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CLIMATIC RECONSTRUCTIONS USING TREE-RING DATA FROM TROPICAL AND TEMPERATE REGIONS OF INDIA – A REVIEW

by

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SUMMARY

There are several reports which indicate that the climate over the Himalayan region is linked both with the monsoon variation on the Indian subcontinent and in the whole of South-East Asia as well as with the El-Niño/Southern Oscillation. To understand the behaviour of these climatic phenomena we need long-term high-resolution climatic records which are in general lacking in this part of the globe. Tree-ring studies have therefore been taken up in the tropical and Himalayan region in India to develop millennium-long climatic reconstructions.

Several tropical trees in India produce annual growth rings due to a distinct seasonality in moisture supply. Some of these species like teak (*Tectona grandis*) and toon (*Cedrela toona*) have datable growth rings and are useful in understanding the long-term monsoon variability in India.

In the Himalayan region several conifers, *Abies pindrow, Cedrus deodara, Picea smithiana, Pinus gerardiana,* and others, are suitable for dendroclimatic studies and several chronologies have been prepared from these taxa. Deodar (*Cedrus deodara*) has an excellent potential for long-term climatic reconstructions. The reconstruction of spring temperature for the last 800 years for the Himalayan region reveals that there were no drastic anomalies and thus no evidence for the so-called Little Ice Age.

Key words: Dendroclimatology, growth rings, climate, India.

INTRODUCTION

In India tree-ring analysis has a vast scope for climatic studies. Due to its latitudinal and altitudinal ranges a variety of micro-climates and in consequence a diversity of forest types from tropical to alpine have to be taken into account (Champion & Seth 1968). Since long many tree species of these forests are known to produce annual rings (Gamble 1902), but systematic dendroclimatic studies have only been performed since the end of the 1970s (Pant 1979; Pant & Borgaonkar 1984; Ramesh et al. 1985, 1986; Pant et al. 1992, 1995; Bhattacharyya et al. 1988, 1992a, b; Bhattacharyya & Yadav 1990, 1992, 1996; Yadav & Bhattacharyya 1992; Borgaonkar et al. 1994, 1999).

In this paper dendroclimatic reconstructions for both Himalayan and tropical forest sites of India will be discussed.

POTENTIAL TREES AND SITES

A large number of conifers growing in various ecological sites between east and west of the Himalayas have been found excellent for dendroclimatic analyses. *Cedrus deodara, Juniperus macropoda, Pinus gerardiana, Taxus baccata,* and *Tsuga dumosa* are suitable in establishing long tree-ring records (Bhattacharyya et al. 1997). Among these *Pinus gerardiana* and *Cedrus deodara* are most promising. Deodar trees around Malari, Harshil in the Garhwal Himalaya, Kistwar in Kashmir and Kinnaur in Himachal Pradesh have been proven to be 400–800 years old. Old stands of *Pinus garardiana* (300–600 years) are common in Kinnaur, H.P. and Kistwar, J&K in dry areas of the inner Himalaya beyond the reach of the monsoon. *Juniperus macropoda*, another inner Himalayan conifer, might be the oldest living conifer in this region but its dendroclimatic potentiality has yet to be established. One *J. macropoda* tree from the Hunza valley, Karakoram has been reported to have 1200 rings (Bilham et al. 1983) but dating of this sample was not possible due to the lack of crossdating between the radii of one and the same disc. By the collection of more samples this lack might be overcome. The same tree species growing on the adjacent Tibetan plateau has been found datable and suitable for dendroclimatic studies (Bräuning 1994).

In comparison to the Himalayan conifers very few tree-ring analyses have been made using tropical trees. An earlier perception was that in tropical regions due to an uniform climate throughout the year with high rainfall and temperature, trees do not produce annual growth rings at all. In India a large part of the tropical forests are under the monsoon climatic regime. Trees in many sites experience periodic water stress causing a distinct seasonality in climate and the formation of annual growth rings. It is estimated that about 25% of the trees of this region are producing growth rings (Chowdhury 1940). The ring borders are visible by various anatomical features (Chowdhury 1964). But datability of these growth rings to the respective years of their formation, which is a prerequisite for dendroclimatological studies, is yet to be established for most of these trees. In the attempts made so far, teak (*Tectona grandis*) and toon (*Cedrela toona*) have been found suitable for such studies. Among these two taxa, teak is widely distributed in the peninsular region of India and has been studied from several sites. These are from dry deciduous forests in Korzi, Andhra Pradesh (Yadav & Bhattacharyya 1996), from a large number of sites in Central India (Wood 1996), and from a moist deciduous forest in Thane, Maharashtra (Pant & Borgaonkar 1983; Bhattacharyya et al. 1992a). These studies reveal that the tree-ring series of teak are valuable proxy data for the reconstruction of climate, especially of precipitation. However, tree-ring data do not reach beyond 100–150 years. To establish long dendroclimatic records, a selection of old stands growing in natural forests is needed and this requires an extensive survey. Teak forests have disappeared to a large extent in most of the sites due to large-scale deforestation mainly because of the desirable timber qualities of teak. This problem of sampling old trees may be overcome with the collection of timbers used for the construction of houses. In addition, several museums are excellent archives of teak samples, e.g., the Forest Research Institute in Dehra Dun, the Forest Depot Museum, Ballarshah, Maharashtra, the Gass Forest

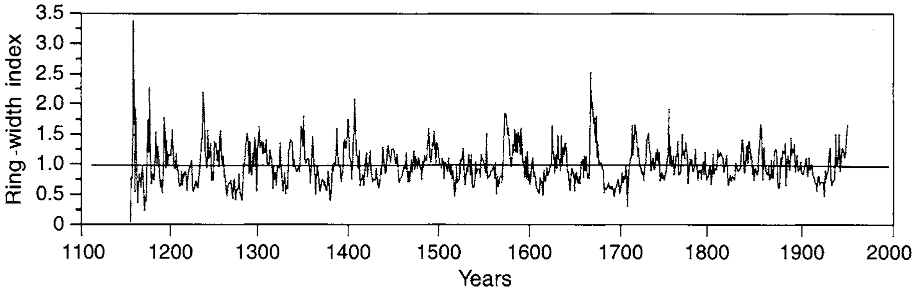

Fig. 1. Ring-width index chronology from 1153–1953 AD of a teak disc in the Wood Museum, Bangalore.

Museum, Coimbatore. Long-term teak chronologies could possibly be made from these samples through crossdating with dated tree-ring series of teak growing preferably in the same region from where the discs were collected in earlier times. So far one attempt has been made by the authors to date a disc in the Wood Museum, Institute of Wood Science and Technology, Bangalore, which shows a total of 801 rings. The widths of these rings have been measured along two radii from the centre to the periphery with the help of an ocular fitted with a scale. The measurements were then standardised to prepare ring-width indices using a cubic spline of two third length of the series with a 50% reduction of variance. The chronology statistics show a mean sensitivity of 0.295, a standard deviation of 0.563, and a first order autocorrelation of 0.7. Crossdating of this floating chronology could be done by comparing its ring-width pattern with a master chronology from the same species or another taxon which has almost similar responses to climate. The present floating chronology was compared with a master chronology extending from 1872 to 1987 AD prepared from teak growing in Andhra Pradesh (Yadav & Bhattacharyya 1996) and tentatively dated to cover the time from 1153–1953 AD (Fig. 1).

TREE-RING CHRONOLOGIES AND CLIMATE RECONSTRUCTIONS

There are several published records suggesting that the climatic conditions in the Himalayan region correlate with the monsoon variability in the Asian region and the El-Niño/Southern Oscillation (Dey & Bhanukumar 1983; Douville & Royer 1996; Li & Yanai 1996; Overpeck et al. 1996). In India, except for some stations, instrumental climatic records do not go beyond 100–150 years. Climatic reconstructions using dendroclimatological techniques offer a possibility for adding such records both in spatial and temporal coverage which is crucial for understanding the contemporary climatic variability. Several tree-ring chronologies made from the Western Himalayan region have added much in extending seasonal climatic records. In this regard, Hughes and Davis (1987) made a pioneer attempt in the analysis of *Abies pindrow* and *Picea smithiana* in the Kashmir valley. Later, Hughes (1992) contributed detailed reconstructions of mean temperature for spring (April–May), late summer (August–September), precipitation since 1780 at Srinagar, Jammu, and Kashmir based on width and density of annual rings of *Abies pindrow*. Borgaonkar et al. (1996) presented a

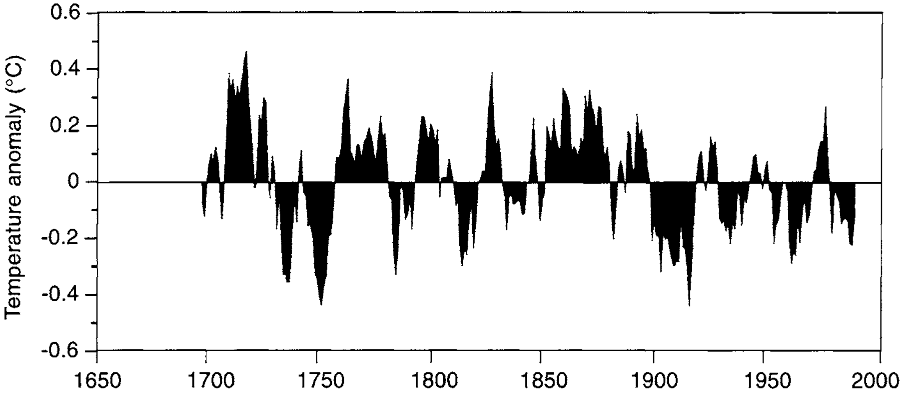

Fig. 2. Dendroclimatological reconstruction of April–May temperature (1698–1998 AD) in the Western Himalayan region plotted as anomalies (after Yadav et al. 1997).

climatic reconstruction using ring-width data of *Cedrus deodara* from Manali, Kufri (Shimla), and Kanasar. They reconstructed pre-monsoon (March–April–May) temperature back to the 19th century. Yadav et al. (1999) extended these data to 1390 AD. Their study is also based on ring-width data of *Cedrus deodara* growing at Harshil, Garhwal Himalaya. Most salient features in this reconstruction are the absence of any prominent large-scale negative anomalies which might indicate the regional influence of a 'Little Ice Age'. On the contrary, the 17th century appears to have had monotonically warm springs. Moreover, evidence for a warming which could be associated with anthropogenic activities during the 20th century has not been detected. The evidence of cool springs during this period has also been recorded in another study where the April–May temperature has been reconstructed based on combined tree-ring chronologies of *Cedrus deodara, Pinus wallichiana,* and *Picea smithiana* from the Garhwal Himalaya (Fig. 2) (Yadav et al. 1997). For the period 1950–1986 the mean April–May temperature in the Western Himalaya has a negative correlation with ENSO Sea Surface Temperature (SST) index of June–December ($r = -0.49$) and a positive correlation with all India summer monsoon rainfall data ($r = +0.37$). The estimated temperature of April–May based on tree-ring data shows lower correlations ($r = -0.22$, $+0.20$, respectively, Yadav et al. 1997). These relationships might be enhanced by using multiple site chronologies of *Cedrus deodara* and *Pinus gerardiana* which are expected to capture maximum regional climatic signal as both the taxa exhibit good crossdating although the trees were growing far apart.

In an exploratory study it was shown that growth of *Cedrus deodara* in Harshil and *Pinus gerardiana* in Kinnaur is low during years of deficient rainfall and also with years of El-Niño events (Bhattacharyya & Yadav 1992).

Although several tree-ring studies have been made in the peninsular region of India no report is available regarding climatic reconstructions. It has been reported earlier that growth of these trees correlate well with variations in monsoon rainfall. Usually narrow rings are formed during drought years and wide rings in wet years. The present 800-year teak chronology also exhibits low growth during drought years of 1871, 1873, 1876, 1891, 1899, 1905, 1918, 1936, and 1937 reported in North Karnataka (Parthasarathy et al. 1987).

CONCLUSIONS

Dendroclimatological studies in India are of great relevance as a large number of conifers and a few tropical hardwood species have exhibited excellent potential. So far reconstructions of temperature and precipitation have been made for the Western Himalayan region. Most of these sites receive precipitation from extratropical origin and the monsoon has only a small contribution. For the reconstruction of monsoon fluctuations, teak has exhibited great potential but climatic reconstruction using tree-ring data of this taxon is yet to be made. A network of climatically sensitive tree-ring chronologies from trees growing in the contrasting climatic zone of the northwestern and eastern parts of the Himalaya and of Peninsular India would be of great significance in understanding the climatic dynamics. In spite of difficulties in getting a large number of samples from older trees, there are possibilities to make long tree-ring records from the wood used for different purposes from both Himalayan and tropical forest. The tree growth/climate relationships of these chronologies would help to extend existing meteorological records back in time. These data would be useful in understanding the monsoon variability and to study its long-term teleconnection with other climatic phenomena like the Eurasian snow cover and ENSO events.

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