Tree ring research in India : an overview

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Dendroclimatic studies in India were taken up towards the end of 1970. Datable growth rings are found in several tree species growing in many regions of tropical forests where moisture supply acts as the limiting factor at least in some part of the growing period. The tree ring sequences from such areas reflect fluctuation in the level of monsoon. Due to difficulty in getting sufficient replication of samples from desired species and locality, progress in tree ring analysis of hardwoods has been impeded to a great extent. Amongst the tested species teak (*Tectona grandis*), because of its long age and ecological diversity, has become the pivotal species for the reconstruction of precipitation.

A major breakthrough in getting 745 years long chronology of *Cedrus deodara* growing on moisture stressed site in Uttar Kashi has been achieved. The statistical properties such as low first order autocorrelation (0.150), high mean sensitivity (0.344) and high signal-noise ratio (20.53) point towards its suitability for the reconstruction of climatic factors, especially precipitation. The length of this chronology is not necessarily limited to the life span of living trees. Cross-dating of ring sequences from old trees with those in stumps, logs and sources of older woods from ancient buildings in the Himalayan region would permit the development of longer chronologies. Besides deodar, other conifers such as pines, spruce and fir also have shown enough potential in dendroclimatic studies.

Key-words—Tree rings, Dendroclimatology, Proxy records, India.

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साराँश

भारत में वृक्ष वलय अनुसन्धान : एक समीक्षा

रामरतन यादव

भारत में वृक्षविज्ञान में शोध-कार्य वर्ष 1970 के अन्त में प्रारम्भ हुआ। उष्णकटिबन्धीय वनों के कई क्षेत्रों में उगने वाले कई वृक्षों में कालनिर्धारण योग्य वृक्ष वलय पाई जाती हैं। इस प्रकार के क्षेत्रों से एकत्र वृक्ष वलयों के अन्वेषण से मानसून का उतार-चढ़ाव व्यक्त होता है। अध्ययन हेतु नमूने एकत्र करने में कई कठिनाइयों के कारण अनुसन्धान कार्य अपनी विशिष्ट गति से नहीं चल पाता। सागौन (**टेक्टोना ग्रेन्डिस**) अपनी लम्बी आयु तथा पारिस्थितिक विभिन्नता के कारण तथा इससे उपलब्ध परिणामों के आधार पर एक अत्यन्त उल्लेखनीय जाति सिद्ध हुई है।

उत्तरकाशी में **सिड्रस देवदारा** के काष्ठ नमूनों का वलय अनुसन्धान द्वारा 745 वर्ष का कालानुक्रमण किया गया है। साँख्यिकीय गुणों के आधार पर भी यह मानसून सम्बन्धी आँकड़े ज्ञात करने के लिए अत्यन्त उपयोगी सिद्ध हुआ है। उक्त कालानुक्रमण वृक्ष की आयु तक ही सीमित नहीं हैं। देवदार के अतिरिक्त पाइन, स्प्रूस एवं फ़र भी वृक्षवैज्ञानिक अध्ययन हेतु उपयुक्त पाये गये हैं।

CLIMATIC vagaries such as occurrence of severe droughts, floods and extreme colds cause devastating effect on national economy. An early warning about the occurrence of such events would greatly help in developing efficient resource management policies. For the development of reliable climate prediction models, long series of meteorological data are required. Century long recorded data do not meet the requirement of the subject. High resolution proxy climate records play important role for the augmentation of recorded meteorological data series. Tree rings have long been recognized as important proxy climate records. The growing knowledge of growth-climate relationship has enabled its applicability in getting various types of environmental informations from annual tree rings (Bitvinskas, 1974; Fritts, 1976; Hughes *et al.*, 1982; Jacoby & Hornbeck, 1987; Cook & Kairiukstis, 1989).

Growth rings in trees are formed due to growth rhythmicity caused due to seasonality in climate and

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reflect the environmental conditions under which they are formed. Tree ring studies have long been popular in India but their application was mainly restricted to the understanding of growth rates, wood production and quality, rotation times and replacement rates (Gamble, 1902). Modern tree ring researches for developing climatic information started recently (Pant, 1979, 1983; Pant & Borgaonkar, 1983, 1984; Ramesh *et al.*, 1985; Hughes & Davies, 1987; Yadav & Bhattacharyya, 1987; Bhattacharyya *et al.*, 1988). The potential of tree ring research in relation to climatology carried out on tropical as well as temperate trees in India has been discussed in the present paper.

Table 1—Seasonal tree growth changes in tropical and subtropical regions (after Jackson, 1978)

MOISTURE SEASONALITY	TEMPERATURE SEASONALITY: Small	moderate	large
large	Dry season leaf fall wet season flushing	Dry season leaf fall	Cold season leaf fall warm season flushing
moderate	Dry season leaf fall dry season flushing	Wet season flushing	Cold season leaf fall warm season flushing
small	Continuous leaf fall continuous flushing	Warm season leaf fall warm season flushing	Cold season leaf fall warm season flushing

TROPICAL TREES

Progress of dendrochronological studies in tropics have been slow mainly due to the difficulties in cross dating of growth rings in tropical trees. The easy availability of alternative samples from temperate regions also has been largely responsible for the negligence of dendrochronological investigations of tropical trees. However, with the understanding of the phenomena in tropics such as Intertropical Convergence Zone and Southern Oscillation directing major influence on global climate, there is a growing concern for undertaking studies on the tropical tree ring analysis.

Tropics are usually characterized by uniform climate throughout the year with high rainfall and temperature with little or no seasonal fluctuation to which plants need to adjust. In such areas most of the trees lack well-defined growth rings. However, in some areas, there exists enough seasonality in precipitation rate which increases the tendency for an anatomical expression of plant growth. Growth behaviour of tropical and subtropical trees in relation to the variability of climatic factors as documented in Table 1 indicates distinct growth rhythmicity in many areas (Jackson, 1978). Trees growing in areas of greater seasonality in climate are very likely to form growth rings.

In India, tropical forests constitute a major part of the geographical areas which experience monsoonal climate. Trees growing in many of such areas where monsoon is more often deficient, are subjected to water stress. Periodic water stress causes distinct seasonality of tree growth producing distinct growth zones which are demarcated by various anatomical features (Chowdhury, 1964). Tree ring study, when deficient monsoon causes water stress, would provide valuable information on the past variability in monsoon. The preliminary study of few tropical trees, which is summarized below, shows promising dendroclimatic potential in India.

Tectona grandis grows in moist to dry deciduous forests where monsoonal precipitation plays important role for tree growth. It has semi-ring-porous to ring-porous wood and growth rings are found to be datable and annual. Pant (1983) and Pant and Borgaonkar (1983) studied limited number of tree ring samples (three trees) of teak from Thane region, Maharashtra. The study shows that the precipitation of previous year's October and in the beginning of current year's growing season plays an important role for tree growth. Study of stable isotope ratio of hydrogen from the annual growth rings has also shown high correlation with maximum temperature for the period from November to February and precipitation from June to September (Ramesh *et al.*, 1989). Availability of long teak ring width data in India further increases its potential for dendroclimatic analysis (Bhattacharyya & Yadav, 1989).

Tree ring studies of *Cedrela toona* from south Indian tropical forests (Bhattacharyya *et al.*, in press) have shown very good cross dating of samples. However, there exists considerable difficulty in getting good samples with circuit uniformity. Trees have been found to be heavily buttressed near the stem bases. The heavy buttressing causes lobing of the annual growth rings making cross dating very difficult. To overcome this difficulty, samples from trees with good circuit uniformity as well as from the above buttressed zone were collected. They exhibit good cross dating. Preliminary growth-climate relationship study shows that tree growth responds negatively to the wetter than average rainy season.

Michelia sp. has been found to have distinct growth rings demarcated by metatracheal parenchyma lines which are reported to be formed in the end of the growing season (Chowdhury, 1940). The study of tree core samples of *M. champaca* and *M. nilagirica* from the tropical evergreen forests, south India (Yadav & Bhattacharyya, 1987) shows that nonsynchronic growth behaviour of trees growing even in the same locality impedes the datability of growth rings. When the climate is almost uniform throughout the year, microclimatic rather than macroclimatic factors seem to play the important role in determining the tree growth.

TEMPERATE TREES

Various conifer species growing in temperate to sub-alpine forests in India have been found to have distinct datable growth rings. Different species growing in different climatic belts respond differently to seasonal variability of climate. The growth-climate relationship data from these species provide proxy climate information for reconstructing various aspects of past climatic variability. Results obtained from the study of different species growing in different geographical areas are summarized below.

Pinus roxburghii forests are found throughout the whole length of the western Himalayas from central Afghanistan to Sikkim and west Bhutan. Its geographical distribution is influenced by the south-west monsoon. Preliminary growth ring studies show that severe drought years are marked by low index values of growth rings. When *P. roxburghii* grows in areas where moisture supply is through summer precipitation, its chronologies from moisture stressed sites are important in understanding the past monsoon behaviour. However, the availability of longer tree ring chronology in India is limited due to its heavy exploitation for resin extraction and thus the old trees are difficult to get for studies.

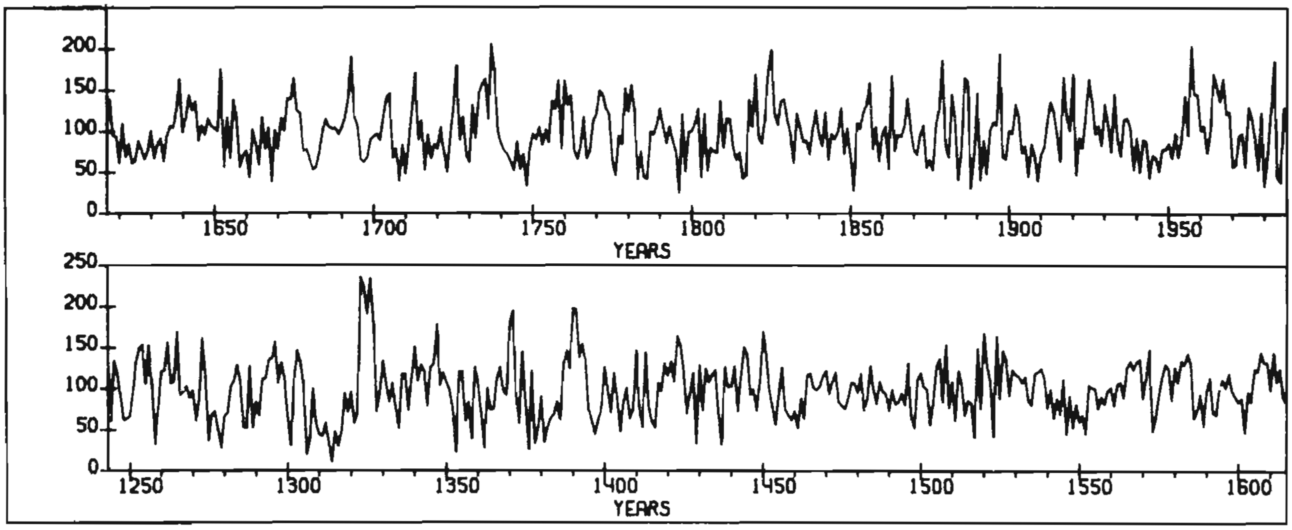
Tree ring study of *Pinus gerardiana* from Shashu and Kistwar in Jammu and Kashmir (Bhattacharyya *et al.*, 1988) has indicated high mean sensitivity, high common variance and low first order autocorrelation. These important parameters bring out clearly the dendroclimatic potential. These authors have observed that 300-400 years old trees are the common components in natural forests. *P. gerardiana* trees also grow in dry zones beyond the reach of monsoon in northwest Himalaya, here the tree ring chronological studies could be useful in the reconstruction of temperature and winter precipitation.

Dendrochronological study of *Pinus wallichiana* using conventional ring width parameters has not yet been done. However, preliminary isotope studies (Ramesh *et al.*, 1985) have indicated its potential in climate studies. Though old stands of *P. wallichiana* have not yet been discovered, recent record of a 296 years old tree in sub-alpine forests of Gangotri, points out the possibility of getting long chronology of this species. Since the trees grow in well drained moist soils, chronology would be indicative of temperature fluctuations.

Ring width and density chronologies of *Abies pindrow* from sub-alpine forests in Kashmir Valley have been studied by Hughes and Davies (1987). Some of the chronologies date back to seventeenth century but good replications were possible only from the early eighteenth century records. These chronologies have been found to be suitable for reconstruction of spring and early summer temperatures. Stable isotope ratios of hydrogen, oxygen and carbon in the annual rings of this species from Kashmir Valley have also shown good common variability (Ramesh *et al.*, 1985, 1986). The isotope ratios are found to be significantly related to the climatic parameters of the growing season (Ramesh *et al.*, 1986).

Cedrus deodara grows in western Himalaya extending from Afghanistan to Garhwal from 1200-3300 m altitude. Its longevity and wide range of ecological requirements make it most suitable species for dendroclimatic studies in India (Bhattacharyya *et al.*, 1988; Bhattacharyya & Yadav,1989, 1990). Growth-climate relationship study of the chronology from Joshimath, Uttar Pradesh has shown that growth is largely favoured by cool and wet summers and warmer winters. Recently a major breakthrough in building a long chronology (745 years) extending from 1243-1987 A.D. (Text-figure 1) from Uttarkashi has been achieved (Yadav & Bhattacharyya, in press). The statistical properties of the chronology such as low first order autocorrelation (0.150), high mean sensitivity (0.344) and high signal-noise ratio (20.53) point out its suitability for the reconstruction of climatic factors. This chronology could further be extended probably beyond one thousand years by linking it with the older tree-ring sequences derived from stumps, logs and other sources of older woods and ancient buildings in the Himalayan region.

Another conifer species—*Juniperus macropoda*, has been found growing since long in the western Himalaya. Bilham *et al.* (1983) reported very old sample tree growing on mountain slope at 3,800 m altitude in Hunza Valley, Karakoram. Due to lobed nature of the stem, wedged growth rings were noted in different radial sections. Simple numerical counting of growth rings showed 1200 rings in the



Text-figure 1—Mean ring-width chronology of *Cedrus deodara* (1243-1987) from Uttarkashi.

sample. The cross-datability of the species is yet to be worked out.

CONCLUSIONS

The evaluation of dendrochronological test studies of various species from tropical and temperate regions conclusively shows strong growth-climate relationship in several trees. This relationship provides the potential to augment the recorded meteorological data for the past few hundred years. The availability of long data series would be of paramount help in understanding climatic behaviour over the past few centuries in India.

From tropical regions *Tectona grandis* and *Cedrela toona* have shown good ring-width and climate relationship and a greater emphasis needs to be given for developing longer and climatically sensitive chronologies. Such chronologies would be helpful in understanding monsoon variability over longer span of time.

Amongst temperate trees studied, all conifer species have been found to have distinct datable growth rings. However, at present, the dating of *Juniperus macropoda* seems to be unreliable due to excessive lobing of the stem. It is hoped that with massive and judicious collection of samples, this problem could be overcome. Objective development of chronologies from climate stressed sites would provide a variety of environmental informations.

Recent record of 745 years long chronology of *Cedrus deodara* from living trees growing on moisture stressed site in Uttarkashi indicates that there exists quite good potential in obtaining longer chronologies. Older tree ring material available from old stumps, logs and ancient buildings would permit extension of chronology probably beyond one thousand years.

Besides being useful as proxy climate records, tree ring research would also have wide application in forestry. The growth rate information from tree ring analysis could be extremely useful for the management of timber as renewable resource. Comparative growth rates for mature trees can also be used to evaluate genetic stocks for reforestation.

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REFERENCES

Bhattacharyya A, LaMarche VC & Telewski FW 1988. Dendrochronological reconnaissance of the conifers of northwest India. *Tree Ring Bull.* **48** : 21-30.

Bhattacharyya A & Yadav RR 1989. Dendroclimatic research in India. *Proc. Indian natn. Sci. Acad.* **55A** : 696-701

Bhattacharyya A & Yadav RR 1990. Growth and climate relationship in deodar (*Cedrus deodara*) from Joshimath, Uttar Pradesh. *Palaeobotanist* **38** : 411-414.

Bhattacharyya A, Yadav RR, Borgaonkar HP & Pant GB (in Press). Growth ring analysis of Indian tropical trees: dendroclimatic potential. *Curr. Sci.*

Bilham R, Pant GB & Jacoby GC 1983. Dendroclimatic potential of Juniper trees from the Sir Sar range in the Karakoram. *Mausam* **7** : 45-50.

Bitvinskas TT 1974. *Dendroclimatic investigations.* Gidrometeoizdat Publishers, Leningrad (in Russian).

Chowdhury KA 1940. The formation of growth rings in Indian trees-II. *Indian For. Rec* **2** : 41-57.

Chowdhury KA 1964. Growth rings in tropical trees and taxonomy. *J. Indian bot. Soc.* **43** : 334-343.

Cook ER & Kairiukstis LA 1989. *Methods of dendrochronology: applications in the environmental sciences.* Kulwer Academic Publishers, The Netherlands.

Fritts HC 1976. *Tree rings and climate.* Academic Press, London.

Gamble JS 1902. *A manual of Indian timbers.* Sampson Low Marston & Co. Ltd., London.

Hughes MK & Davies AC 1987. Dendroclimatology in Kashmir using tree ring widths and densities in subalpine conifers. *In* Kairiukstis LA, Bednarz Z & Feliksik E (editors)—*Methods in dendrochronology 1: east west approaches* : 163-175. International Institute for Applied System Analysis, Luxemburg, Austria/Polish Academy of Sciences, Warsaw.

Hughes MK, Kelly PM, Pilcher JR & LaMarche VC 1982. *Climate from tree rings.* Cambridge Univ. Press, Cambridge.

Jackson JF 1978. Seasonality of flowering and leaf fall in a Brazilian subtropical lower montane moist forest. *Biotropica* **10** : 38-42.

Jacoby GC & Hornbeck JW (editors) 1987. *Proceedings of International Symp. on Ecological aspects of tree ring analysis.* U.S. Department of Commerce, Springfield, Virginia.

Pant GB 1979. Role of tree ring analysis and related studies in palaeoclimatology: preliminary survey and scope for the Indian region. *Mausam* **30** : 349-448.

Pant GB 1983. Climatological signals from the annual growth rings of selected tree species in India. *Mausam* **34** : 251-256.

Pant GB & Borgaonkar HP 1983. Growth rings of teak trees and regional climatology (an ecological study of Thane region). *Proc. Environ. Management, Allahabad* : 153-158. Geogr. Soc., Univ. Allahabad.

Pant GB & Borgaonkar HP 1984. Growth rate of chirpine (*Pinus roxburghii*) tree in Kumaon area in relation to regional climatology. *Him. Res. Dev.* **3** : 1-5.

Ramesh R, Bhattacharya SK & Gopalan K 1985. Dendrochronological implications of isotope coherence in trees from Kashmir Valley, India. *Nature* **317** : 802-804.

Ramesh R, Bhattacharya SK & Gopalan K 1986. Climatic correlations in the stable isotope records of silver fir (*Abies pindrow*) trees from Kashmir, India. *Earth Planet. Sci. Lett.* **79** : 66-74.

Ramesh R, Bhattacharya SK & Pant GB 1989. Climatic significance of δD variations in a tropical tree species from India. *Nature* **337** : 149-150.

Yadav RR & Bhattacharyya A 1987. Non-synchronity in the formation of terminal parenchyma in *Michelia L. J. Tree Sci.* **6** : 101-105.

Yadav RR & Bhattacharyya A (in press). A 745 years chronology of *Cedrus deodora* from western Himalaya, India and its dendroclimatic potential. *Dendrochronologia.*