richness and measures to monitor critical areas. Case studies using this approach were carried out in tropical and temperate forests widely (Chandrashekhar *et al*., 2003; Giriraj *et al*., 2009; Roy *et al*., 2005) to identify level of habitat fragmentation and disturbance to delineate conservation zones for the sustenance of biodiversity. Thus geoinfomratics based landscape approach is an emerging tool for identification of *hotspots* for biodiversity conservation in the mountains, and especially to appropriately include human dimension in the conservation management planning.

3. Conclusion

The outcome of this paper reveals that geoinformatics serves as a powerful tool for providing geospatial information for monitoring land use and land cover changes, changes in landscape, mapping potential species distributions, impacts on climate change and biodiversity loss, however, a few critical areas of research need to addressed. Assessment and quantification need to be geospatial data driven, decision support system and dependent on multi-scale spatial and temporal resolution supporting multi-thematic information.

Understanding the environmental drivers of species distributions and levels of species richness and how they operate in different geospatial contexts is a fundamental challenge of modern biology (Gross *et al*. 2009; Menon and Bawa 1997; Tuner *et al*., 2003). This challenge is considered important with the ongoing simplification of native ecosystems, declining populations and escalating loss of biodiversity. To stalk this loss, it is necessary to understand where and why species occurring and what areas needs protection and which are rich in species and areas of high endemism. Geoinformatics ought to provide challenging task like which areas need project implementation with proven methods and clear solution in managing biodiversity. In the recent decades, tremendous increases in the launch of earth observation satellites with better repetitivity, improvement in spectral bands, spatial resolution from 50cm to 1km and also unprecedented number of remote sensing tools with which to address these challenges. These tools are found in both public and private sectors of the economy and are not limited to any particular country or region.

The question that always remains unanswered in the context of the burgeoning role of geoinformatics is the precision of information gathering and efficiency of information sharing. One major megascience initiative led by Global Biodiversity Information Facility (GBIF), an independent international organization whose members are 47 countries and 30 other international organizations. GBIF's data portal now integrates tens of millions of records of primary biodiversity data from hundreds of databases worldwide in museums, botanical gardens, and observation networks such as those of bird watchers. In promoting such a platform allows countries / users to openly share biodiversity data in the form of geoinformation or metadata to identify potential distribution of species and also to understand biodiversity protection and conservation needs.

To make improvement and challenges conservationist, evolutionary biologists, landscape ecologists, and biodiversity specialist should combine their datasets on vegetation types, species richness and diversity, distribution maps, areas of endemism and extinction, levels of disturbance together and analyse them from global to locals for better ways of monitoring and conserving biodiversity. For example, Mildrexler *et al*. (2007) combined vegetation and land surface properties to detect disturbance. Similarly Irfan-Ullah *et al*. (2007) combined climate and topography along with species locations to identify potential species distribution. Finally biodiversity database can be further put to advanced niche modeling to derive species distribution and potential habitats as defined by its biophysical parameterization. Derived spatial distribution suitably integrated with coarse scale information of spatial and non-spatial nature, can be used for resolving the stakeholders interests to achieve conservation and sustainability, by geospatial query, visualization and analysis.

References

Armenteras, D., Gast, F., and Villareal, H. (2003). Andean forest fragmentation and the representativeness of protected natural areas in the eastern Andes, Colombia. *Biological conservation*, 113(2), 245-256.

Barbaro, L., Rossi, J.-P., Vetillard, F., Nezan, J., and Jactel, H. (2007). The spatial distribution of birds and carabid beetles in pine plantation forests: the role of landscape composition and structure. *Journal of Biogeography*, 34(4), 652-664.

BioCAP. (1999). User manual for landscape analysis and modelling biological richness. Indian Institute of Remote Sensing.

Carstens, B. and Richards, C. (2007) Integrating coalescent and ecological niche modeling in comparative phylogeography. *Evolution*, 61, 1439–1454.

Chai, S.L., Tanner E., and Mclaren K. (2009). High rates of forest clearance and fragmentation pre- and post-National Park establishment: The case of a Jamaican montane rainforest. *Biological Conservation*, 142, 2484-2492.

Chandrashekhar, M. B., Singh, S., and Roy, P. S. (2003). Geospatial modelling techniques for rapid assessment of phytodiversity at landscape level in western Himalayas, Himachal Pradesh. *Current science*, 84(5), 663.

Chettri, N., Sharma, E., Shakya, B., and Bajracharya, B. (2007). Development - Developing Forested Conservation Corridors in the Kangchenjunga Landscape, Eastern Himalaya. *Mountain Research and Development*, 27(3), 211.

Cochrane, M. A. (2000). Using vegetation reflectance variability for species level classification of hyperspectral data. *International Journal of Remote Sensing*., 21, 2075-2088

Coops, N C, and Catling, P. C. (1997). Predicting the complexity of habitat in forests from airborne videography for wildlife management. *International Journal of Remote Sensing*, 18(12), 2677-2682.

Coops, Nicholas C, Wulder, M. A., and Iwanicka, D. (2009). Large area monitoring with a MODIS-based Disturbance Index (DI) sensitive to annual and seasonal variations. *Remote Sensing of Environment*, 113(6), 1250-1261.

Cordeiro, N. J., and Howe, H. F. (2003). Forest fragmentation severs mutualism between seed dispersers and an endemic African tree. *Proceedings of the National Academy of Sciences* USA, 100, 14052-14056.

Ebert, D. W., and Wade, Timothy G. (2004). Analytical Tools Interface for Landscape Assessments User Manual.

Fahrig, L. (2002). Habitat Fragmentation - Effect of habitat fragmentation on the extinction threshold: A synthesis. *Ecological applications*, 12(2), 346.

Forman, R.T.T. (1995). Land Mosaics: the ecology of landscapes and regions (Cambridge, Cambridge University Press).

Ganeshaiah, K. N., Barve, N., Nath, N., Chandrashekara, K., Swamy, M., and Shaanker, R. U. (2003). Predicting the potential geographical distribution of the sugarcane woolly aphid using GARP and DIVA-GIS. *Current science*, 85(11), 1526.

Gaston, K.J. (2000) Global patterns in biodiversity. *Nature*, 405, 220–227

Giriraj, A., Murthy, M. S. R., and Beierkuhnlein, C. (2010). Evaluating forest fragmentation and its tree community composition in the tropical rain forest of Southern Western Ghats (India) from 1973 to 2004. *Environmental monitoring and assessment*, 161(1-4), 29-44.

Giriraj, A., Murthy, M. S. R., Ramesh, B. R., and Dutt, C. B. S. (2009). A method for assessing evergreen habitats using phytodiversity and geospatial techniques in tropical rain forests of Southern Western Ghats (India). *Ecological Research*, 24(4), 749-760.

Giriraj, A., Ramesh, B. R., Karunakaran, P. V., Jentsch, A., and Murthy, M. S. R. (2008). Mapping the potential distribution of *Rhododendron arboreum* Sm. ssp. *nilagiricum* (Zenker) Tagg (Ericaceae), an endemic plant using ecological niche modelling. *Current Science*, 94(12), 1605-1612.

Gong, P., Pu, R., and Yu, B. (1997). Conifer Species Recognition: An Exploratory Analysis of In Situ Hyperspectral Data. *Remote Sensing of Environment*, 62(2), 189-200.

Gross, J. E., Goetz, S. J., and Cihlar, J. (2009). Application of remote sensing to parks and protected area monitoring: Introduction to the special issue. *Remote Sensing of Environment*, 113, 1343-1345.

Günlü, A., Kadioğullari, A. I., Keleş, S., and Başkent, E. Z. (2009). Spatiotemporal changes of landscape pattern in response to deforestation in Northeastern Turkey: a case study in Rize. *Environmental Monitoring and Assessment*, 148(1-4), 127-137.

Gustafson, E. J. (1998). Quantifying Landscape Spatial Pattern: What Is the State of the Art?. *Ecosystems* 1(2), 143-156.

Heywood, V. H., and Watson, R. T(1995). Global biodiversity assessment. Cambridge; New York, NY, USA: Cambridge University Press.

Hirano, A., Madden, M., and Welch, R. (2003). Hyperspectral image data for mapping wetland vegetation. *Wetlands*, 23(2), 436-448.

Irfan-Ullah, M., Amarnath, G., Murthy, M. S. R., and Peterson, A. T. (2007). Mapping the geographic distribution of *Aglaia bourdillonii* Gamble (Meliaceae), an endemic and threatened plant, using ecological niche modeling. *Biodiversity and Conservation*, 16(6), 1917-1925.

Jha, C. S., Goparaju, L., Tripathi, A., Gharai, B., Raghubanshi, A. S., and Singh, J. S. (2005). Forest fragmentation and its impact on species diversity: an analysis using remote sensing and GIS. *Biodiversity and Conservation*, 14(7), 1681-1698.

Joshi, P. K., Pani, P., Mahopatra, S.N. and Singh, T.P. (2009). Geoinformatics for Natural Resource Management. USA: NOVA Publishers.

Kareiva, P., and Wennergren, U. (1995). Connecting landscape patterns to ecosystem and population processes. *Nature* (6512), 299.

McGarigal, Kevin, Marks, B. J., and Pacific Northwest Research, S. (1995). FRAGSTATS : spatial pattern analysis program for quantifying landscape structure. Portland, Or.: U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

McGaughey, R. J., and Ager, A. A. (1997). Utools and Uview: analysis and visualization software. Retrieved from http://forsys.cfr.washington.edu/rsense_utools.html.

Menon, S., and Bawa, K. S. (1997). Applications of geographic information systems, remote sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science*, 73, 134-145.

Mildrexler, D. J., Zhao, M., Heinsch, F. A., and Running, S. W. (2007). A new satellite-based methodology for continental-scale disturbance detection. *Ecological Applications*, 17(1), 235-250.

Murthy, M. S. R., Giriraj, A., and Dutt, C. B. S. (2003). Geoinformatics for biodiversity assessment. *Biological letters*, 40(2), 75-100.

Murthy, M. S. R., Pujar, G. S., and Giriraj, A. (2006). Geoinformatics-based management of biodiversity from landscape to species scale - An Indian perspective. *Current Science*, 91(11), 1477-1485.

Nagendra, H., and Gadgil, M. (1999). Satellite imagery as a tool for monitoring species diversity: an assessment. *Journal of Applied Ecology*, 36(3), 388-397.

Neel, M. C., McGarigal, K, and Cushman, S. A. (2004). Behavior of class-level landscape metrics across gradients of class aggregation and area. *Landscape Ecology*, 19(4), 435-455.

Nemani, R., and Running, S. (1997). Land cover characterization using multitemporal red, near-IR, and thermal-IR data from NOAA/AVHRR. *Ecological Applications*, 7(1), 79-90.

Noss, R. F. (1990) Indicators for Monitoring Biodiversity: a Hierarchical Approach. *Conservation Biology* 4 (4): 355-364.

O'Neill, R. V., Hunsaker, C. T., Jones, K. B., and Riiters, K. H., (1997). Monitoring Environmental Quality at the Landscape Scale: Using landscape indicators to assess biotic diversity, watershed integrity, and landscape stability. *Bioscience*, 47(8), 513-520.

Peterson, A.T., Martínez-Meyer, E. and González-Salazar, C. (2004) Reconstructing the Pleistocene geography of the Aphelocoma jays (Corvidae). *Diversity and Distributions*, 10, 237–246.

Phillips, S. J., and Dudik, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, 31(2), 161-175.

Riitters, K. H., O'Neill, R. V., Hunsaker, C. T., and Wickham, J. D. (1995). A factor analysis of landscape pattern and structure metrics. *Landscape Ecology*, 10(1), 23.

Riitters, K. H., Wickham, J. D., O'Neill, R. V., Jones, K. B., and Smith, E. (2000). Global-scale patterns of forest fragmentation. *Conservation Ecology*, 4, 3.

Rosenzweig, M.L. (1995) Species Diversity in Space and Time, Cambridge University Press

Roy, P. S. (2003). Geoinformatics for Tropical Ecosystems (p. xii, 639 p.). Dehra Dun: Bishen Singh Mahendra Pal Singh.

Roy, P. S., and Joshi, P. K. (2002). Landscape fragmentation and biodiversity conservation. Landscape. Retrieved from http://www.gisdevelopment.net/application/environment/conservation/envc0001.htm.

Roy, P. S., Padalia, H., Chauhan, N., Porwal, M. C., Gupta, S., Biswas, S., (2005). Validation of Geospatial model for Biodiversity Characterization at Landscape Level: a study in Andaman and Nicobar Islands, India. *Ecological Modelling*., 185(2), 349.

Roy, P. S., Porwal, M. C., and Sharma, L. (2001). Mapping of *Hippophae rhamnoides* Linn. in the adjoining areas of Kaza in Lahul and Spiti using remote sensing and GIS. *Current science*, 80, 1107-1111.

Sasai, T., K. Okamoto, T. Hiyama, and Y. Yamaguchi. (2007). Comparing Terrestrial Carbon Fluxes from the Scale of a Flux Tower to the Global Scale. Ecological Modelling. 208 (2-4), 135-144.

Skole, D., and Tucker, C. (1993). Tropical Deforestation and Habitat Fragmentation in the Amazon: Satellite Data from 1978 to 1988. *Science*, 260(5116), 1905.

Soulé, M. E. (1986). Conservation biology : the science of scarcity and diversity. Sunderland, Mass: Sinauer.

Steininger, M.K., Tucker, C.J., Ersts, P., Killeen, T.J., Villegas, Z., and Hecht S.B. (2001) Clearance and fragmentation of tropical deciduous forest in the Tierras Bajas, Santa Cruz, Bolivia. *Conservation Biology*, 15, 856–866.

Stoms, D. M. (1992). Effects of Habitat Map Generalization in Biodiversity Assessment. *Photogrammetric Engineering and Remote Sensing*, 58(11), 1587.

Tao F., Yokozawa, M., Zhang, Z., Hayashi, Y., Ishigooka Y. (2008) Land surface phenology dynamics and climate variations in the North East China Transect (NECT), 1982-2000. International Journal of Remote Sensing, 29(19), 5461-5478.

Torras, O., Gil-Tena, A., and Saura, S. (2008). How does forest landscape structure explain tree species richness in a Mediterranean context?. *Biodiversity and Conservation*, 17(5), 1227-1240.

Tuner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., and Steininger, M. (2003). Remote sensing for biodiversity science and conservation. *Trends in Ecology and Evolution*, 18(6), 306-314.

Turner, M. G. (1989). Landscape ecology: the effect of pattern of process. *Annual Review of Ecology and Systematics*, 20, 171-197.

Turner, M. G. (1990). Landscape changes in nine rural counties in Georgia, Photogrammetric Engineering and Remote Sensing, 56(3), 379–386.

Wabnitz, C. C., Andrefouet, S., Torres-Pulliza, D., Muller-Karger, F. E., and Kramer, P. A. (2008). Regional-scale seagrass habitat mapping in the Wider Caribbean region using Landsat sensors: Applications to conservation and ecology. *Remote sensing of Environment*, 112(8), 3455.

Wickham, J. D., Neill, R. V., and Jones, K. B. (2000). Forest fragmentation as an economic indicator. *Landscape Ecology*, 15, 171-179.

Wickham, J. D., Riitters, K. H., Wade, T G, and Coulston, J. W. (2007). Temporal change in forest fragmentation at multiple scales. *Landscape Ecology*, 22(4), 481-489.

Zhang, Y., and Guindon, B. (2005). Landscape analysis of human impacts on forest fragmentation in the Great Lakes region. *Canadian Journal of Remote Sensing*, 31(2), 153-166.

de Siqueira, M.F., Durigan, G., de Marco P., and Peterson A.T. (2009). Something from nothing: Using landscape similarity and ecological niche modeling to find rare plant species. *Journal for Nature Conservation*, 17, 25-32.