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Forest Remote Sensing, Biodiversity and Climate

Climate has a significant influence on the distribution, structure and ecology of forests and their biodiversity content and vice versa; and these studies are increasingly benefitted from modern tools such as remote sensing, GIS and GPS. It is evident from the projections of global models that as a result of changes in temperature, precipitation, soil moisture, greenhouse gases, etc., majority of the forests would undergo shifts. Certain climatic regimes are associated with particular plant functional types; hence it is reasonable to assume that changes in climate would alter the distribution pattern and composition of forest ecosystems and their biodiversity content.

Geoinformatics technologies and information systems serve as complementary systems to ground-based studies on biodiversity and ecology. Remote sensing offers the opportunity for large area characterization of biodiversity in a systematic, repeatable and spatially exhaustive manner. A combination of direct and indirect approaches is useful in deriving four key indicators of diversity, viz. productivity, disturbance, topography and land cover from remote sensing data. Any geoinformatics technology-based biodiversity database and information system has many advantages such as: (i) all the species are tagged to their locational information, (ii) the database is amenable to easy modification, retrieval, query, etc., (iii) is receptive to addition and deletion of any number of spatial and non-spatial attributes for any specific biodiversity study, and is thereby useful for many related studies on biodiversity such as species distribution modelling and climate change.

The variation in species richness/plant diversity is strongly correlated with changing climatic conditions. Environmental conditions act in a fundamental way on species richness by regulating both the potential pool of species and the productivity of the habitat. Increasing temperature, moisture availability and soil fertility favour species richness. In the tropics, availability of abundant sunlight in combination with higher moisture promotes the metabolic activities of the plants, thus reducing extinction rates and resulting in higher biodiversity/species richness. Many hypotheses have highlighted the increase in species richness as a consequence of higher temperatures, but the case is true only for temperatures up to 40°C, beyond which the desiccation turns opposite. According to one of the oldest ideas, the climate has a strong controlling influence on variations in plant species richness, and the great clines in richness may be related to some aspect of the climate.

The advantage of using LiDAR remote sensing for forestry applications is that it provides data on three-dimensional forest structures characterizing vegetation height, vertical distribution of canopy material, crown volume, sub-canopy topography, vertical foliage diversity and multiple layers, height to live crown, large tree density, leaf area index, and physiographic or life form diversity through direct and indirect retrievals. Vegetation height is a function of species composition, climate and site quality, and can be used for land cover classification or in conjunction with vegetation indices. If coupled with species composition and site quality information, height serves as an estimate of stand age or successional stages. Since the vertical components of stands change with age, older stands can be characterized by canopy gaps, thereby providing vital inputs for biodiversity characterization.

Chitale and Behera (**page 1126**) report with greater than 90% certainty that sal (*Shorea robusta* Gaertn. f.), a dominant timber species, would shift towards northern and eastern India under climate change scenario (SRES A1-B) for the year 2020, and have identified moisture as the key player that would influence the distributional shift. They have (i) generated the 1960s scenario of sal species distribution on the basis of the existing literature; (ii) confirmed the species occurrence data using archives satellite imagery owing to spectral signature for the period 1972–75; (iii) run the Maxent Species Distribution Model to predict the distribution for the year 2020 under climate change scenario SRES A1-B, and (iv) validated the prediction using more than double the amount of species occurrence data gathered during the last decade (1998–2008). The study highlights: (i) the utility of satellite remote sensing technique that proved useful in identification and characterization of sal species (as they occur in consociations and represent the top canopy) in generating past distribution scenarios, thereby providing inputs for modelling studies leading to biological and ecological conservation implementation, and (ii) the utility of field location data gathered in the 'Biodiversity characterization at landscape level' project as a basis of the model output validation study.

Roy *et al*. (**page 1136**) have narrated the importance of a national GIS-enabled plant diversity database for utility in further studies and research in today's changing climate, and discussed various means of its dissemination. They have revealed that a total of 7596 plant species have been recorded across the country that involved field inventory of 16,518 geo-referenced nested quadrat plots of 0.04 ha. The species database provides information on the endemic, rare, endangered, threatened and economically/medicinally important species, and has found extensive applications in policy planning, operational management, biodiversity conservation, bio-prospecting and climate change studies. The entire spatial and non-spatial data on Indian plant biodiversity have been organized and are available in BIS, with its five major components, viz. *BIO-SPATIAL* for biodiversity spatial query shell, *PHYTOSIS* for plant species information system, *FRIS* for database related to forest resources from various sources, *BIOSPEC* for bio-prospecting and molecular taxonomy and *BioConsSDSS* for biodiversity conservation spatial decision support system. They advocate that the data have become immensely useful in varied areas of research, and policy-making processes, including climate change and development of international monitoring protocols.

Chawla *et al*. (**page 1143**) argue that long-term ecological studies are a pre-requisite for documenting responses of global climate change to biological diversity, and understanding of the relationships between vegetation and environment. They discuss the CSIR network plan and methodology for establishment of permanent monitoring plots in various ecoregions, especially in the data-void Himalayan region. Detailed ecological observations consisting of abiotic parameters (viz. topographic, climatic, edaphic), vegetation patterns, including phenological observations, community structure, forest disturbance and evolutionary patterns as well as the decomposition, mineralization and fine root dynamics are being planned. Initial results revealed a positive trend of herbal diversity with increasing soil carbon and nitrogen concentration in the Great Himalayan National Park. They have found that satellite remote sensing tool is useful in LTEM study, including biodiversity assessment and monitoring of ecosystem ecology and climate change research. In future, they hope that the study would reverse the 'data-deficient' tag from the Himalayan region, as mentioned in the IPCC 4th Assessment Report.

Shilpa *et al.* (**page 1157**) have used ecological niche modelling to understand the ecological and geographic distribution of *Pterocarpus santalinus* L.f. (Red Sanders), an endemic and endangered species, in relation to climate and physiognomy. The species is becoming endangered primarily due to anthropogenic disturbances (logging, fire and non-timber forest produce collection), rather than natural processes. They observed that the potential distribution fell mainly in areas not protected and those experiencing high anthropogenic pressure owing to economic and medicinal value. They ran niche models and tested whether these have significant predictive power when applied to other sectors of the species distribution. The study shows that anthropogenic disturbances have profound influence on environmental change and alter the environment of the native species, thereby endangering the habitats of *P. santalinus*. The conservation action plan for any species or ecosystem is meant for minimizing the threat and reducing the vulnerability of the species.

Nayak and Mandal (**page 1166**) study the regional variation of temperature trends (warming or cooling) over western India and the contribution of land-use and land-cover (LULC) changes towards this warming or cooling based on 37 years (1973–2009) temperature datasets. They have estimated the contribution of LULC to warming or cooling based on deviation in temperature in the observation and reanalysis datasets. They found that the observed temperature dataset indicates decadal warming of 0.13°C in western India. This is the combined effect of increase in concentration of greenhouse gases and LULC changes. The impact of LULC changes on temperature trends over western India has been estimated using 'Observation minus reanalysis' method which indicates that the LULC changes contribute to warming by 0.06°C per decade. The study cautions that the impact of land-use change to be more significant in future and highlights the utility of satellite data for periodic LULC studies in climate change research.

Roy and Srivastava (**page 1174**) have identified human-driven LULC change as one of the most important causes for depletion of biodiversity. They have utilized geospatial modelling technique to combine the drivers of LULC change with spatial distribution of LULC change and topographic impedances to characterize hotspots of LULC change in Goa, Western Ghats. The study has undoubtedly revealed that the natural areas having high population density in the vicinity are highly prone to LULC change.

Matthias *et al*. (**page 1181**) have tried to prove a point by asking whether a biodiversity study can benefit from information on the vertical structure of forests, and have attempted to answer it with the help of LiDAR remote sensing. They have utilized the LiDAR data to generate digital terrain model, digital surface model, vegetation height model, detection of gaps, detection and mapping of tree stands, mapping of density classes of the middle layer and detection of coniferous trees. They advocate that the stand height and structural information derived from LiDAR imagery can potentially contribute to the characterization of biodiversity through vertical stratification.

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