Studies on ecosystem function and dynamics in Indian sub-continent and emerging applications of satellite remote sensing technique

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Abstract

The capacity of an ecosystem to sustain a specific function depends on its structural dynamics and interplay of several extrinsic factors with its functional components. The study of mechanisms involved in the dynamics of an ecosystem, and a critical evaluation of these mechanisms are fundamental to address various challenges that the ecosystems are facing today e.g. changing environment and socio-economic forces. In this thematic issue, we present 15 articles, which deal with such diverse functional attributes of an ecosystem as nutrient cycling, hydrology, biomass and carbon. The structural dynamics include forest and land use changes, and changes in fuel wood extraction and diversity patterns. The articles are arranged in three sections viz., Ecosystem Function, Ecosystem Dynamics, and Biomass and Carbon. At least 65% of these articles have used satellite remote sensing technique. We realize that the utilization of satellite remote sensing data has been emerging as a dominant trend in tropical ecological studies in Indian sub-continent.

Keywords Biomass and carbon · Forest diversity · Land use change · Nutrient dynamics

Introduction

The 2nd international workshop on Biodiversity and Climate Change (BDCC-2018) was held on 24–27 February 2018 at the Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, India. The workshop deliberated on functional diversity and climate change, Himalayan biodiversity, and geomatics tools. The workshop focused on the new methods and developments in ecological studies in the face of changing climate and land uses. A bilateral workshop with Indo-UK Terrestrial Carbon Group (IUTCG) comprising both Indian and UK scientists (UKERI) was held in December 2012, proposed effective integration of field observations collected through various monitoring networks, and satellite platforms for terrestrial carbon monitoring and modelling (Behera and Dash 2013).

In this issue, the authors of the articles have used latest scientific methods, models and statistical approaches to analyze various structural and functional attributes of ecosystems. Of the 15 papers, nine papers have used satellite remote sensing data, and six papers have used analytical approach with respect to ecosystem function and dynamics. The increasing utilization of satellite remote sensing data in ecosystem function and dynamics studies has been a dominant trend in India and Nepal. The first three papers deal with forest nutrient and nutrient resorption efficiency using rigorous laboratory analysis. The next two papers on ecosystem function discuss on satellite-based studies on solar induced chlorophyll fluorescence and evapotranspiration. Subsequent two papers demonstrated utility of satellite data for study of shifting cultivation fallow lands by capturing spatio-temporal dynamics; and land use modeling using drivers of change. The next study on coupling of socio-ecological attributes using remote sensing datasets and field observations revealed the patterns of fuelwood use dynamics in Nepal. In another study, the authors have reiterated rich biodiversity of sacred forests, which are representatives of the past climax forest ecosystems. Of the six papers accommodated under ‘Biomass and Carbon’ section, the first two emphasises on diversity and productivity relationship, and treeline carbon sequestration. Subsequent three papers

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discuss correlation of soil organic carbon along an elevation gradient, the diversity and productivity relationship, and blue carbon in broad-leaved forest. In the last paper of this issue, the Indo-UK Terrestrial Carbon Group (IUTCG) comprising both Indian and UK scientists has proposed that effective integration of field observations through various monitoring networks and satellite platforms, and modelling could be the pathway for future terrestrial carbon monitoring and investigations.

Ecosystem function

The release of nutrients through litterfall and decomposition govern the pools and fluxes of forest nutrient cycling. It is a complex process that involves several physical, chemical, and biological factors and processes, mostly mediated by the microbial organisms. The microbial activities are accelerated by favourable environmental conditions and therefore are season-dependent. A study by Nonghuloo et al. (2020) revealed that litter production and decomposition rates, and litter nitrogen and phosphorous contents were significantly higher in the broadleaved forest compared to the pine forest, indicating greater functional dynamism of the former. They recommend conservation of broadleaved forests which can help in climate change adaptation and would also ensure the flow of several ecosystem services. During leaf senescence, nutrients such as nitrogen, phosphorus, and other elements are transported back to the younger leaves, and growing seeds, or are stored for the incoming growth season through a process called nutrient resorption. Nutrient resorption helps in conservation of nutrients by preventing their loss from the senescing leaves to the soil through litterfall. The study of Nongbri and Barik (2020) on nitrogen resorption efficiency of four tree species belonging to different functional groups revealed that it was high in deciduous trees (*Alnus nepalensis* and *Schima wallichii*) in comparison to evergreen trees (*Pinus kesiya* and *Lithocarpus dealbatus*). These results indicate that deciduous tree species conserve more nitrogen through resorption than evergreen trees. In another study Thapa et al. (2020) found that the evergreen and deciduous trees in the old-growth forest tightly conserve nutrients with higher leaf N and P concentrations and higher N and P resorption efficiencies than the regenerating forest stand. They inferred that soil fertility has profound effects on the internal nutrient cycling and nutrient economy of evergreen and deciduous tree species.

Solar induced chlorophyll fluorescence is a very useful indicator of the primary production, vegetation photosynthetic dynamics and nutrient stress in plants due to its association with photosynthesis. Satellite remote sensing based observations of solar induced chlorophyll fluorescence provides an alternative non-invasive approach to investigate plant productivity. Chhabra and Gohel (2020) studied the

spatio-temporal patterns of remote sensing based observations of solar induced chlorophyll fluorescence and its correlation with plant productivity over diverse terrestrial vegetation of India; and reported better correlation with evergreen broadleaved forests. The findings of their study would serve as useful inputs to plant productivity modelling and improved understanding of terrestrial carbon cycle. Evapotranspiration is the loss of water from the land surface and plant canopy to the atmosphere; and is associated with stomatal conductance, $\text{CO}_2\text{--H}_2\text{O}$ gas exchange, and water use efficiency in plant canopies that affects the plant growth process and productivity. Singh et al. (2020) estimated the evapotranspiration over a chosen site using a one-source model, which calculates the net radiation, soil heat flux, and sensible heat flux at every pixel level. The evapotranspiration presented in the form of a map, well represented the spatial variations of broad land cover, and has potential in water resource management at local scale.

Ecosystem dynamics

River basin level land use pattern reflects the character of interaction between man and environment in a waterscape. Behera and Behera (2020) used a land use and land cover model to study the pattern during the years 1975–2010 in Ganga River basin and extrapolated the pattern for the year 2045, using remote sensing and GIS techniques. The study indicated agricultural expansion at the expense of other land cover owing to population pressure. Shifting cultivation (slash and burn cultivation locally called as *jhum*) is one of the principal driving forces of deforestation in tropical Asia, and is the predominant agricultural practice in the seven hill states of northeastern India. Pasha et al. (2020) applied an integrated spectral enhancement technique to map the shifting cultivation fallow and current *jhum* areas in northeastern India for 2014, 2016 and 2018 using satellite images from Landsat-8. Though application of automated methods to identify shifting cultivation areas in complex landscape remains a major challenge, satellite-based images provide undisputable evidence for studying spatio-temporal dynamics of shifting cultivation fallow/ current *jhum* areas.

The increasing dependence of humans on timber, fodder, non-timber forest products, and fuelwood have put tremendous pressure on forests in developing countries. Chitale et al. (2020) applied an innovative approach of coupling socio-ecological attributes using remote sensing datasets and field observations to understand the patterns of fuelwood dynamics in Nepal. The socio-ecological coupling provided quantification of most significant drivers of fuelwood dynamics; and indicated lower forest loss in community forests compared to outside community forests. Sacred forests are one of the most effective forms of biodiversity conservation set up by an age-old tradition based on the

cultural and religious practices of the indigenous communities. Suchiang et al. (2020) compared the tree diversity and community composition in six sacred forests of Meghalaya with those of six adjacent community forests to reiterate that community-protected sacred forests have better diversity and community characteristics than those in the other types of community forests. This study provides yet another example to recommend the inclusion of sacred forests under formal forest management framework.

Biomass and carbon

Malhi et al. (2020) have demonstrated synergetic use of in situ and hyperspectral remote sensing data for effective biodiversity and aboveground biomass assessment. They found strong correlation between biodiversity and aboveground biomass, implying scope in generating framework required for the conservation and sustainable forest management practices. Rai et al. (2020) assessed dry matter dynamics of forests along treeline in Western Himalaya and found that during warmer summer, the forest had higher amounts of dry matter storage, and production and decomposition rates. The treeline forests showed high dry matter assimilation rate implying potential for carbon sequestration under a warming climate.

Khadanga and Jayakumar (2020) attempted to establish relationship among stem density, biomass and carbon stock along an elevation gradient and disturbance regime in a tropical dry deciduous forest in Eastern Ghats, India. While disturbance negatively affected biomass, total SOC estimated in different elevation zones showed a strong significant positive correlation with elevation. Gogoi et al. (2020) quantified and compared the plant diversity and carbon stock in a sub-tropical broadleaved and a sub-tropical pine forest in north-eastern India. They reported greater tree DBH, biomass and carbon stock for the sub-tropical broad-leaved forest than the pine forest with a strong positive relationship between tree diversity and carbon stock. Banerjee et al. (2020) have accounted high blue carbon for mangrove forests with field-based measurements of aboveground plant and soil carbon from a test site in Bhitarkanika wildlife sanctuary in Eastern India. These studies emphasize the need to develop conservation strategy on a priority basis for species-rich broad-leaved forest ecosystems.

An Indo-UK Terrestrial Carbon Group (IUTCG) comprising both Indian and UK scientists explored ways in which earth observation data can be effectively utilised in mitigating the impacts of climate change through vegetation management. Dash et al. (2020) proposed effective integration of field observations, collected through various monitoring networks, and satellite sensor data to undertake country-wide terrestrial carbon monitoring and vegetation dynamics modelling.

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