Upward shift of Himalayan pine in Western Himalaya, India

The timber-line species are at the threshold of their climatic limits. Any change in climate, which perturbs the vegetation–climate equilibrium, will lead to significant changes in the demographic patterns of these species. Previous studies from the tree line zones[1–4] show that the vegetation has fluctuated in the past in response to long-term climatic changes. Studies on the impact of ongoing warming under the background influence of greenhouse gases also show that during the past few decades plant species have shifted to higher elevations and the shifting rate varies with species and largely depends on their sensitivity to climate[5,6]. Though such studies are important for understanding the future directions of vegetational change at the climate-sensitive upper elevations, no such information is available from the Indian region. We report here on the sapling recruitment pattern of Himalayan pine at the upper tree line zones in Saram, Parabati Valley, Himachal Pradesh.

The Himalayan pine (*Pinus wallichiana* A. B. Jackson), a common upper ecotonal species in western Himalaya, is the primary colonizer on dry sandy soils[7] and grows pure or in association with Himalayan birch (*Betula utilis* D. Don) and juniper (*Juniperus macropoda* Boiss.). At Saram, the present study area (Figure 1), it forms pure stand at around 3300 m altitude. The trees grow on organic rich glacio-fluvial soil. During 2002 autumn we observed young saplings getting increasingly established at upper elevations above the tree line zone. To understand the rate of upward shift we recorded the sapling recruitment pattern at two sites, one each on north (32°05′N, 77°29′E) and south (32°06′N, 77°28′E) facing slopes at a distance of around 2 km (Figure 1). Number, height, girth, node and internodes of saplings were recorded in 100 m² plots along altitudinal transects. The saplings of sufficient thickness were cored using increment borer of 4 mm diameter at the possible lowest distance from the ground. The increment borers were directed in such a way as to retrieve the exact pith. Occasionally when the borer went off the centre, the coring procedure was repeated in order to get the exact pith of the stem. The growth rings were dated by identifying marker rings[8] in core samples. The age of saplings was estimated by counting the number of growth rings at the coring height and then adding the years required by the tree to gain the coring height using age/height relationship in saplings occurring on north and south facing slopes, respectively. The oldest sapling recorded in each 100 m² plot along the altitudinal transects were used to estimate the rate of upward shift of pine saplings.

The age of Himalayan pine saplings recorded along the altitudinal transects showed younger saplings towards upper elevations (Figure 2). The pine sapling recorded at the uppermost elevation on south slope (3563 m asl) was established, as dated by us, around AD 1997 (Figure 3). This sapling is around 263 m up from the thick Himalayan pine stand at 3300 m asl. The estimated rate of upward shift of saplings is higher on south

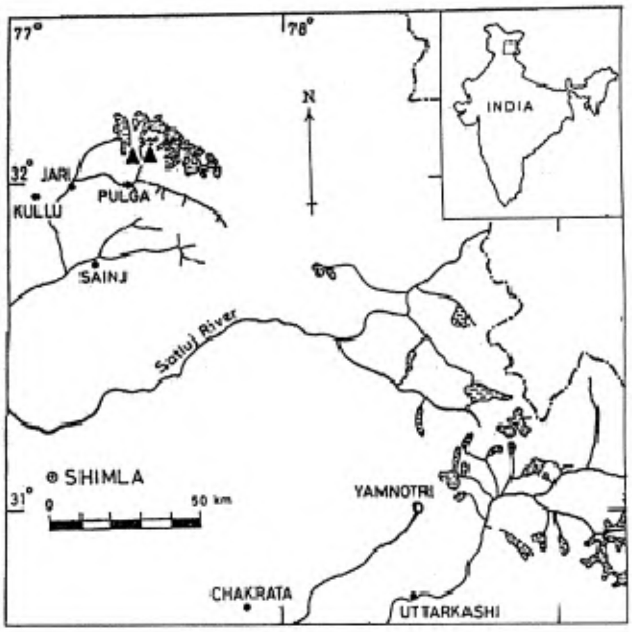

Figure 1. Map showing the location of sites used in the present study.

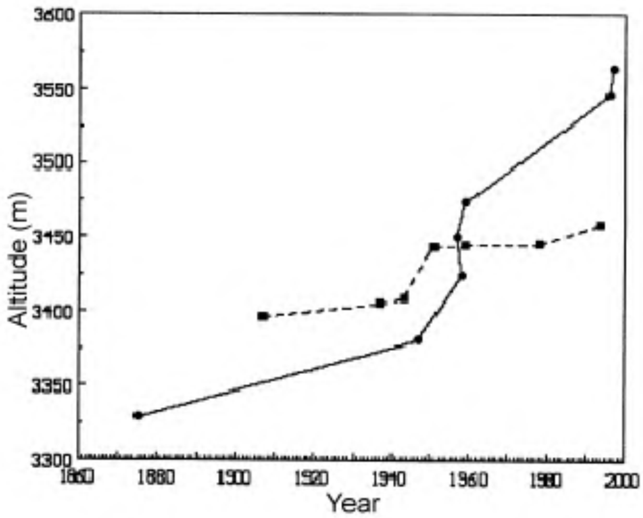

Figure 2. The upward recruitment of Himalayan pine along altitudinal transects on north (broken line) and south (continuous line) slope.

Figure 3. Young sapling of Himalayan pine growing at 3563 m asl established in 1997. The sapling is 263 m atop of the ecotonal Himalayan pine forest in the area on south slope.

(19 m/10 yrs) in comparison to north (14 m/10 yrs) facing slope. This could be because of relatively warmer south facing slopes due to higher solar insolation favouring growth. The average ring width calculated from the mean of five saplings with nearly 50 growth rings each from north and south slopes also show higher annual increment on south (mean ring width 1.9 mm) in comparison to north (mean ring width 1.0 mm) slope. The upward shifts of the Himalayan pine during 1944–1952 on north slope (35 m) and during 1959–1960 on south slope (49 m) are exceptionally high. These two episodic events at the above sites, for not being synchronic, could not be expected to be climate forced. The most plausible reason for this could be the survival of outlier saplings established at protected spots in the respective sites during the above two periods.

The climate records of Shimla (31°10′N, 77°17′E; 2205 m asl), 110 km from the study site, show warming of 0.54°C/100 yrs during the 20th century. Considering the lapse rate in the western Himalayan region (0.56°C/100 m), the expected rate of shift should be around 10 m/10 yrs. The high rate of upward shift of Himalayan pine observed by us (19 m/10 yrs on south and 14 m/10 yrs on north slope) reflects its sensitivity to climatic warming. The observed rate of upward shift of pine in the Himalayan region is higher in comparison to other species recorded in Alps and elsewhere, where the maximum upward migration has been recorded to be around 4 m/10 yrs (refs 5 and 6). Higher rate of colonization on south slopes in comparison to north reflects that the pine populations on south slopes are more vulnerable to climate change as compared to those on north slopes. Earlier study on radial growth dynamics of Himalayan pine from Chirbasa near Gangotri, Uttarkashi[9] demonstrated exponential increase in growth since 1950s. Such an increasing trend at ecotonal limits is attributed to climatic warming.

The present study shows that the Himalayan pine at its upper elevational limit in western Himalaya is sensitive to climatic change. The information obtained through such studies would be useful in predicting the future directions of vegetational changes at the climate sensitive upper elevations. However, prior to achieving this, we need to standardize species and site-specific results by expanding such studies to wider geographic areas in the Himalayan region.

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ACKNOWLEDGEMENTS. B.D. and R.R.Y. thank the Department of Science and Technology, New Delhi, India for financial assistance. Department of Forests, Government of Himachal Pradesh provided necessary help during the collection of samples.

Received 3 May 2003; revised accepted 21 July 2003

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