Modeling Forest Landscape Dynamics

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MODELING FOREST LANDSCAPE DYNAMICS

Abstract

Landscapes are the composition of dynamic heterogeneous components of complex ecological, economic, and cultural elements on which human and other life forms depend directly. Landscape dynamics driven by land use land cover (LULC) changes due to anthropogenic activities are affecting ecology, biodiversity, hydrological regime, and hence people’s livelihood. There has been increasing apprehensions about environmental degradation, depletion of natural resources due to uncontrolled anthropogenic activities, and its consequences on the long-term sustainability of socio-economic systems around the world. This necessitates an understanding of landscape dynamics and the visualization of likely changes for evolving appropriate strategies for prudent management of natural resources. Modeling of forest cover changes offers to incorporate human decision making on land use in a systematic and spatially explicit way through an accumulation of land use choices, social interaction, and adaptation at various levels. Several models developed by the research community so far has largely been utilized to evaluate the empirical studies, explore theoretical aspects of particular systems rather than forecasting their effectiveness across the various landscapes representing bio-physical dissimilarities. In this regard, the objectives of the current research are to understand and model the spatiotemporal patterns of landscape dynamics in the Uttara Kannada district of Central Western Ghats. This involves, (i) developing an appropriate modeling framework incorporating the spatiotemporal changes in the forested landscape at the regional level; (ii) implementing a hybrid model to capture the changes at the landscape level by integrating bio-ecological aspects with socio-economic growth; (iii) evaluating the environmental conditions in response to scenarios of drivers of change like developmental policies and their potential impacts; (iv) assessing the likely scenario of the landscape dynamics based on policies of conservation of ecologically sensitive regions (ESR) and other recommendations.

The vegetation dynamics quantified using spatial data acquired through spaceborne sensors at regular intervals along with collateral data shows a decline in vegetation cover from 92.87% (1973) to 80.42% (2016). Land use analyses through supervised classifiers based on the Gaussian maximum likelihood algorithm reveals a deforestation trend as evident from the decline of evergreen-semi evergreen forest cover to 29.5% (2016) from 67.73% (1973). In addition, agricultural spatial extent (7.00 to 14.3 %) and the area under human habitations
have also shown a steep increase. This has also led to forest fragmentation (interior forest cover lost by 64.42 to 22.25 %) in the district. In order to visualize the likely changes, the current work proposes a modified Hybrid Fuzzy-Analytical Hierarchical Process-Markov Cellular Automata model by accounting for the land use changes and to evaluate the role of policy decisions. The proposed hybrid modeling approach with the constraints in the cellular automata technique has been used to simulate various scenarios (i) managed growth rate (2022), (ii) IPCC climate change rapid growth (2031, 2046), (iii) policy-induced constrained Ecological Sensitive Regions. The rapid growth rate scenario highlights a likely loss of forest cover by 11.1%, with an increase in plantations covering 20.9% and built-up as 10.2% of the region by 2046. Land use changes assessed through considering constraints of Ecological Sensitive Regions (ESR-1) and the protection of intact or contiguous (interior) forest patches, highlights the role of policy decisions in land use changes. ESR-1 protection scenario shows forest cover is likely to remain at 48% (2021) and 45% (2031) though there is an increase in built-up area from 5.8 to 7% (2031) and agriculture area. The comparison of policy scenario-1 (ESR-1) and scenario-2 (protection of interior forest) depicts scenario-1 focuses more on conservation and limits the growth to the ESR-2, 3 and 4 regions, whereas scenario-2 shows growth can occur throughout the district excluding regions covered with interior forests, which is likely to induce further fragmentation of forests. This research shows that the insights from the changes to the forest cover and its dynamics through modeling will aid decision making processes for formulating appropriate land use policies. It is important that such policies mitigate changes in the ecologically sensitive regions and maintain sustenance of natural resources to ensure water and food security while supporting the livelihood of local people. The book consists of six chapters.

Chapter 1 introduces the landscape, ecosystem process, and issues and concerns associated with land use land cover changes. This chapter elaborates on the necessity of modeling landscape dynamics and provides a detailed review of the different geospatial modeling techniques (spatial, non-spatial, statistical, geospatial, agent-based modeling techniques, etc.) and their effective usage in planning and natural resource management. The review also looks at various studies on forest land use changes and modeling techniques used for the Indian and global context.

Chapter 2 provides an overview of current modeling techniques and the development of a suitable hybrid model and its mathematical formulation.
Chapter 3 provides a brief overview of the study area considered i.e. Uttara Kannada district, Central Western Ghats for implementation of models. The chapter provides details of geology, climate, rainfall, demography, the economic, historic significance of the region. It also articulates the various data sets used for the analysis and their significance.

Chapter 4 presents land use land cover dynamics in the Uttara Kannada district and fragmentation of forests based on remote sensing analysis.

Chapter 5 proposes the framework for identification of Ecologically Sensitive Regions (ESR) for conservation by integrating spatial, bio-geo climatic, and social variables. This chapter also provides the allowable developmental activities for the sustainable growth of the region.

Chapter 6 presents modeling and simulation of the region and project likely changes in the ecologically significant landscape. This chapter also presents the results of the proposed hybrid Fuzzy-AHP-MCCA technique and simulates likely changes, and also evaluates the likely scenario of the landscape dynamics with the conservation of ESR and policy recommendations. The model helps understand how the identification of ESR, and its integration in the model to set the limits for the growth under (i) implementation of conservation in ESR-1 and allowing development in ESR-2-4; (ii) limiting LU conversion by considering interior forest and protected areas as constraints; will affect the changes in the land use patterns. Finally, the research is concluded with the significant results from this modeling effort, which helps policy and decisionmakers.

Finally, the book concludes with the significant results from the modeling efforts and inferences that can be drawn on how the model helps policy and decisionmakers understand the impact of the choices made at a macro-scale and their impact at the local levels.

**Keywords**

Landscape dynamics; Fragmentation; Land use land cover [LULC]; Modeling; Policies
1. Antrop, M., 2005. Why landscapes of the past are important for the future. Landscape and urban planning, 70(1-2), pp.21-34.


“Modelling Forest Landscape Dynamics”, which has both temporal and spatial assessment of the diverse forest habitats of this district. I wish the modelling framework suggested here by using rich spatio-temporal data for the governance forest landscape of the region may prove to be appropriate in the coming days. I am certain that it would not only help the research students, researchers and conservation practitioners, but also the people who are actually working on the field for the cause of conservation and sustainable utilization of natural resources. I believe for the first time such a scholarly book is coming out on the forest ecology of Uiltria Kamnada, for which I express my sincerest appreciations.”

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“This book about modelling forest landscape dynamics provides insights that are is innovative, clear, and able to open pathways to new ideas in the science of pattern analysis and conservation planning. It's detailed analysis of landscape dynamics, patterns and its visualisation with scenario based approach on ESR would bring in fresh thinking for any planned activities in and around forest”

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