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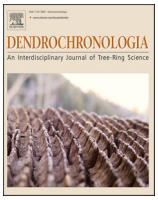

# Dendrochronology in the tropics using tree-rings of *Pinus kesiya*

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ABSTRACT

The recent decade has witnessed considerable progress in the number of tree-ring studies using the tropical conifer taxa, *Pinus kesiya*. Several tree-ring networks have been established in less explored regions in Northeast India, Southwest China and Vietnam. The seasonal climate response of *P. kesiya* tree-rings has been examined and used to reconstruct temperature and soil moisture variability over the past century and augment the short instrumental records in South and Southeast Asia. In addition to standard approaches, the application of stable isotope, wood density, and blue intensity measurements indicates a significant development in *P. kesiya* studies. This review elaborates the future prospects of using multiple tree-ring parameters to establish discrete proxies besides tree-ring width. We recommend blue intensity as a cost-effective alternative to quantitative wood anatomy in tropical pines, and call for routine assessments of the temporal stability of climate-growth responses to identify and study potentially non-stationary climate signals. Efforts should be made towards developing extensive networks of long *P. kesiya* tree-ring chronologies to extend regional climate reconstructions.

## 1. Introduction

*Pinus kesiya* Royle ex. Gordon (Khasi pine) is a widespread three-needle tropical pine species distributed between 12° and 30°N latitude in Southeast Asia (Armitage and Burley, 1980; Farjon and Filer, 2013; Hansen et al., 2003; Wright and Isaza, 1997). This species is found naturally growing in the northeastern region of India, Myanmar, China, Thailand, Laos, Cambodia, Vietnam and Philippines (Fig. 1) (Armitage and Burley, 1980; Farjon, 2010), mainly occurring at elevations ranging 350–2900 m a.s.l., primarily above 1000 m (Armitage and Burley, 1980). The growth is most favorable under moist conditions with moderate to high rainfall and at elevations of 600–1800 m a.s.l. (Hansen et al., 2003). Unlike many regions in Southeast Asia where *P. kesiya* is commonly found co-occurring with other species of the genus *Pinus*, it is often the only *Pinus* species occurring in the (sub)tropical regions of Northeast India. Shah and Bhattacharyya (2012) used tree-rings of *P. kesiya* along with *P. merkusii* and *Pinus wallichiana* growing in different parts of Northeast India to assess their distribution and climate-growth relationships. Using Pearson correlation and multivariate statistical techniques, they found a distinct clustering broadly based on each species. Shah and Bhattacharyya (2012) also observed a largely synchronous (asynchronous) growth pattern within species (between species). The response function and correlation analysis also suggested species-specific growth response to climate between the three *Pinus* species providing further evidence for their distinct distribution in Northeast India. According to a study by Zimmer and Baker (2009), historical recruitment within stands of *P. kesiya* and *P. merkusii* from Northern Thailand was found to be synchronous within stands, but asynchronous at the site and regional level. Zimmer and Baker (2009) mainly attributed these different patterns in recruitment to the influence of factors other than climate (such as local disturbance regimes). The authors however observed that cool and wet dry seasons favored recruitment and found no evidence of recruitment during periods with below average temperature and rainfall.

*P. kesiya* has been used as preferred tree species in reforestation and afforestation programs due to its high adaptability to a wide range of climates and environments and fast-growing nature (van Wyk, 2002). *P. kesiya* has been introduced as a plantation species in many tropical and sub-tropical regions within and beyond its natural habitat (Sahni, 1990) including Africa and South America (Costa e Silva and Graudal, 2008; Wright and Isaza, 1997). New shoots of *P. kesiya* emerge during February–March along with the development of male and female cones (Singh and Venugopal, 2011; Troup, 1921). Annually, *P. kesiya* trees produce three flushes of new needles and branches during the months of

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