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RESEARCH REPORT

POTENTIAL FOR DEVELOPING FIRE HISTORIES IN CHIR PINE (*PINUS ROXBURGHII*) FORESTS IN THE HIMALAYAN FOOTHILLS

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ABSTRACT

We report on the potential for developing long-term fire histories from chir pine (*Pinus roxburghii* Sarg.) forests in the Western Himalayan foothills based on a preliminary study from a stand located in the state of Uttarakhand in northern India. Rings from trees collected to develop a master skeleton plot chronology were generally complacent with false rings present during most years, but were crossdatable with only minor difficulty. The oldest tree confidently crossdated back to 1886, with good sample depth (5 trees) from 1911, which helped date the fire scars in cross-sections collected from three trees. Fire frequency as determined from fire-scar dates was high, with mean and median fire intervals of 3 years from 1938 to 2006. Fires were likely from human ignitions given the prevalence of human land use in the site. Fire scars were generally recorded at false-ring boundaries and likely represent burning during the hot, dry period in May or early June before the onset of monsoon rainfall beginning in mid-June. Although only three fire-scarred trees were sampled, this preliminary assessment shows there is a potential for additional samples from other stands to develop longer-term fire histories to better understand the role of fire in the ecology and management of chir pine throughout its range in the Himalaya region.

Keywords: Dendrochronology, tree rings, fire scars, fire frequency.

INTRODUCTION

Chir pine (*Pinus roxburghii* Sarg.) is a common tree in lower elevation forests (450–2,300 m a.s.l.) in the outer ranges and foothills of the Himalaya Mountains extending from Pakistan to Arunachal Pradesh in India (Sahni 1990). Chir pine generally occurs at lower elevations than other pines in the Himalaya, often forming the first low-elevation forests above dry deciduous woodlands and shrublands. Chir pines are often large trees, reaching heights of 30–50 m and diameters of up to 2 m. Similar to other dry-site, low-elevation pine species such as *P. ponderosa* (Laws.) in western North America (*e.g.* Agee 1998), chir pines exhibit several fire-adaptive traits that enable mature trees to survive episodic, low-intensity surface fires (Tewari 1994, Semwal and Mehta 1996, Sangye 2005). Basal bark on mature trees is generally thick (>3 cm) and provides protection from complete cambial mortality during surface burns. The leaves are needle-like, in fascicles of three, and range from 20–35-cm long, which provides large surface-to-volume ratios and low surface fuel bulk densities that readily support surface fire. Crowns of mature trees are usually well off the ground because of self-pruning of lower branches, which reduces the likelihood of "ladder" fuels that contribute to canopy mortality of individual trees. In addition, chir pine stands are generally open with low tree density (*ca.* <100 mature trees ha^{-1}) and correspondingly low crown bulk density, so that active crown fires (with fire spread through aerial fuels) are less likely to occur.

However, to date there has been no systematic effort to develop fire histories or assess tree-

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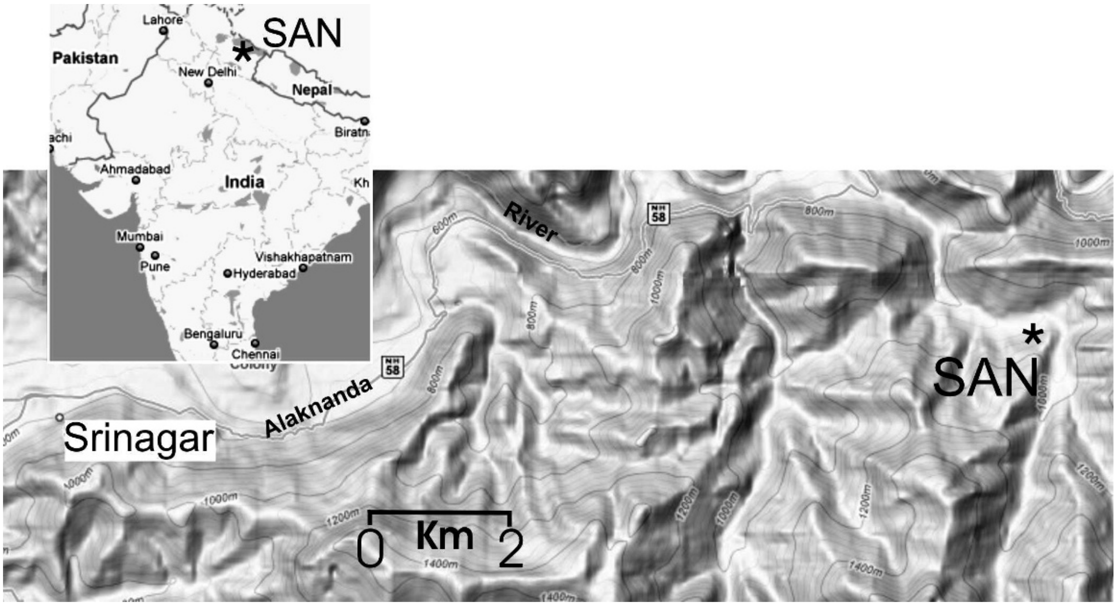

Figure 1. Location of site SAN in the Alaknanda River valley, Uttarakhand, India.

or stand-level fire effects across the range of chir pine forests (Semwal and Mehta 1996). Such information is of critical importance for understanding both the basic ecology of these forests and to provide better information for sustainable management of chir pine ecosystems. For example, similar to the situation with fire exclusion in many western US forests (*e.g.* Allen *et al.* 2002), fire exclusion in some chir pine forests has apparently led to increased horizontal and vertical fuel loadings and continuity that have increased the likelihood of destructive crown fires (Sangye 2005). Chir pine forests provide a variety of ecosystem services to surrounding communities (Semwal and Mehta 1996, Maikhuri *et al.* 2000, Kala 2004), and information on the role of fire in the maintenance and regeneration of chir pines is needed for conservation and management of these forests.

In this study, we examined the crossdatability, potential ages, and possibilities for developing long-term fire histories from fire scars in a chir pine forest in the Garhwal Himalaya in the state of Uttarakhand in northern India. The selected stand is generally representative of lower elevation (*ca.* 700 to 1,000 m a.s.l.) chir pine forests found in this region. We discuss our results in regard to the potential of this species for developing longer term fire and forest history data both for this region and throughout its range in the Himalaya.

METHODS

Site Description

The site sampled (SAN) is located in the Garhwal Himalaya region of the western Himalaya, near the city of Srinagar in the state of Uttarakhand in the Alaknanda River valley (30.228062°N Latitude, 78.898290°E Longitude; Figure 1). The Alaknanda River is a main tributary of the Ganges River. The site is located on a steep (30° to 45°) generally north-facing slope and ridge at *ca.* 912 m to 955 m a.s.l. The sampled stand is an open forest of pure chir pine (visually estimated at *ca.* 100 trees ha^{-1}) with little to no shrub or ground cover at the time we sampled during the dry season in mid-May, 2009 (Figure 2). Very little dead wood was seen at the site because of wood collection by nearby villagers and farmers, and most of the trees had their lower branches pruned by axe or saw cuts (whether the branches were dead before pruning could not be assessed). Much of the stand had recently been

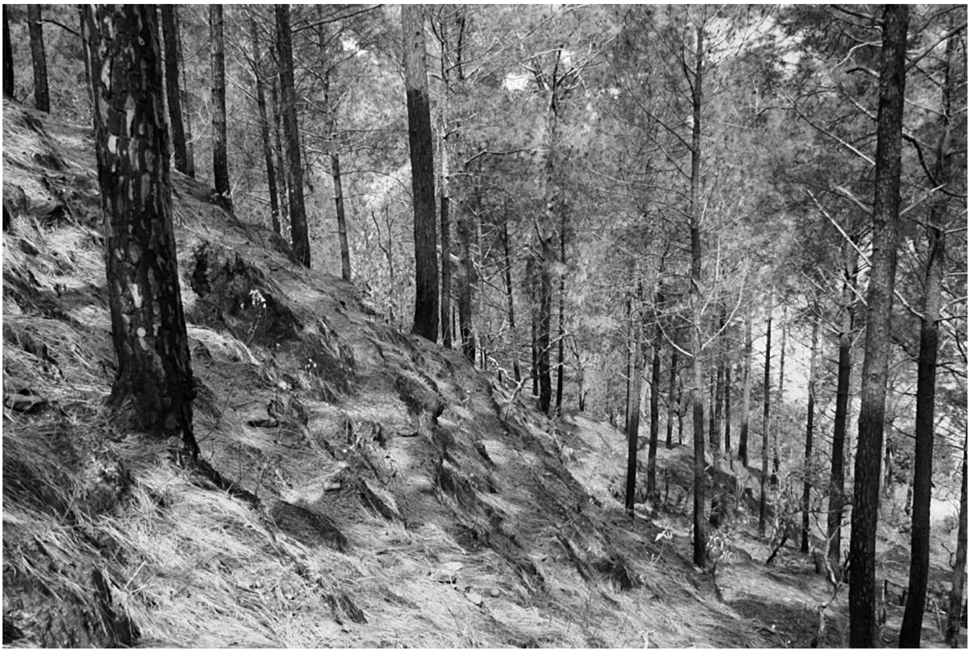

Figure 2. Representative view of the SAN site. Note lack of understory vegetation at the time of sampling in May, 2009.

burned, probably within a month of our sampling. There was only a thin dusting of needle cast as ground cover over much of the stand when we were there, although sprouting grasses were present in some profusion and likely would have been much more prominent after the start of the monsoon rains.

Precipitation at Srinagar is weakly bi-modal, with a small peak of >100 mm during January and the majority of total rainfall occurring during the Indian monsoon of June through September (Bhandari *et al.* 2000). Total average annual precipitation exceeds 1,000 mm. October through December and March through May are very dry, with the latter period also extremely hot (average daily high temperatures often exceeding 40°C).

Dendrochronology

We collected two increment cores from each of 35 living trees to assess tree ages and potential for crossdating. Cores were collected from larger (*ca.* 40- to 80-cm diameter) and older-looking trees over an area of *ca.* 2 ha. Chir pine exhibits color variation in bark with age (similar to that seen in, for example, *P. ponderosa*), in that younger trees have uniformly dark bark that gradually turns orange-to-yellow with increasing tree size and age. We also collected cross-sections from each of three living fire-scarred chir pine trees using a chainsaw. Fire-created "catfaces" were noted on several trees in the stand, and in this preliminary assessment we collected cross-sections from only these three trees that exhibited the most visible scars. Similar to fire-scarred trees around the world, catfaces were often (but not always) on the uphill sides of trees and usually did not extend very far up the stem (<2 m).

Cores and cross-sections were surfaced using a combination of an electric planer, belt sanders, and hand sanding to enhance visibility of cell structure within ring series. We compiled skeleton plots from individual cores and trees (Stokes and Smiley 1968) for crossdating and to develop a master skeleton plot chronology for the site. Once ring series were crossdated with confidence using a combination of both visual crossdating and skeleton plots, fire scars recorded on the fire-scarred sections were dated to both their years of occurrence and their positions within annual ring boundaries, the latter to provide some information on past fire seasonality. Fire scar dates were

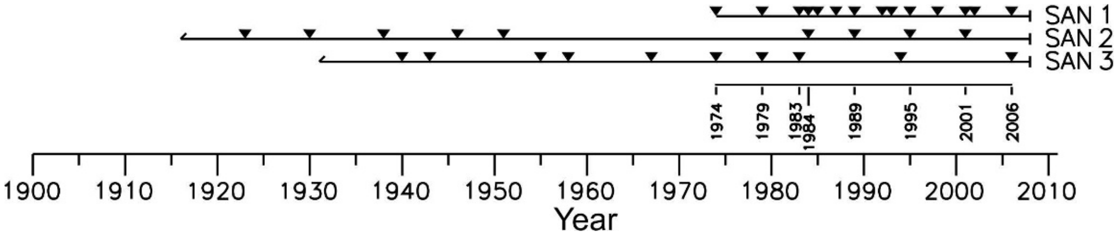

Figure 3. Fire chronology from the SAN site. Time spans of individual trees are represented by horizontal lines with dates of fire-scars indicated by inverted triangles. Dates shown are fire dates recorded on two trees in the stand (no date was recorded on all three).

compiled into a fire chronology using the program FHX2 (Grissino-Mayer 2001).

RESULTS

The oldest tree confidently crossdated went back to 1886, with good sample depth (5 trees) from 1911. Radii from a total of 22 trees were used to develop the master chronology. Rings were mostly complacent, with obvious false rings evident during most years, although a few key years did not have distinctive false rings, which greatly aided in the crossdating effort. No missing rings were noted in any of the crossdated trees.

All three of the fire-scarred trees crossdated well with the master chronology (Figure 3). Figure 4 is a photograph of sample SAN 1, which had the most fire scars of the three sections (top line in Figure 3). SAN 1 often had consecutive annual scars, although these were not noted on either SAN 2 or SAN 3. Many of the scar dates were recorded on at least two of the trees, but none were recorded on all three (Figure 3). Scars occurred most often in the middle of the ring, usually in the false-ring latewood band, although two scars (both on SAN 1) were recorded at the beginning of the ring in the very first part of the earlywood for the year. The mean and median fire intervals from 1938 to 2006 (when a minimum of two trees were recording scars) were 3 years. The last fire scar was recorded in 2006 on both SAN 1 and SAN 3; the most recent fire from 2009 was not recorded on any of the three trees sampled.

DISCUSSION

This is the first study we know of that reports on dating of fire scars in chir pine trees. The trees we sampled had very clear fire scars, and the crossdating—although difficult because of the false rings—was possible. However, in the stand sampled we did not find very old trees, although older chir pine (> 300 years) have been collected from other areas of its range in the Himalaya. Previous studies from both the Uttarkashi region in the Garhwal Himalaya (Shah 2006) and from the Central Himalaya in Nepal (Bhattacharyya *et al.* 1992) found chir pine trees dating from the late

Figure 4. Image of cross-section sample cut from tree SAN 1.

1600s. In general, it is difficult to find older trees because of chir pine's extensive use as lumber, but isolated trees and stands may be located in areas where they were not logged or otherwise were preserved under special circumstances. It also may be possible to extend chronologies using stumps or logs in some locations, although we saw no remnant trees in the stand sampled.

SAN 1 was collected just above the road at the bottom of the site and may have recorded more fire as a result of increased ignitions. There are several references in the literature to human burning of chir pine forests to increase forage, for mushroom gathering, and for other purposes (Kala 2004). The high frequency of fire in our study area suggests that nearby farmers and villagers often have burned this hillside. Based on scar positions within the rings, the fires are usually started in the dry May–early June period when false rings are likely formed in between the wetter early spring and later summer monsoon wet periods. Fires also appear to have been patchy and possibly not to have burned uniformly across the entire site based on the fact that fire scars were recorded on only a single tree or at most two trees for any particular fire year. No fire year was recorded on all three trees. However, this may be caused by differential heating of cambium on individual trees and subsequent scar formation, as we did not find any scars recorded for the recent burning that was noted at the bases of both SAN 1 and SAN 2 at the time of sampling (mid-May, 2009).

Overall results from this preliminary study suggest that longer-term (at least 100+ years and probably multi-century) fire histories could be developed from this species across its range in the Himalayan foothills. Such data will assist in scientific efforts to better understand the ecological role of fire in the maintenance of chir pine ecosystems and the regeneration dynamics of individual chir pine trees. Better understanding of fire histories and fire effects will both benefit efforts at sustainable management of chir pine forests needed to provide continued ecosystem services to surrounding communities (*e.g.* Kala 2004) as well as provide data on long-term fire/climate/human interactions in these forests.

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