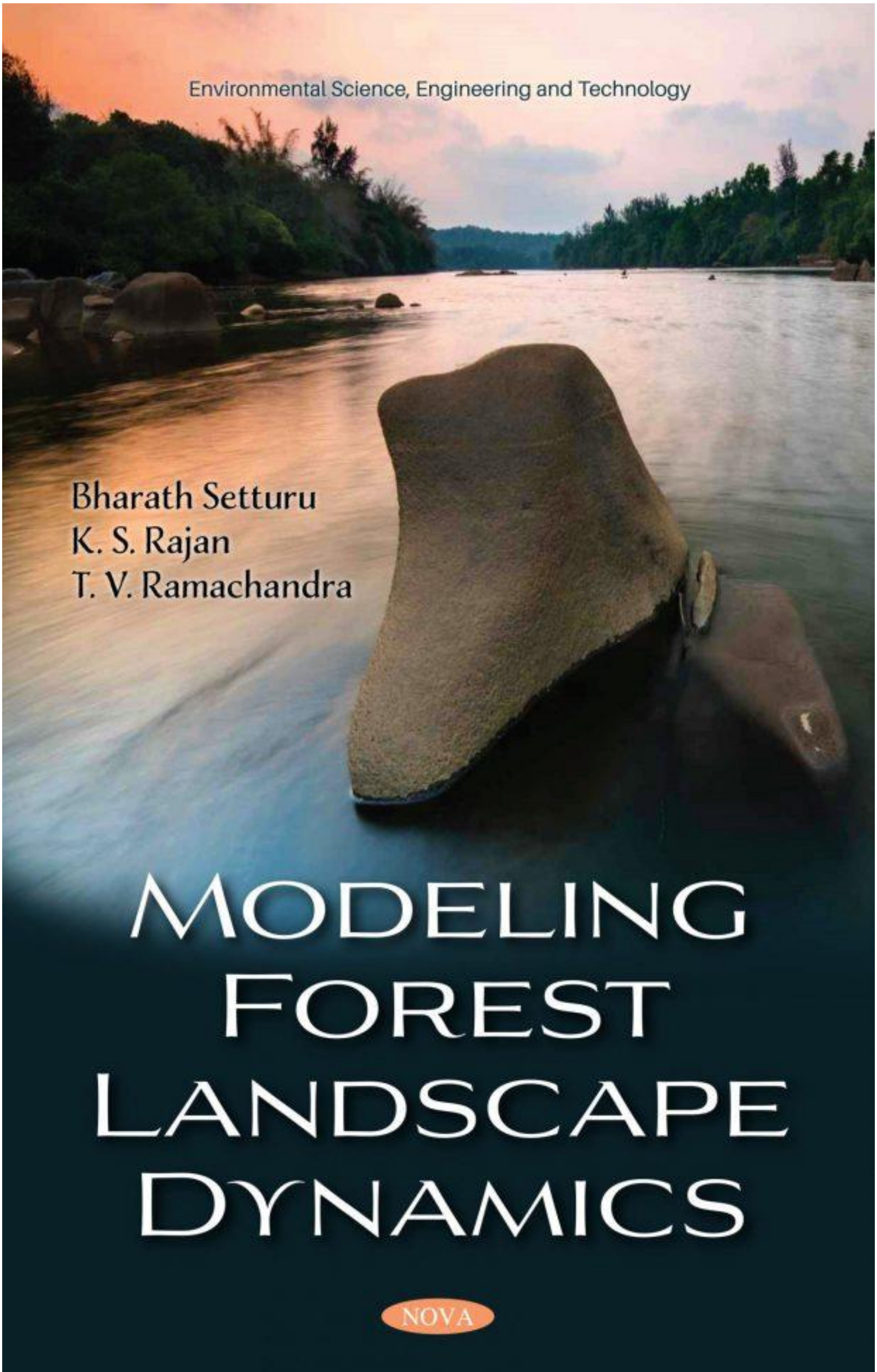
Environmental Science, Engineering and Technology
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MODELING
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Modeling Forest Landscape Dynamics

Contents

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

(0.38% to 4.97%) 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

References

1. Antrop, M., 2005. Why landscapes of the past are important for the future. *Landscape and urban planning*, *70*(1-2), pp.21-34.
2. Adhikari, S. and Southworth, J., 2012. Simulating forest cover changes of Bannerghatta National Park based on a CA-Markov model: a remote sensing approach. *Remote Sensing*, *4*(10), pp.3215-3243.
3. Agarwal, C., Green, G.M., Grove, J.M., Evans, T.P. and Schweik, C.M., 2001. A review and assessment of land-use change models. Dynamics of space, time, and human choice. Bloomington and South Burlington. Center for the Study of Institutions, Population, and Environmental Change, Indiana University and USDA Forest Service. CIPEC Collaborative Report Series, 1.
4. Arsanjani, J.J., Kainz, W. and Mousivand, A.J., 2011. Tracking dynamic land-use change using spatially explicit Markov Chain based on cellular automata: the case of Tehran. *International Journal of Image and Data Fusion*, *2*(4), pp.329-345.
5. Areendran, G., Raj, K., Mazumdar, S., Munsi, M., Govil, H. and Sen, P.K., 2011. Geospatial modeling to assess elephant habitat suitability and corridors in northern Chhattisgarh, India. *Tropical Ecology*, *52*(3), pp.275-283.
6. Armenteras, D., Rudas, G., Rodriguez, N., Sua, S. and Romero, M., 2006. Patterns and causes of deforestation in the Colombian Amazon. *Ecological indicators*, *6*(2), pp.353-368.
7. Arts, B., Buizer, M., Horlings, L., Ingram, V., Van Oosten, C. and Opdam, P., 2017. Landscape Approaches: A State-of-the-Art Review. *Annual Review of Environment and Resources*, *42*, pp.439-463.
8. Atkinson, P.M. and Lewis, P., 2000. Geostatistical classification for remote sensing: an introduction. *Computers & Geosciences*, *26*(4), pp.361-371.
9. Baker, W.L., 1989. A review of models of landscape change. *Landscape ecology*, *2*(2), pp.111-133.
10. Barange, M., Beaugrand, G., Harris, R., Perry, R.I., Scheffer, M. and Werner, F., 2008. Regime shifts in marine ecosystems: detection, prediction and management. *Trends in Ecology & Evolution*, *23*(7), pp.402-409.
11. Bates, P.J.J. and Harrison, D.L., 2000. *Bats of the Indian subcontinent*. ETI, University of Amsterdam.
12. Batty, M., and Torrens, P.M., 2001. Modeling complexity: The limits to prediction. Cybergeo, 21.
13. Beinat, E., 1997. Value functions for environmental management. In *Value Functions for Environmental Management* (pp. 77-106). Springer, Dordrecht.
14. Bernasconi, M., Choirat, C. and Seri, R., 2010. The analytic hierarchy process and the theory of measurement. *Management Science*, *56*(4), pp.699-711.
15. Bharath, H.A., Chandan, M.C., Vinay, S. and Ramachandra, T.V., 2018. Modelling urban dynamics in rapidly urbanising Indian cities. *The Egyptian Journal of Remote Sensing and Space Science*, *21*(3), pp.201-210.
16. Bhat, P., Hegde, G. and Hegde, G.R., 2012. Ethnomedicinal practices in different communities of Uttara Kannada district of Karnataka for treatment of wounds. *Journal of ethnopharmacology*, *143*(2), pp.501-514.
17. Bogaert, J., Ceulemans, R. and Salvador-Van Eysenrode, D., 2004. Decision tree algorithm for detection of spatial processes in landscape transformation. *Environmental management*, *33*(1), pp.62-73.

18. Behera, M.D., Borate, S.N., Panda, S.N., Behera, P.R. and Roy, P.S., 2012. Modelling and analyzing the watershed dynamics using Cellular Automata (CA)–Markov model–A geo-information based approach. *Journal of earth system science*, *121*(4), pp.1011-1024.
19. Brose, U., Martinez, N.D. and Williams, R.J., 2003. Estimating species richness: sensitivity to sample coverage and insensitivity to spatial patterns. *Ecology*, *84*(9), pp.2364-2377.
20. Briassoulis, H. 2000. Analysis of Land Use Change: Theoretical and Modeling Approaches. The Web Book of Regional Science. Vol. 410. Regional Research Institute, West Virginia University.
21. Bürgi, M., Hersperger, A.M. and Schneeberger, N., 2004. Driving forces of landscape change-current and new directions. Landscape ecology, 19(8): 857-868.
22. Bürgi, M., Straub, A., Gimmi, U. and Salzmann, D., 2010. The recent landscape history of Limpach valley, Switzerland: considering three empirical hypotheses on driving forces of landscape change. *Landscape Ecology*, *25*(2), pp.287-297.
23. Cagnolo, L., Cabido, M. and Valladares, G., 2006. Plant species richness in the Chaco Serrano Woodland from central Argentina: ecological traits and habitat fragmentation effects. *Biological conservation*, *132*(4), pp.510-519.
24. Carpenter, S.R., 2002. Ecological Futures: Building an Ecology of the Long Now1. *Ecology*, *83*(8), pp.2069-2083.
25. Chandran, M.D.S., Rao, G.R., Gururaja, K.V. and Ramachandra, T.V., 2010. Ecology of the swampy relic forests of Kathalekan from Central Western Ghats, India. *Bioremediation, Biodiversity and Bioavailability*, *4*(1), pp.54-68.
26. Chang, N.B., Parvathinathan, G. and Breeden, J.B., 2008. Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of environmental management*, *87*(1), pp.139-153.
27. Chaturvedi, R.K., Gopalakrishnan, R., Jayaraman, M., Bala, G., Joshi, N.V., Sukumar, R. and Ravindranath, N.H., 2011. Impact of climate change on Indian forests: a dynamic vegetation Modeling approach. *Mitigation and Adaptation Strategies for Global Change*, *16*(2), pp.119-142.
28. Chitale, V.S., Behera, M.D. and Roy, P.S., 2014. Future of endemic flora of biodiversity hotspots in India. *PLoS One*, *9*(12), p.e115264.
29. Cowling, R.M., Egoh, B., Knight, A.T., O'Farrell, P.J., Reyers, B., Rouget'll, M., Roux, D.J., Welz, A., Wilhelm-Rechman, A., 2008. An operational model for mainstreaming ecosystem services for implementation. Proc Natl Acad Sci USA, 105:9483-9488.
30. Daniels, R.R., Joshi, N.V. and Gadgil, M., 1990. Changes in the bird fauna of Uttara Kannada, India, in relation to changes in land use over the past century. *Biological Conservation*, *52*(1), pp.37-48.
31. Daniels, R.R., 2005. *Amphibians of peninsular India*. Universities Press.
32. Daniels, R.R. and Vencatesan, J., 2008. *Western Ghats: Biodiversity, People, Conservation*. Rupa & Company.
33. Daniel, C.J., Frid, L., Sleeter, B.M. and Fortin, M.J., 2016. State-and-transition simulation models: a framework for forecasting landscape change. Methods in Ecology and Evolution, 7(11), pp.1413-1423.
34. De Leeuw, J., Georgiadou, Y., Kerle, N., De Gier, A., Inoue, Y., Ferwerda, J., Smies, M. and Narantuya, D., 2010. The function of remote sensing in support of environmental policy. *Remote sensing*, *2*(7), pp.1731-1750.
35. Duda, R.O., Hart, P.E. and Stork, D.G., 2012. *Pattern classification*. John Wiley & Sons.

36. Echeverria, C., Coomes, D.A., Hall, M. and Newton, A.C., 2008. Spatially explicit models to analyze forest loss and fragmentation between 1976 and 2020 in southern Chile. *Ecological Modeling*, *212*(3), pp.439-449.
37. Esty, D.C., 2004. Environmental protection in the information age. *NYUL Rev.*, *79*, p.115.
38. Evans, T.P., Manire, A., de Castro, F., Brondizio, E., McCracken, S., 2001. A dynamic model of household decision-making and parcel level landcover change in the Eastern Amazon. *Ecological Modeling* 143, pp.95–113.
39. FAO, 2011. State of the World's Forests. Research and Extension, FAO, Viale delle Terme di Caracalla, 00153. Rome, Italy.
40. FAO, 2016. State of the World's Forests. Forests and Agriculture: Land-Use Challenges and Opportunities, Viale delle Terme di Caracalla, 00153. Rome, Italy.
41. Filatova, T., Polhill, J.G., van Ewijk, S., 2006. Regime shifts in coupled socio-environmental systems: review of Modeling challenges and approaches. *Environment Modeling Softwate*, *75*, pp.333–47.
42. Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K. and Helkowski, J.H., 2005. Global consequences of land use. *science*, *309*(5734), pp.570-574.
43. Forman, R.T.T., Gordron, M., 1986. *Landscape Ecology*. JohnWiley & Sons, New York, ISBN 0-471-87037-4.
44. Fraser, R.H., Olthof, I. and Pouliot, D., 2009. Monitoring land cover change and ecological integrity in Canada's national parks. *Remote Sensing of Environment*, *113*(7), pp.1397-1409.
45. Fu, B.J., Zhang, Q.J., Chen, L.D., Zhao, W.W., Gulinck, H., Liu, G.B., Yang, Q.K. and Zhu, Y.G., 2006. Temporal change in land use and its relationship to slope degree and soil type in a small catchment on the Loess Plateau of China. *Catena*, *65*(1), pp.41-48.
46. Fuller, D.O., 2001. Forest fragmentation in Loudoun County, Virginia, USA evaluated with multitemporal Landsat imagery. *Landscape Ecology*, *16*(7), pp.627-642.
47. Gadgil, M. and Chandran, M.S., 1989. Environmental impact of forest based industries on the evergreen forests of Uttara Kannada district: A Case Study. *Final report', submitted to Department of Ecology and Environment. Government of Karnataka*.
48. Gadgil, M., Daniels, R.R., Ganeshaiah, K.N., Prasad, S.N., Murthy, M.S.R., Jha, C.S., Ramesh, B.R. and Subramanian, K.A., 2011. Mapping ecologically sensitive, significant and salient areas of Western Ghats: proposed protocols and methodology. *Current Science*, *100*(2), pp.175-182.
49. Garrido, P., Elbakidze, M., Angelstam, P., Plieninger, T., Pulido, F. and Moreno, G., 2017. Stakeholder perspectives of wood-pasture ecosystem services: A case study from Iberian dehesas. *Land Use Policy*, *60*, pp.324-333.
50. Gaucherel, C. and Houet, T., 2009. Preface to the selected papers on spatially explicit landscape Modeling: current practices and challenges. *Ecological Modeling*, *220*(24), pp.3477-3480.
51. Gibon, A., Sheeren, D., Monteil, C., Ladet, S. and Balent, G., 2010. Modeling and simulating change in reforesting mountain landscapes using a social-ecological framework. *Landscape Ecology*, *25*(2), pp.267-285.
52. Giriraj, A., Irfan-Ullah, M., Murthy, M.S.R. and Beierkuhnlein, C., 2008. Modeling spatial and temporal forest cover change patterns (1973-2020): A case study from South Western Ghats (India). *Sensors*, *8*(10), pp.6132-6153.
53. Girod, B., Wiek, A., Mieg, H. and Hulme, M., 2009. The evolution of the IPCC's emissions scenarios. *Environmental science & policy*, *12*(2), pp.103-118.

54. Goldstein, B.A., Polley, E.C. and Briggs, F.B., 2011. Random forests for genetic association studies. *Statistical applications in genetics and molecular biology*, *10*(1).
55. Green, B.H., Simmons, E.A. and Woltjer, I., 1996. *Landscape conservation: Some steps towards developing a new conservation dimension*. University of London, Department of Agriculture, Horticulture and Environment, Wye College, Ashford, Kent, UK.
56. Groeneveld, J., Müller, B., Buchmann, C.M., Dressler, G., Guo, C., Hase, N., Hoffmann, F., John, F., Klassert, C., Lauf, T. and Liebelt, V., 2017. Theoretical foundations of human decision-making in agent-based land use models–A review. *Environmental Modeling & software*, *87*, pp.39-48.
57. Gupta, R.K., Prasad, T.S., Rao, P.K. and Manikavelu, P.B., 2000. Problems in upscaling of high resolution remote sensing data to coarse spatial resolution over land surface. *Advances in Space Research*, *26*(7), pp.1111-1121.
58. Hansen, M.C. and Loveland, T.R., 2012. A review of large area monitoring of land cover change using Landsat data. *Remote sensing of Environment*, *122*, pp.66-74.
59. Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R. and Kommareddy, A., 2013. High-resolution global maps of 21st-century forest cover change. *science*, *342*(6160), pp.850-853.
60. Harper, K.A., Macdonald, S.E., Burton, P.J., Chen, J., Brosofske, K.D., Saunders, S.C., Euskirchen, E.S., Roberts, D.A.R., Jaiteh, M.S. and Esseen, P.A., 2005. Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology*, *19*(3), pp.768-782.
61. Heistermann, M., Muller, C., & Ronneberger, K., 2006. Land in sight?: Achievements, deficits and potentials of continental to global scale land-use Modeling. *Agriculture, Ecosystems & Environment, 114*(2–4), pp.141–158.
62. Holderieath, J., 2016. Spatiotemporal management under heterogeneous damage and uncertain parameters. An agent-based approach. In *2016 Annual Meeting, July 31-August 2, 2016, Boston, Massachusetts* (No. 235850). Agricultural and Applied Economics Association.
63. Holland, E.P., Aegerter, J.N., Dytham, C. and Smith, G.C., 2007. Landscape as a model: the importance of geometry. *PLoS Computational Biology*, *3*(10), p.e200.
64. Hutchinson, J.J., Campbell, C.A. and Desjardins, R.L., 2007. Some perspectives on carbon sequestration in agriculture. *Agricultural and forest meteorology*, *142*(2-4), pp.288-302.
65. IPCC, W., 2000. Special report on emissions scenarios. *Intergovernmental panel on climate change special reports on climate change. Cambridge University Press, Cambridge*, *570*.
66. IPCC, 2007. Summary for policymakers. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 7-22.
67. IPCC, 2008. In: Moss, R., Babiker, M., Brinkman, S., Calvo, E., Carter, T., Edmonds, J., Elgizouli, I., Emori, S., Erda, L., Hibbard, K., Jones, R., Kainuma, M., Kelleher, J., Lamarque, J.F., Manning, M., Matthews, B., Meehl, J., Meyer, L., Mitchell, J., Nakicenovic, N., O'Neill, B., Pichs, R., Riahi, K., Rose, S., Runci, P., Stouffer, R., Vuuren, D.v., Weyant, J., Wilbanks, T., Ypersele, J.P.v., Zurek, M. (Eds.), Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies. IPCC, Geneva.

68. Irwin, E.G. and Geoghegan, J., 2001. Theory, data, methods: developing spatially explicit economic models of land use change. *Agriculture, Ecosystems & Environment, 85*(1), pp.7-24.
69. Joshi, A.R., Dinerstein, E., Wikramanayake, E., Anderson, M.L., Olson, D., Jones, B.S., Seidensticker, J., Lumpkin, S., Hansen, M.C., Sizer, N.C. and Davis, C.L., 2016. Tracking changes and preventing loss in critical tiger habitat. *Science advances*, *2*(4), p.e1501675.
70. Kamath, S.U., 1985. *Karnataka State Gazetteer, Uttara Kannada District*. Government of Karnataka Press.
71. Kennedy, R.E., Townsend, P.A., Gross, J.E., Cohen, W.B., Bolstad, P., Wang, Y.Q. and Adams, P., 2009. Remote sensing change detection tools for natural resource managers: Understanding concepts and tradeoffs in the design of landscape monitoring projects. *Remote sensing of environment, 113*(7):1382-1396.
72. Kenyon, W., Hill, G. and Shannon, P., 2008. Scoping the role of agriculture in sustainable flood management. *Land Use Policy*, *25*(3), pp.351-360.
73. Keshavarzi, A., 2010. Land Suitability Evaluation using fuzzy continuous classification (A Case Study: Ziaran Region). Modern Applied Science, 4, pp.72-81.
74. Keshtkar, H. and Voigt, W., 2016. A spatiotemporal analysis of landscape change using an integrated Markov chain and cellular automata models. *Modeling Earth Systems and Environment*, *2*(1), p.10.
75. Kinzig, A.P., Ryan, P., Etienne, M., Allison, H., Elmqvist, T. and Walker, B.H., 2006. Resilience and regime shifts: assessing cascading effects. *Ecology and society*, *11*(1).
76. Kok, K., Farrow, A., Veldkamp, A. and Verburg, P.H., 2001. A method and application of multi-scale validation in spatial land use models. *Agriculture, Ecosystems & Environment*, *85*(1), pp.223-238.
77. Kordi, M. and Brandt, S.A., 2012. Effects of increasing fuzziness on analytic hierarchy process for spatial multicriteria decision analysis. *Computers, Environment and Urban Systems*, *36*(1), pp.43-53.
78. Krishnanjan, P., Arya, V.S. and Sudhakar, S., 2014. Biodiversity hot-spot Modeling and temporal analysis of Meghalaya using Remote sensing technique. *International Journal of Environmental Sciences*, *4*(5), pp.772-785.
79. Kuèas, A.N., Trakimas, G., Balèiauskas, L.I.N.A.S. and Vaitkus, G., 2011. Multi-scale analysis of forest fragmentation in Lithuania. *Baltic Forest*, *17*(1), pp.128-135.
80. Kumar, U., Kerle, N., Punia, M. and Ramachandra, T.V., 2010. Mining land cover information using multilayer perceptron and decision tree from MODIS data. *Journal of the Indian Society of Remote Sensing*, *38*(4), pp.592-603.
81. Kumar, R., Nandy, S., Agarwal, R. and Kushwaha, S.P.S., 2014. Forest cover dynamics analysis and prediction modeling using logistic regression model. *Ecological Indicators*, *45*, pp.444-455.
82. Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C. and George, P., 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, *11*(4), pp.261-269.
83. Lambin, E.F., Geist, H., Lepers, E., 2003. Dynamics of land use and land cover change in tropical regions. Environent and Resources, 28: 205–241.
84. Laurance, W.F., Lovejoy, T.E., Vasconcelos, H.L., Bruna, E.M., Didham, R.K., Stouffer, P.C., Gascon, C., Bierregaard, R.O., Laurance, S.G. and Sampaio, E., 2002. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology*, *16*(3), pp.605-618.

85. Li, Y., Liao, Q.F., Li, X., Liao, S.D., Chi, G.B., Peng, S.L., 2003. Towards an operational system for regional-scale rice yield estimation using a time-series of Radarsat Scan SAR images. International Journal of Remote Sensing, 24: 4207–4220.
86. Li, Z., Liu, W. and Zheng, F., 2013, December. The land use changes and its relationship with topographic factors in the Jing river catchment on the Loess Plateau of China. In *SpringerPlus* (Vol. 2, No. S1, p. S3). Springer International Publishing.
87. Lillesand, T., Kiefer, R.W. and Chipman, J., 2014. *Remote sensing and image interpretation*. John Wiley & Sons.
88. Lindenmayer, D., Hobbs, R.J., Montague-Drake, R., Alexandra, J., Bennett, A., Burgman, M., Cale, P., Calhoun, A., Cramer, V., Cullen, P. and Driscoll, D., 2008. A checklist for ecological management of landscapes for conservation. *Ecology letters*, *11*(1), pp.78-91.
89. Liu, C., Frazier, P. and Kumar, L., 2007. Comparative assessment of the measures of thematic classification accuracy. *Remote sensing of environment*, *107*(4), pp.606-616.
90. Liu, Y., 2012. Modeling sustainable urban growth in a rapidly urbanising region using a fuzzy-constrained cellular automata approach. *International Journal of Geographical Information Science*, *26*(1), pp.151-167.
91. Maes, J., Paracchini, M.L., Zulian, G., Dunbar, M.B. and Alkemade, R., 2012. Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. *Biological conservation*, *155*, pp.1-12.
92. Martinuzzi, S., Radeloff, V.C., Joppa, L.N., Hamilton, C.M., Helmers, D.P., Plantinga, A.J. and Lewis, D.J., 2015. Scenarios of future land use change around United States' protected areas. *Biological Conservation*, *184*, pp.446-455.
93. Mas, J.F., Kolb, M., Paegelow, M., Olmedo, M.T.C. and Houet, T., 2014. Inductive pattern-based land use/cover change models: A comparison of four software packages. *Environmental Modeling & Software*, *51*, pp.94-111.
94. Matthews, R., Gilbert, N., Roach, A., Polhill, J., Gotts, N., 2007. Agent-based land-use models: a review of applications. *Landscape Ecology*, *22*, pp.1447–1459
95. Messier, C., Puettmann, K., Filotas, E. and Coates, D., 2016. Dealing with non-linearity and uncertainty in forest management. *Current Forestry Reports*, *2*(2), pp.150-161.
96. Mesta, P.N., Bharath, Setturu, Subash Chandran, M.D., Rajan, K.S. and Ramachandra, T.V., 2014. Inventorying, mapping and monitoring of mangroves towards sustainable management of West Coast, India. *J Geophysics Remote Sensing*, *3*, pp.130-138.
97. Meyer, W.B., 1995. Past and Present Land-use and Land-cover in the U.S.A. *Consequences*. 1(1), pp.25-33.
98. Mladenoff, D.J., White, M.A., Pastor, J., Crow, T.R., 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications, 3: 294–306.
99. MoEF, 2000. Report of the Committee on identifying parameters for designating Ecologically Sensitive Areas in India (Pronab Sen Committee Report).
100. Moen, J. and Keskitalo, E.C.H., 2010. Interlocking panarchies in multi-use boreal forests in Sweden. *Ecology and Society*, *15*(3).
101. Mondal, M.S., Sharma, N., Garg, P.K. and Kappas, M., 2016. Statistical independence test and validation of CA Markov land use land cover (LULC) prediction results. *The Egyptian Journal of Remote Sensing and Space Science*, *19*(2), pp.259-272.
102. Moran, E., Ojima, D., Buchmann, N., Canadell, J., Graumlich, L., Jackson, R., Jaramillo, V., Lavorel, S., Leadly, P., Matson, P. and Murdiyarso, D., 2005. GLP (2005): Science Plan and Implementation Strategy. *IGPB Report No. 53/IHDP Report No. 19*.

103. Mosadeghi, R., Warnken, J., Tomlinson, R., Mirfenderesk, H., 2015. Comparison of Fuzzy-AHP and AHP in a spatial multi-criteria decision making model for urban land-use planning. *Computers Environment Urban System, 49*, pp.54–56.
104. Muddle, D., Briggs, K., Dashwood, C. and Dijkstra, T., 2015. The influence of slope geology on landslide occurrence during extreme rainfall. In *proceedings of XVI European Conference on Soil Mechanics and Geotechnical Engineering*. Edinburgh, Scotland, September.
105. Mukhopadhaya, S., 2016. Land use and Land Cover Change Modeling using CA-Markov Case Study: Deforestation Analysis of Doon Valley. *Journal of Agroecology and Natural Resource Management, 3*(1), pp.1-5.
106. Munroe, D.K., Croissant, C. and York, A.M., 2005. Land use policy and landscape fragmentation in an urbanizing region: Assessing the impact of zoning. *Applied Geography, 25*(2), pp.121-141.
107. Myllyviita, T., Hujala, T., Kangas, A. and Leskinen, P., 2011. Decision support in assessing the sustainable use of forests and other natural resources-a comparative review. *The Open Forest Science Journal, 4,* pp.24-4.
108. Nakicenovic, N., Alcamo, J., Grubler, A., Riahi, K., Roehrl, R.A., Rogner, H.H. and Victor, N., 2000. *Special report on emissions scenarios (SRES), a special report of Working Group III of the intergovernmental panel on climate change*. Cambridge University Press.
109. National Research Council (NRC), 1999. *Global environmental change: Research pathways for the next decade*. National Academies Press.
110. National Research Council (NRC), 2001. Committee on Grand Challenges in Environmental Sciences. *Grand challenges in environmental sciences*. National Academy Press.
111. National Research Council (NRC), 2014. Advancing Land Change Modeling: Opportunities and Research Requirements; The National Academies Press: Washington, DC, USA, 2014.
112. Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E. and Wulder, M.A., 2014. Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment*, *148*, pp.42-57.
113. Opdam, P., Steingröver, E. and Van Rooij, S., 2006. Ecological networks: a spatial concept for multi-actor planning of sustainable landscapes. *Landscape and urban planning*, *75*(3-4), pp.322-332.
114. Ostapowicz, K., Vogt, P., Riitters, K.H., Kozak, J. and Estreguil, C., 2008. Impact of scale on morphological spatial pattern of forest. *Landscape ecology*, *23*(9), pp.1107-1117.
115. Overmars, K.P. and Verburg, P.H., 2005. Analysis of land use drivers at the watershed and household level: Linking two paradigms at the Philippine forest fringe. *International Journal of Geographical information science*, *19*(2), pp.125-152.
116. Paloniemi, R. and Tikka, P.M., 2008. Ecological and social aspects of biodiversity conservation on private lands. *Environmental Science & Policy, 11*(4), pp.336-346.
117. Parker, D.C., Manson, S.M., Janssen, M.A., Hoffmann, M.J. and Deadman, P., 2003. Multi-agent systems for the simulation of land-use and land-cover change: A review. *Annals of the association of American Geographers*, *93*(2), pp.314-337.
118. Payés, A.C.L.M., Pavão, T. and dos Santos, R.F., 2013. The conservation success over time: Evaluating the land use and cover change in a protected area under a long re-categorization process. *Land Use Policy, 30*(1), pp.177-185.

119. Plexida, S.G., Sfougaris, A.I., Ispikoudis, I.P. and Papanastasis, V.P., 2014. Selecting landscape metrics as indicators of spatial heterogeneity—A comparison among Greek landscapes. *International Journal of Applied Earth Observation and Geoinformation*, *26*, pp.26-35.
120. Poelmans, L. and Van Rompaey, A., 2010. Complexity and performance of urban expansion models. *Computers, Environment and Urban Systems*, *34*(1), pp.17-27.
121. Pohl, C., 1996, *Geometric aspects of multisensor image fusion for topographic map updating in the humid Tropics*. ITC publication No. 39 (Enschede: ITC), ISBN 90 6164 121 7.
122. Pontius, R.G., Cornell, J.D., and Hall, C.A.S., 2001. Modeling the spatial pattern of land-use change with GEOMOD2: Application and validation for Costa Rica. *Agriculture, Ecosystems & Environment*, *85*(1–3), pp.191–203.
123. Pontius Jr, R.G. and Millones, M., 2011. Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. *International Journal of Remote Sensing*, *32*(15), pp.4407-4429.
124. Prasad, P.R.C., Sringeswara, A.N., Reddy, C.S., Nagabhatla, N., Rajan, K.S., Giriraj, A., Murthy, M.S.R., Raza, S.H. and Dutt, C.B.S., 2009. Assessment of forest fragmentation and species diversity in North Andaman Islands (India): a geospatial approach. *International Journal of Ecology & Development™*, *14*(F09), pp.33-46.
125. Puettmann, K.J., 2014. Restoring the adaptive capacity of forest ecosystems. *Journal of sustainable forestry*, *33*(sup1), pp.S15-S27.
126. Puyravaud, J.P., 2003. Standardizing the calculation of the annual rate of deforestation. *Forest ecology and management*, *177*(1-3), pp.593-596.
127. Qiaomin, Z. and Shuzhen, S., 2001. The mangrove wetland resources and their conservation in China. *Journal of natural resources*, *16*(1), pp.28-36.
128. Ramachandra, T.V. and Shruthi, B.V., 2007. Spatial mapping of renewable energy potential. *Renewable and Sustainable Energy Reviews*, *11*(7), pp.1460-1480.
129. Ramachandra, T.V., Savitha Ganapathy, 2008. Vegetation analysis in Uttara Kannada district using GIS and Remote sensing techniques, *ENVIS Technical Report* (24), CES, IISc.
130. Ramachandra, T.V. and Kumar, U., 2011. Characterisation of landscape with forest fragmentation dynamics. *Journal of Geographic Information System*, *3*(3), pp.242-253.
131. Ramachandra, T.V., Bharath, Setturu., Bharath H.A., 2012a. Peri-Urban to Urban Landscape Patterns Elucidation through Spatial Metrics, International Journal of Engineering Research and Development, 2(12): 58-81.
132. Ramachandra, T.V., Chandran, M.D.S., Joshi, N.V., Pallav Julka., Uttam Kumar., Bharath H.A., Prakash N.M., Rao, G.R., and Vishnu Mukri., 2012b. *Landslide Susceptible Zone Mapping in Uttara Kannada, Central Western Ghats*, ENVIS Technical Report 28, Energy & Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, 560012.
133. Ramachandra, T.V., Bharath, Setturu. and Bharath, A., 2014a. Spatio-temporal dynamics along the terrain gradient of diverse landscape. *Journal of Environmental Engineering and Landscape Management*, *22*(1), pp.50-63.
134. Ramachandra, T.V., Hegde, G. and Krishnadas, G., 2014b. Scope of solar energy in Uttara Kannada, Karnataka State, India: roof top PV for domestic electricity and standalone systems for irrigation. *Productivity*, *55*(1), p.100.

135. Ramachandra, T.V., Hegde, G. and Krishnadas, G., 2014c. Potential assessment and decentralized applications of wind energy in Uttarakannada, Karnataka. *International Journal of Renewable energy Resources*, *4*(1), pp.1-10.
136. Ramachandra, T.V., Hegde, G., Bharath, Setturu. and Krishnadas, G., 2014d. Bioenergy: A sustainable energy option for rural India. *Advances in Forestry Letters (AFL)*, *3*(1), pp.1-15.
137. Ramachandra, T.V., Chandran, M.D.S., Joshi, N.V., Karthick, B. and Mukri, V.D., 2015. Ecohydrology of Lotic Systems in Uttara Kannada, Central Western Ghats, India. In *Environmental Management of River Basin Ecosystems* (pp. 621-665). Springer, Cham.
138. Ramachandra, T.V., Bharath, Setturu., and Chandran, M.D.S., 2016. Geospatial analysis of forest fragmentation in Uttara Kannada District, India,2016. Forest Ecosystems, 3(1), pp.1-15. https://doi.org/10.1186/s40663-016-0069-4
139. Ramachandra, T.V. and Bharath, Setturu, 2018. Geoinformatics based Valuation of Forest Landscape Dynamics in Central Western Ghats, India. J Remote Sensing & GIS, 7(227), p.2.
140. Ramachandra, T.V., Bharath, Setturu., 2020. Carbon Sequestration Potential of the Forest Ecosystems in the Western Ghats, a Global Biodiversity Hotspot. Natural Resources Research, 29, pp.2753–2771. https://doi.org/10.1007/s11053-019-09588-0
141. Ramachandra, T.V., Vinay, S., Bharath, Setturu., Chandran, M.D. and Aithal, B.H., 2020. Insights into riverscape dynamics with the hydrological, ecological and social dimensions for water sustenance. *Current Science (00113891)*, *118*(9).
142. Ramachandra, T.V. and Bharath, S., 2021. Carbon Footprint of Karnataka: Accounting of Sources and Sinks. In *Carbon Footprint Case Studies* (pp. 53-92). Springer, Singapore.
143. Ramakrishnan, P.S., 2000. *Mountain biodiversity, land use dynamics, and traditional ecological knowledge*. Oxford & IBH Pub. Co.
144. Reddy, C.S., Singh, S., Dadhwal, V.K., Jha, C.S., Rao, N.R. and Diwakar, P.G., 2017. Predictive Modeling of the spatial pattern of past and future forest cover changes in India. *Journal of Earth System Science*, *126*(1), pp.8.
145. Reis, S., 2008. Analyzing land use/land cover changes using remote sensing and GIS in Rize, North-East Turkey. *Sensors*, *8*(10), pp.6188-6202.
146. Renard, Q., Pélissier, R., Ramesh, B.R. and Kodandapani, N., 2012. Environmental susceptibility model for predicting forest fire occurrence in the Western Ghats of India. *International Journal of Wildland Fire, 21*(4), pp.368-379.
147. Revenga, C., 2005. Developing indicators of ecosystem condition using geographic information systems and remote sensing. *Regional Environmental Change*, *5*(4), pp.205-214.
148. Riitters, K.H., Wickham, J.D., O'neill, R.V., Jones, K.B., Smith, E.R., Coulston, J.W., Wade, T.G. and Smith, J.H., 2002. Fragmentation of continental United States forests. *Ecosystems*, *5*(8), pp.0815-0822.
149. Riitters, K.H., Wickham, J.D. and Coulston, J.W., 2004. A preliminary assessment of Montreal process indicators of forest fragmentation for the United States. *Environmental monitoring and assessment*, *91*(1-3), pp.257-276.
150. Rounsevell, M.D., Pedroli, B., Erb, K.H., Gramberger, M., Busck, A.G., Haberl, H., Kristensen, S., Kuemmerle, T., Lavorel, S., Lindner, M., Lotze-Campen, H., 2012. Challenges for land system science. *Land Use Policy*, *29*(4), pp.899-910.

151. Roy, P.S., Murthy, M.S.R., Roy, A., Kushwaha, S.P.S., Singh, S., Jha, C.S., Behera, M.D., Joshi, P.K., Jagannathan, C., Karnatak, H.C. and Saran, S., Reddy, C.S., Kushwaha, D., Dutt, C.B.S., Porwal, M.C., Sudhakar, S., Srivastava, V.K., Hitendra Padalia, Subrata Nandy, and Stutee Gupta, 2013. Forest fragmentation in India. *Current Science, 105*(6), pp.774-780.
152. Saaty, T.L., 2008. Decision making with the analytic hierarchy process. *International journal of services sciences*, *1*(1), pp.83-98.
153. Santé, I., García, A.M., Miranda, D. and Crecente, R., 2010. Cellular automata models for the simulation of real-world urban processes: A review and analysis. *Landscape and Urban Planning*, *96*(2), pp.108-122.
154. Schulz, J.J. and Schröder, B., 2017. Identifying suitable multifunctional restoration areas for Forest Landscape Restoration in Central Chile. *Ecosphere*, *8*(1).
155. Serra, P., Pons, X. and Saurí, D., 2008. Land-cover and land-use change in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors. *Applied Geography*, *28*(3), pp.189-209.
156. Silva, E.A., and Clarke, K.C., 2002. Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal. Computers, *Environment and Urban Systems, 26*(6), 525–552.
157. Singh, C.P., Chauhan, J.S., Parihar, J.S., Singh, R.P. and Shukla, R., 2015. Using environmental niche Modeling to find suitable habitats for the Hard-ground Barasingha in Madhya Pradesh, India. *Journal of Threatened Taxa*, *7*(11), pp.7761-7769.
158. Skakun, S., Vermote, E., Roger, J.C. and Franch, B., 2017. Combined Use of Landsat-8 and Sentinel-2A Images for Winter Crop Mapping and Winter Wheat Yield Assessment at Regional Scale. *AIMS Geosciences*, *3*(2), pp.163-186.
159. Southworth, J., Nagendra, H. and Tucker, C., 2002. Fragmentation of a landscape: Incorporating landscape metrics into satellite analyses of land-cover change. *Landscape Research*, *27*(3), pp.253-269.
160. Steiner, F., Blair, J., McSherry, L., Guhathakurta, S., Marruffo, J. and Holm, M., 2000. A watershed at a watershed: the potential for environmentally sensitive area protection in the upper San Pedro Drainage Basin (Mexico and USA). *Landscape and urban planning*, *49*(3-4), pp.129-148.
161. Synes, N.W., Brown, C., Watts, K., White, S.M., Gilbert, M.A. and Travis, J.M., 2016. Emerging opportunities for landscape ecological modelling. *Current Landscape Ecology Reports*, *1*(4), pp.146-167.
162. Tabor, K., Burgess, N.D., Mbilinyi, B.P., Kashaigili, J.J. and Steininger, M.K., 2010. Forest and woodland cover and change in coastal Tanzania and Kenya, 1990 to 2000. *Journal of East African Natural History*, *99*(1), pp.19-45.
163. Tang, K., Zhang, K. and Lei, A., 1998. Critical slope gradient for compulsory abandonment of farmland on the hilly Loess Plateau. *Chinese Science Bulletin*, *43*(5), pp.409-412.
164. Termorshuizen, J.W. and Opdam, P., 2009. Landscape services as a bridge between landscape ecology and sustainable development. *Landscape ecology*, *24*(8), pp.1037-1052.
165. Terra, T.N. and dos Santos, R.F., 2012. Measuring cumulative effects in a fragmented landscape. *Ecological Modeling*, *228*, pp.89-95.
166. Terra, T.N., dos Santos, R.F. and Costa, D.C., 2014. Land use changes in protected areas and their future: The legal effectiveness of landscape protection. *Land Use Policy*, *38*, pp.378-387.

167. Tewari, V.P., Álvarez-gonzález, J.G. and García, O., 2014. Developing a dynamic growth model for teak plantations in India. *Forest Ecosystems*, *1*(1), pp.1-10.
168. Thom, D. and Seidl, R., 2016. Natural disturbance impacts on ecosystem services and biodiversity in temperate and boreal forests. *Biological Reviews*, *91*(3), pp.760-781.
169. Thomas, H. and Laurence, H.M., 2006. Modeling and projecting land-use and land-cover changes with a cellular automaton in considering landscape trajectories: An improvement for simulation of plausible future states. *EARSeL eProceedings*, *5*, pp.63-76.
170. Tóth, S.F., Haight, R.G. and Rogers, L.W., 2011. Dynamic reserve selection: Optimal land retention with land-price feedbacks. *Operations Research*, *59*(5), pp.1059-1078.
171. Turner, M.G., 2010. Disturbance and landscape dynamics in a changing world. *Ecology*, *91*(10), pp.2833-2849.
172. van Vliet, J., Bregt, A.K., Brown, D.G., van Delden, H., Heckbert, S. and Verburg, P.H., 2016. A review of current calibration and validation practices in land-change modeling. *Environmental Modeling & Software*, *82*, pp.174-182.
173. Verburg P.H., Soepboer W., Limpiada R. and Espaldon V. 2002. Modeling the spatial dynamics of regional land use: The CLUE-S model. *Environmental Management*, *30*(3), pp. 391–405.
174. Verburg, P. H., Schot, P.P., Dijst, M.J., & Veldkamp, A., 2004. Land use change Modeling: Current practice and research priorities. *GeoJournal*, *61*, pp.309–324.
175. Verburg, P.H., Kok, K., Pontius Jr, R.G. and Veldkamp, A., 2006. Modeling land-use and land-cover change. In Land-use and land-cover change (pp. 117-135). Springer Berlin Heidelberg.
176. Verburg, P.H., van Berkel, D.B., van Doorn, A.M., van Eupen, M. and van den Heiligenberg, H.A., 2010. Trajectories of land use change in Europe: a model-based exploration of rural futures. *Landscape ecology*, *25*(2), pp.217-232.
177. Verburg, P.H., Dearing, J.A., Dyke, J.G., Van Der Leeuw, S., Seitzinger, S., Steffen, W. and Syvitski, J., 2016. Methods and approaches to Modeling the Anthropocene. *Global Environmental Change*, *39*, pp.328-340.
178. Vinay, S., Bharath, Setturu., Bharath, H.A. and Ramachandra, T.V., 2013, November. Hydrologic model with landscape dynamics for drought monitoring. In *proceeding of: Joint International Workshop of ISPRS WG VIII/1 and WG IV/4 on Geospatial Data for Disaster and Risk Reduction, Hyderabad, November* (pp. 21-22).
179. Visser, H. and De Nijs, T., 2006. The map comparison kit. *Environmental Modeling & Software*, *21*(3), pp.346-358.
180. Watson, J.E., Grantham, H.S., Wilson, K.A. and Possingham, H.P., 2011. Systematic conservation planning: past, present and future. *Conservation biogeography*, pp.136-160.
181. West, T.O., Le Page, Y., Huang, M., Wolf, J. and Thomson, A.M., 2014. Downscaling global land cover projections from an integrated assessment model for use in regional analyses: results and evaluation for the US from 2005 to 2095. *Environmental Research Letters*, *9*(6), p.064004.
182. 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), pp.481-489.
183. Wu, J., and David, J.L., 2002. A spatially explicit hierarchical approach to Modeling complex ecological systems: theory and applications. *Ecological Modeling*, *153*(1), pp.7-26.

184. Wu, G., de Leeuw, J., Skidmore, A.K., Prins, H.H. and Liu, Y., 2007. Concurrent monitoring of vessels and water turbidity enhances the strength of evidence in remotely sensed dredging impact assessment. *Water Research*, *41*(15), pp.3271-3280.
185. Wu, L.Y., He, D.J., You, W.B., Ji, Z.R., Tan, Y. and Zhao, L.L., 2017. The dynamics of landscape-scale ecological connectivity based on least-cost model in Dongshan Island, China. *Journal of Mountain Science*, *14*(2), pp.336-345.
186. Xu, C., Gertner, G.Z. and Scheller, R.M., 2009. Uncertainties in the response of a forest landscape to global climatic change. *Global Change Biology*, *15*(1), pp.116-131.
187. Ying, X., Zeng, G.M., Chen, G.Q., Tang, L., Wang, K.L. and Huang, D.Y., 2007. Combining AHP with GIS in synthetic evaluation of eco-environment quality—A case study of Hunan Province, China. *Ecological modelling*, *209*(2-4), pp.97-109.
188. Yousefpour, R., Jacobsen, J.B., Thorsen, B.J., Meilby, H., Hanewinkel, M. and Oehler, K., 2012. A review of decision-making approaches to handle uncertainty and risk in adaptive forest management under climate change. *Annals of forest science*, *69*(1), pp.1-15.
189. Zhang, J., Su, Y., Wu, J. and Liang, H., 2015. GIS based land suitability assessment for tobacco production using AHP and fuzzy set in Shandong province of China. *Computers and Electronics in Agriculture*, *114*, pp.202-211.
190. Zhou, W., Troy, A. and Grove, M., 2008. Object-based land cover classification and change analysis in the Baltimore metropolitan area using multitemporal high resolution remote sensing data. *Sensors*, *8*(3), pp.1613-1636.

"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 Uttara Kannada, for which I express my seiner 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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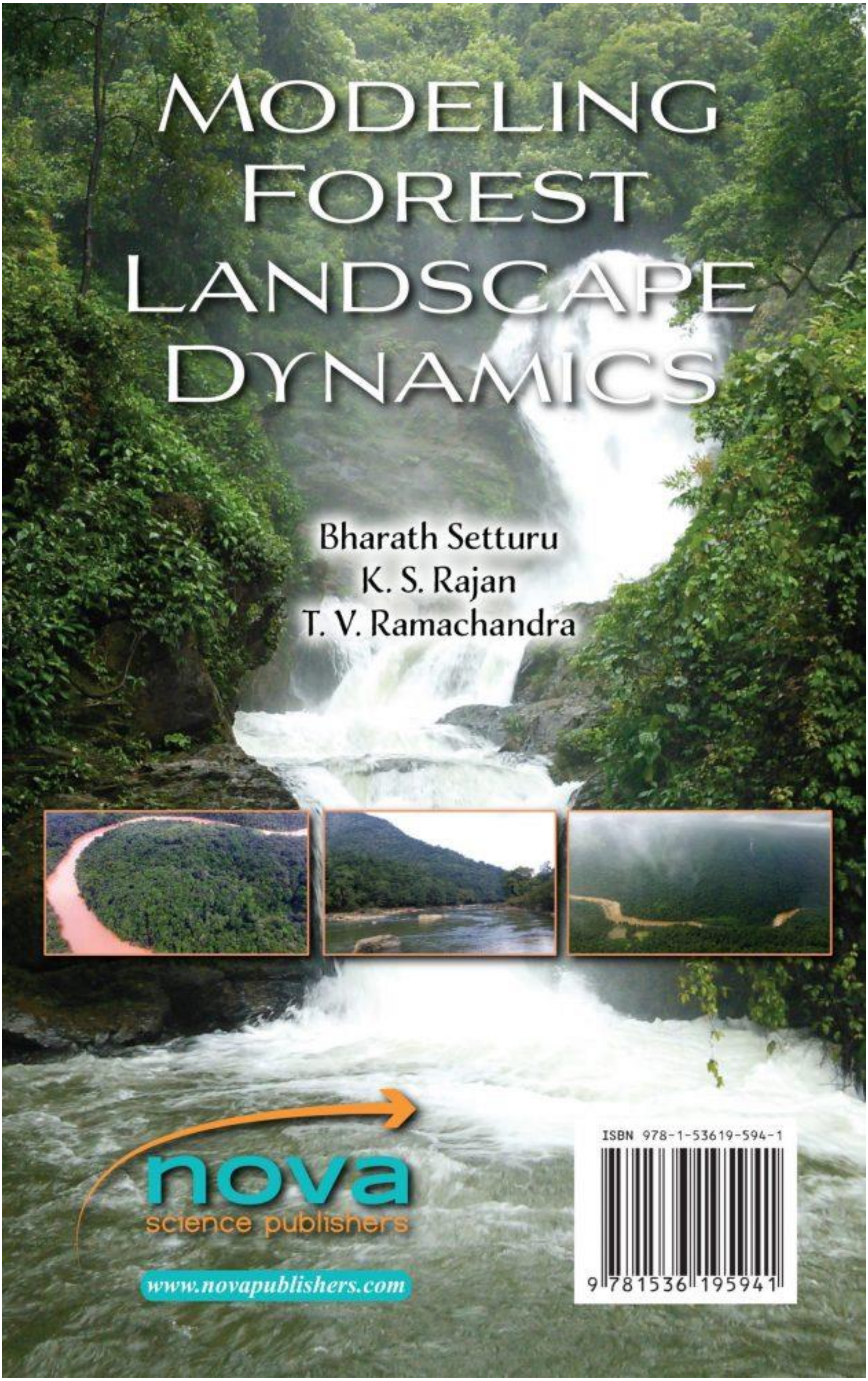
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