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ORIGINAL ARTICLE

Tree-ring analysis over western Himalaya and its long-term association with vapor pressure and potential evapotranspiration

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ABSTRACT

Multi species tree-ring chronologies of the western Himalaya revealed strong significant negative relationship with potential evapotranspiration (PET) and vapor pressure (VP), and positive with moisture index (MI) and Palmer Drought Severity Index (PDSI) during spring season (March to May). The preliminary study showed that the MI and PDSI particularly in spring season might have a large scale positive association in developing of annual ring-width patterns, whereas PET and VP during the season are found not to be conducive for the trees growth. PET and VP from the beginning of the year 1917 showed strong influence on tree growth. High and low PET/VP might be associated with low and high MI/PDSI of the region. Extremely narrow ring width indices were observed in the year of 1921, 1941, 1953, 1954 and 1985 at most of the tree sites which are under the severe moisture stress condition due to extremely high PET and VP of the region. Also, extremely low PET and VP were found during 1917, 1933 and 1982, reflecting ring-width index above the normal due to enough moisture supply. Thus, the released and suppressed tree growth over the region is probably linked with the high and low MI/PDSI of the region. Loss or accumulation of soil moisture of the region might be precondition before the starting of growing season of the trees. The recent observation also suggests a weakening of VP and PET's influence on tree growth during recent few decades as compared to early period in sliding 31-years windows over western Himalaya. Correlation analysis of PET with MI and VP as well as PDSI for the period 1902–2002 during spring season indicated statistically strong correlation ($r = -0.53, 0.82, -0.50$) respectively which is highly significant at 0.01% level.

Introduction

The Himalaya plays a vital role in controlling and maintaining the Asian region monsoon system. The patterns of long-term climate variability (rainfall and temperature) of several hundred years back over Himalayan region have been discussed and compared since the medieval warm period using tree-rings records of different species from low to high altitude locations (Bhattacharyya et al., 2006; Borgaonkar et al., 1994, 1996, 1999, 2011; Borgaonkar, 1996; Chaudhary and Bhattacharyya, 2000; Hughes, 1992; Pant et al., 1995, 1998, 2000; Singh et al., 2006, 2004; Singh and Yadav, 2007; Yadav and Singh, 2002; Yadav et al., 1997, 2004, 2006, 2009). The reconstructed summer temperatures since the last millennium in western Himalaya show multiple warm and cold episodes. Some of them are coincides with medieval warm periods (MWP) and Little Ice Age (LIA) (Yadav et al., 2009; Singh et al., 2006). However, all these studies are based on the relationship between tree growth and rainfall/temperature parameters only.

Tree-ring width index chronologies from Himalayan region also indicate better relationship with PDSI than rainfall (Cook et al., 2010; Ram, 2012b; Ram and Borgaonkar, 2013). Teak tree-ring chronologies from central and peninsular India also indicate strong association with MI and PDSI as compared to rainfall (Ram et al., 2008, 2010, 2011a, 2011b; Ram, 2012a; Borgaonkar et al., 2010). So far, the available tree-ring based reconstructions are limited to rainfall and temperature. In view of this, the relationship between tree growth and climatic variables (MI, PET, VP and PDSI) other than rainfall and temperature may give more information to understand tree growth climate relationship. Long-term paleoclimatic records other than rainfall and temperature of the region may be a very useful tool for better understanding of long-term climate variability and its large scale spatial linkages.

The present paper attempts the analysis to see the relationship between tree growth and climatic variables other than rainfall and temperature of the region. The significant relationships between tree-ring chronologies and climatic variables (MI, PET, VP and PDSI) have been observed in the present study.

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Materials and methods

Tree-ring data

Multi species tree-ring-width data network of the western Himalaya (Borgaonkar, 1996; Borgaonkar et al., 1996, 1999; Pant et al., 1998) have been used in the present study. The locations of tree-ring width data have been shown in a square box (Fig. 1). Numbers of cores per tree and detail site information of the study area were discussed in the previous study (Borgaonkar et al., 1999).

Total seven tree-ring chronologies including 3 *Cedrus deodara* and each of 2 *Picea smithiana* and *Abies pindrow* have been considered in the present study (Table 1). Their standardization options and chronologies preparation technique were discussed in details by Borgaonkar et al. (1999). The correlation coefficients (CCs) among the residual tree-ring chronologies for the common period 1778–1988 were shown in Table 2. They show significant positive correlation among all the chronologies. Significant correlation of the chronologies from distant locations demonstrated the persistence of common forcing in tree-ring width variations (Borgaonkar et al., 1999; Borgaonkar, 1996). Based on the significant relationships, the principal component analysis (PCA) among the site chronologies for the common period was also carried out to capture the existence of spatially coherent modes of tree-ring width variations. PCA is found appropriate when a numbers of observed variables are available. This analysis accounts the common variance in observed variables. 1st principal component (PC1) which explains the highest 50% of the common variance in chronologies that regionally reflect large-scale variations of climate forcing on the tree growth has been used in the present study (Fig. 2).

Climate data

The network of meteorological stations of the western Himalaya is very sparse which make difficult to establish tree growth–climate relationship over the region. Due to lack of the meteorological observations and complex topography over western Himalaya, the gridded monthly mean temperature, vapor pressure and rainfall (0.5° × 0.5°) data were used in the present study (CRU, University of east Anglia) (Mitchell and Jones, 2005).

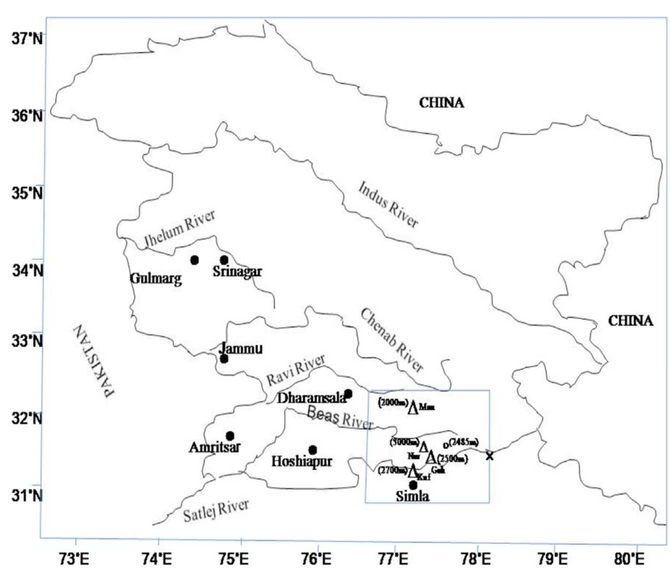

Fig. 1. Map of the study area (values in parentheses are average altitude). Δ = Location of tree ring sites, o = grid point meteorological data, × = PDSI.

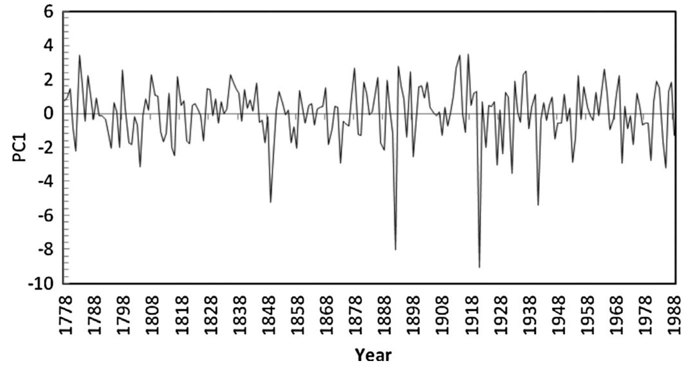

Fig. 2. Time series of principal component (PC) of tree-ring chronologies from western Himalaya during 1778–1988.

To check the reliability of grid point data of rainfall and temperature, We have compared the observed data of climatic variables (rainfall, temperature) of Mukteswar (29°28′ N, 79°39′ E); Mussoorie (30°27′ N, 78°05′ E); Dehradun (30°19′ N, 78°02′ E); Srinagar (34°05′ N, 74°50′ E); Nainital (29°24′ N, 79°28′ E); Almora (29°35′ N, 79°41′ E) and Simla (31°06′ N; 77°10′ E) with the corresponding grid point data viz. 29.75° N, 79.25° E; 29.75° N, 78.25° E; 29.75° N, 78.75° E; 34.25° N, 73.25° E; 29.75° N, 79.75° E; 30.25° N, 79.25° E and 30.25° N, 78.75° E respectively. This comparison is based on the 78 and more years data. The relationship between observed and grid point data was found to be highly significant at 0.01% level in all the cases with correlation coefficients range from 0.41 to 0.94 in monthly rainfall and 0.41 to 0.95 in monthly temperature analysis. Such high correlations indicate the reliability and consistency of the grid point data. Also, it is found reliable in tree growth climate relationship (Friedrichs et al., 2008; Ram, 2012b; Ram and Borgaonkar, 2013; Ramzi et al., 2005). In view of this, the grid point (31.25° N, 77.75° E; 2485 m) climatic data nearest to all the sites as a representative of meteorological station in the absence of observed data is used in the present analysis (Fig. 1). Monthly PET has also been computed using empirical formula developed by Thornthwaite (1948). Mean monthly temperature and precipitation as well as PET are illustrated in Fig. 3.

The MI (P-PET) which is a function of rainfall and temperature was also used in tree growth climate relationship, where *P* is monthly precipitation and PET is potential evapotranspiration (Ram et al., 2008). In addition, tree-ring chronologies have also been compared with the nearest PDSI (31.25° N, 78.75° E) (Dai et al.,

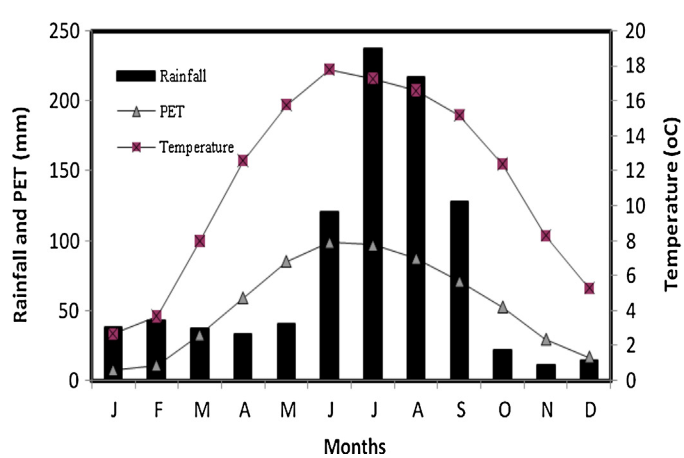

Fig. 3. Mean monthly variation of temperature(–■–), rainfall (bars), and PET (–►–) during1901–2002.