Assessing impact of climate change on forest cover type shifts in Western Himalayan Eco-region

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Abstract: Climate is a critical factor affecting forest ecosystems and their capacity to produce goods and services. Effects of climate change on forests depend on ecosystem-specific factors including dimensions of climate (temperature, precipitation, drought, wind etc.). Available information is not sufficient to support a quantitative assessment of the ecological, social and economic consequences. The present study assessed shifts in forest cover types of Western Himalayan Eco-region (700–4500 m). 100 randomly selected samples (75 for training and 25 for testing the model), genetic algorithm of rule set parameters and climatic envelopes were used to assess the distribution of five prominent forest cover types (Temperate evergreen, Tropical semi-evergreen, Temperate conifer, Subtropical conifer, and Tropical moist deciduous forests). Modelling was conducted for four different scenarios, current scenario, changed precipitation (8% increase), changed temperature (1.07°C increase), and both changed temperature and precipitation. On increasing precipitation a downward shift in the temperate evergreen and tropical semi-evergreen was observed, while sub-tropical conifer and tropical moist-deciduous forests showed a slight upward shift and temperate conifer showed no shift. On increasing temperature, an upward shift in all forest types was observed except sub-tropical conifer forests without significant changes. When both temperature and precipitation were changed, the actual distribution was maintained and slight upward shift was observed in all the forest types except sub-tropical conifer. It is important to understand the likely impacts of the projected climate change on the forest ecosystems, so that better management and conservation strategies can be adopted for the biodiversity and forest dependent community. Knowledge of impact mechanisms also enable identification and mitigation of some of the conditions that increase vulnerability to climate change in the forest sector.

Keywords: Climate change; forest cover types; shift; western Himalaya; genetic algorithm

Introduction

Forests are the vegetation type resulting from the process of succession on land areas except local conditions including climate, soil and biotic factors which arrest development at an earlier seral stage (Bryant 1986; Xu et al. 2009; Geri et al. 2010; Dale et al. 2010; Guo and Werger 2010). Expanding human population and economies are rapidly transforming forest ecosystems (Allen et al. 2010). Climate is another important factor affecting forests (Lasch et al. 2002; Soja et al. 2007). It has an influence on the distribution, structure and productivity (Horikawa et al. 2009) of the forests. Naturalists provide many classification schemes of forest types, but there is a general agreement in considering climatic factors (Champion and Seth 1968; Bryant 1986). Changes in the climate are inevitable and well documented in wide range of literature (IPCC 2007; Miller et al. 2009; Omann et al. 2009; Allen et al. 2010; Lindner et al. 2010). This can severely impact forests, and significant forest dieback can occur (Schickhoff 2000; IPCC 2007; Baker et al. 2010). There is a probability of shifts in forest biomes due to an increase in temperature and/or changes in water regimes and precipitation pattern (Gasner et al. 2010; Hanewinkel et al. 2010). It has been estimated that with 1°C rise in temperature ecological zones move on earth by 160 km in North-South direction (Thuiller 2007). Many species shifted their ranges to more suitable habitats due to increase in temperature, moving towards higher altitudes (Lenoir et al. 2008; Vennetier and Rippert 2009). Past evidences showed forest migration rates exceed 50 km per century (Noss 2001; Parmesan and Yohe 2003; Woddall et al. 2009). It is expected that tropical forest areas might get seriously affected (Ravindranath et al. 2006; Schickhoff 2008; Suresh et al. 2010).

Geospatial tools and modelling techniques play important role in monitoring the forest ecosystems (Copin and Bauer 1996; Fraser et al. 2005; Coops et al. 2010; Selkowitz 2010). Modelling can help researchers and planners to make future predictions in time or spatial estimations in a region (Dale et al. 2010). Spa-
tial models have become an important branch of scientific endeavour. In environmental sciences they include weather forecasting, climate models, ground water models, biological ecosystems models, ecological niche models, etc. (Wegener 2001; Jakeman et al. 2008). Models help to formalize our understanding and develop theory about how spatial patterns and ecological processes interacts (Gustafson et al. 2006).

Integrating climate change scenarios in geospatial models can provide insights of shifts in forest cover types. Such shifts are very important to understand for the adaptation planning of the communities dependent on the forest ecosystems. Incidentally around 200 000 villages in India are classified as forest villages; there is obviously large dependence of communities on forest resources (Ravindranath and Sudha 2004). In India, forests accounts for 21% of the geographical area (ISFR 2009). Forests play an important role in environment and economy (Negi 2009). As per study of Ravindranath et al. (2006) around, 77% (A2 scenario) and 68% (B2 scenario) of the forest types in India might shift towards wetter forest types in north-east region and drier forest types in the north-west region in absence of anthropogenic disturbances.

Such estimates are very important for Western Himalayan Eco-region, which represent unique areas for the detection of climatic change and the assessment of climate-related impacts. One reason for this is that, the climate changes rapidly with height over relatively short horizontal distances, so does vegetation and hydrology (Whiteman 2000). Second, the human and forest resource interaction is relatively very high unlike other parts of the country. Finally, mountain systems attract large numbers of people in search of opportunities for recreation and tourism (Godde et al. 2000). It is important to understand the likely impacts of the projected climate change on the forest ecosystems, so that better management and conservation strategies can be adopted for the biodiversity and the forest dependent community. This study was taken because the impacts on the forest types are already visible. Moreover, the recent scientific studies showed impacts on the productivity, forest type shifts, invasions, etc. This study used remote sensing, GIS and niche modelling to provide an evidence for the expected shift in the forest cover types due to climate change in the western Himalaya (between 700 and 4 500 m altitude).

Materials and methods

Study site

Western Himalayas (altitude of 700–4 500 m) were chosen as the study site. The study area consists of parts of Srinagar, Gangotri national park, Joshimath, Gopeshwar, regions of Pauri and Ku-maoon. The climatic zone of western Himalaya includes alpine region (above 4 500 m), sub-alpine (3 500–4 500 m), temperate (2 000–3 500 m), sub-tropical (700–2 000 m) and tropical (below 700 m). The climate is from largely semi-arid to arid and the growth of trees is limited by moisture stress. Lower western Himalayan temperate forest includes: (1) ban oak forest with Quercus leucotricophora, deodar and rhododendron; (2) moru oak forest: Q. dilatata, Q. leucotricophora, Q. semecarpifolia, fir, spruce, deodar, blue pine, rhododendron, chestnut, walnut, Betula and Acer; (3) moist deodar forest extensively developed in western Himalaya and in parts of Nepal; (4) western mixed coniferous forest: fir, spruce and deodar; (5) moist temperate deciduous forest: Acer, Carpinus, Betula and Fraxinus, and low level blue pine fir. Upper region includes upper oak-fir forest. In trans-Himalayan region dry temperate forest, high level blue pine forest, dry junipers forests are found.

Software

ERDAS Imagine version 9.2 provided by Leica Geosystems was used for satellite pre-processing and analysis. ArcGIS version 9.2 provided by ESRI was used for visual interpretation, and map preparation and analysis. Data processing was carried out on HP xw4550 workstations on Windows XP Professional platform. The facilities available with the Geoinformatics Laboratory at the TERI University, New Delhi were used for this.

Data

Landsat MSS data (path/row 156/39) available with the Global Land Cover Network (GLCN) was used. The datasets are free for the academic and research purposes. For the recent data, IRS P6 LISS III data (path/row 98/50, 98/49, 97/50, 97/49) of 2006 was used. The datasets were taken from the archived databank of the Geoinformatics Laboratory of the TERI University, New Delhi. The Global Land Cover map (2000) prepared for south central Asia using SPOT Vegetation dataset was procured (Agarwal et al. 2003). Climate data for the current time period was obtained from worldclim site. Climate data include annual precipitation, bio 1-bio 19 and altitude. The digital elevation model (DEM) data of Shuttle Radar Topographic Machine (SRTM) was downloaded from the website (http://www.srtm.csi.cgiar.org/, http://www.srtm.usgs.gov/) and imported to Arc-Map for producing the layer maps of aspect and slope.

Data processing

Satellite data for 1976 was downloaded from the Landsat website (www.landsat.org). The IRS P6 LISS III data were borrowed from the National Resource Repository Initiative of National Remote Sensing Centre (NRSC) that is being executed at TERI University. Landsat MSS data were geometrically and radiometrically corrected. IRS P6 LISS III data were processed for geometric and radiometric correction, following procedure used by GLCF while processing Landsat datasets. Onscreen enhancements like local stretching, histogram adjustment, grey level thresholding, filtering and changes in band combinations, etc. were used while interpreting the dataset. The enhancement techniques applied were very locale specific to extract the maximum possible information and delineate the boundaries between the LULC classes.

A strip was subset from the GLC 2000 map, and a vector