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Climate change impact and vulnerability assessment of forests in the Indian Western Himalayan region: A case study of Himachal Pradesh, India

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ABSTRACT

Climate change impact and vulnerability assessment at state and regional levels is necessary to develop adaptation strategies for forests in the biogeographically vital Himalayan region. The present study assesses forest ecosystem vulnerability to climate change across Himachal Pradesh and presents the priority districts for vulnerability reduction under 'current climate' and 'future climate' scenarios. Vulnerability of forests under 'current climate' scenario is assessed by adopting indicator-based approach, while the vulnerability under 'future climate' scenario is assessed using climate and vegetation impact models. Based on the vulnerability index estimated to present the vulnerability of forests under current and projected climate change impacts representing climate driven vulnerability, five districts – Chamba, Kangra, Kullu, Mandi and Shimla are identified as priority forest districts for adaptation planning. Identifying vulnerable forest districts and forests will help policy makers and forest managers to prioritize resource allocation and forest management interventions, to restore health and productivity of forests and to build long-term resilience to climate change.

Introduction

Forest ecosystems play an important role in the global biogeochemical cycle and exert significant influence on the earth's climate. The boundaries of forest biomes often closely follow patterns of climatic variables; particularly temperature and/or moisture (Stephenson, 1990). A close link between climate and forests implies that a dramatic change in one will influence the other (FAO Forestry paper, 2013). The paleoecological records indicate that forest vegetation has the potential to respond within years to a few decades of climate change (IPCC, 2014). Fischlin (2007) report that 20–30% of the plant and animal species would be at increased risk of extinction if the global average temperature increase exceeded 2–3 °C above the

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pre-industrial level. According to IPCC (2014) climate and non-climate stressors are projected to impact forests during the 21st century leading to large-scale forest die-back, biodiversity loss and diminished ecological benefits.

Climate change is projected to be a dominant stressor on terrestrial ecosystems in the second half of the 21st century, particularly under high emission scenarios such as RCP6.0 and 8.5 (IPCC, 2014). In high altitude and high latitude terrestrial ecosystems, climatic changes exceeding those projected under RCP2.6, will lead to major changes in species distributions and ecosystem function (IPCC, 2014). The vulnerability of forest ecosystems to climate change, i.e. their propensity to be adversely affected, is determined by the sensitivity of ecosystem processes to the particular elements of climate undergoing change and the degree to which the system (including its coupled social elements) can maintain its structure, composition and function in the presence of such change, either by enduring or adapting to it (IPCC, 2014).

In India, national level assessment studies for impact of climate change on forests are available (Chaturvedi et al., 2011; Gopalakrishnan et al., 2011). However such studies are lacking at the regional level. Using climate projections of the Regional Climate Model of the Hadley Centre (HadRM3) and the dynamic global vegetation model IBIS for A2 and B2 scenarios Chaturvedi et al., 2011 have reported that 39 and 34% of forest grids in India are likely to undergo change of forest type under the A2 and B2 scenarios, respectively by the end of this century. This study also concluded that the upper Himalayas, northern and central parts of Western Ghats and certain parts of central India are most vulnerable to projected impacts of climate change, while North-eastern forests are more resilient.

Despite intensive research efforts and planning of adaptation measures for forest management, it remains challenging to take into account the anticipated climatic conditions over the 21st century. This is because: (1) there is still considerable uncertainty about the future climate development and the current climate projections are characterized by uncertainty about the projection of future climate variability and extreme events; and, (2) the existing impact assessments vary widely depending on the impact models applied and climate scenarios investigated.

Himalayan ecosystems are projected to be extremely sensitive under future climate (Chaturvedi et al., 2011). As a part of the Himalayan mountain ecosystem, Himachal Pradesh hosts a wide range of natural resources. The state has unique forests and diverse habitats with large altitudinal variations. Any change in temperature or rainfall pattern will adversely impact the entire ecosystem. Further, Himalayan ecosystems are highly vulnerable due to the stress caused by forest land diversion, increasing pressure from human population, exploitation of natural resources, infrastructure development, mining, and other related challenges. The effect of these current stressors is likely to be exacerbated due to climatic changes, which would be additional (Ravindranath et al., 2006).

Analysis of temperature trends in the Himalayan region shows that temperature increases are greater in the uplands than that in the lowlands (Shrestha et al., 1999). Observed impacts of historical trends include movement of apple orchards to higher altitudes, loss of certain tree species, drying of traditional water sources, changes in bird types and populations, reduction in crop yields, and increased vulnerability of winter cropping due to changes in rainfall patterns and planting dates (ADB, 2010). District level mapping of Himachal Pradesh using a composite of biophysical, social and technological indicators (1960–1990) showed lowest adaptive capacity for Chamba and Kullu and highest adaptive capacity for Kangra, Hamirpur, Una, Solan and Sirmour districts (O'Brien et al., 2004). The districts of Hamirpur, Una, Solan, Bilaspur and Sirmour have been categorised as highly exposed and vulnerable towards climate change whereas, Kullu and Shimla have medium level of vulnerability (O'Brien et al., 2004).

In the present study, we assess vulnerability of forests under current climate scenario (also referred to as 'inherent vulnerability' of forests – Sharma et al., 2013) and climate change driven vulnerability under future climate scenario. All the twelve districts in Himachal Pradesh are ranked according to vulnerability of forests under the two scenarios. We use indicator-based vulnerability assessment methodology under current climate scenario. CMIP5 (Coupled Model Inter-comparison Project phase 5) models-based climate projections under different RCPs and IBIS (Integrated Biosphere Simulator) dynamic vegetation model are used to assess the climate change driven vulnerability under future climate scenario. Such information is useful to prioritize the most vulnerable districts and to develop adaptation strategies and practices in order to build long-term forest resilience to climate change. The following specific research questions are addressed in the present study.

a) What is the forest vulnerability ranking of different districts in Himachal Pradesh under 'current climate' scenario?
b) Forests in which districts are likely to be impacted under 'future climate' scenario?
c) Which are the priority districts for adaptation planning under impending climate change?

Study area: Himachal Pradesh

Geography and location

The hilly, mountainous forests of Himachal Pradesh nested in the Indian Himalayan region (IHR) are spread across three climatic zones namely, the outer Himalayas, the inner Himalayas, and the Alpine zone. It is located between latitude 30° 22′ to 33° 12′ N and longitude 75°45′ to 79° 04′ E. The altitude of the state varies from 248 m to 6735 m above the mean sea level and the total geographical area is 55,673 km^2 (Fig. 1).