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Role of tree-ring analysis and related studies in palaeoclimatology : Preliminary survey and scope for Indian region

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ABSTRACT. The subject of palaeoclimatology and various methods of palaeoclimatological research are introduced as a multidisciplinary approach. The methods of infering climatological information from the tree-ring analysis and related studies along with relevant details of sample collection and limitations of the method are discussed. Current status of research in dendroclimatology is reviewed and important techniques are summarised. Available literature relating to growth-ring studies for Indian trees is surveyed and important findings and limitations relevant to planning and establishment of dendroclimatic research in India are discussed. The scope and importance of dendroclimatic research in India in the light of existing information and a complex relationship of tropical climate with the tree-growth characteristics is presented. The trees of Pinus family such as Chir and other conifers along the Himalayan snowline and sub-Himalayan mountains with relatively prominent ring-structure are believed to show a significant response to temperature and snowfall. Maintenance of favourable water balance throughout the year for the trees in the regions of scanty rainfall and occasional droughts is essential for their proper growth. Study of the interaction between various climatic factors during the growing season and possible effects of previous seasons on tree growth is essential for orchard owners and forest planners in these regions. Therefore, the urgent need for an intensive study of response of certain tree species in semi-arid tropical regions of India to rainfall, in particular the instances of severe droughts, is recommended. The optimum water balance requirements of plant communities can be estimated on the basis of the statistical relationship between the growth parameters and the seasonal rainfall amounts. A comparison of growth parameters of trees from reserve forests and largely inhabited regions of similar climatic zones may bring out much demanded information about the role of forests on the ecological balance.

1. Introduction

The knowledge of past climate and its future projections are vital for proper planning of human and natural resources. In an agriculture based economy, where the production of food, fodder and raw material for many industries largely depends on the timely occurrence of seasonal rains; the understanding of past climatic events is vital for the assessment of unfavourable climatic conditions and their future likelihood. Climate and climatic changes have their impact on wide spectrum of activities involving the flora and fauna on the earth. The extent of these changes may vary from time to time and place to place and their impact on some occassions may appear as a calamity and on others as a gradual change to which the earth and life can adapt itself. Prediction of future course of climate is possible only if the processes bringing about these changes are well understood and verified in relation to past evidences whose permanent records are manifested in nature's own laboratory. Study of past climate on the basis of evidences left behind by nature on the surface of the earth or buried deep into the earth/ocean surface is known as Palaeoclimatology. Palaeoclimatological evidences date back to the periods of early interaction of earth-ocean-atmosphere system and are available in numerous forms. These evidences may relate to the periods as old as the early geological times and as young as the documented historical records. On spatial scale these may relate to global as well as local phenomena. The complexity of research in Palaeoclimatology is further increased by the multidisciplinary approach essential for collection and analysis of these evidences. Some of the important disciplines, which provide valuable information to Palaeoclimatologist are the historical and archaeological studies, study of tree-rings, vegetation and animal zones from living and fossil sources; geomorphological studies of river basins, sand dunes and soil characteristics; geological, chemical and radioisotope and pollen grain analysis of lake and deep sea sediments, glaciers and fossil samples.

One of the important problems in Palaeoclimatology is to know with certainity that how old a particular sample is. In India the first definite date falls around 300 B.C. and even during the historical periods definite documented dates are not available for certain periods. In Egypt and Mesopotamia the historical chronology can be built up to third millennium B.C. but in India the period is obscure unless the records of Indus civilization are reliably deciphered. Thanks to the modern advances in physical sciences and technology that there are methods available for dating the past based on the radioactive decay of some natural isotopes. For example, the interaction of high energy cosmic rays with atmospheric nitrogen produces a very small fraction of radioisotope of carbon (C^{14}) which

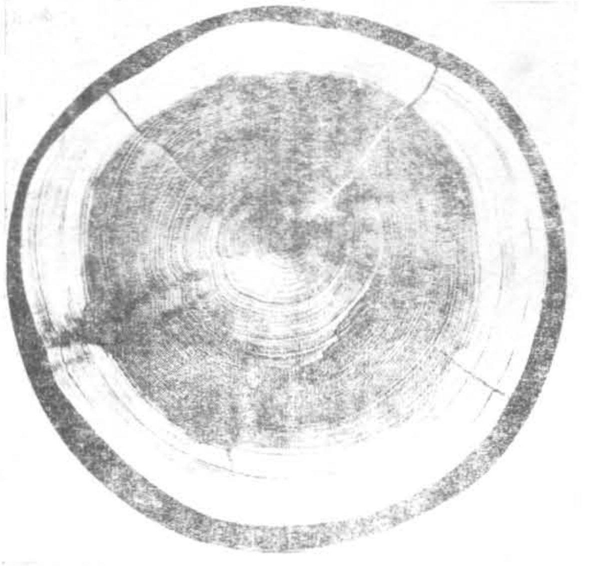

Fig. 1(a). A section of Douglass Fir (New Mexico) with prominent growth-rings (Photo : A.E. Douglass)

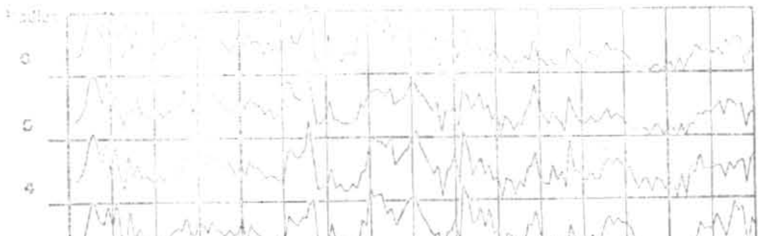

Fig. 1(b). Graph of growth-ring width measurements along six radii for Douglass Fig. 1 (a)

takes part in the carbon cycle of organic matter and as the source of organic matter dies the radioactive decay of C^{14} starts without replenishment with a half life of about 5730 years. Thus the radiocarbon method is suitable for dating back upto about 50,000 years. The facilities for radiocarbon dating in India are available at Physical Research Laboratory, Ahmedabad and Birbal Sahani Institute of Palaeobotany, Lucknow (For details *see* Agrawal *et al.* 1974). For geological times the K-Ar, Rb-Sr and many other radioisotope methods are currently in use. Having determined the age of the sample the Palaeoclimatologists' main interest is to infer the climatic factors from the proxy data considering the current climatic conditions as a guide.

2. The dendroclimatology and related studies

The main aim of this article is to discuss in detail one of the simplest and useful methods of studying the climate of the recent past based on the climatic inferences drawn from the annual growth-rings of certain trees, known as Dendroclimatology. A tree normally lives for centuries exposed to the environment of a particular site. The growth cycle of tree in general follows the annual pattern adding one growth ring per year between the old wood and the bark. When the growing season begins large number of thin cells are added to the tree and as the summer advances or the wet season ceases these cells become increasingly smaller and more thickly walled until the production of cells virtually stops. This process is repeated every year

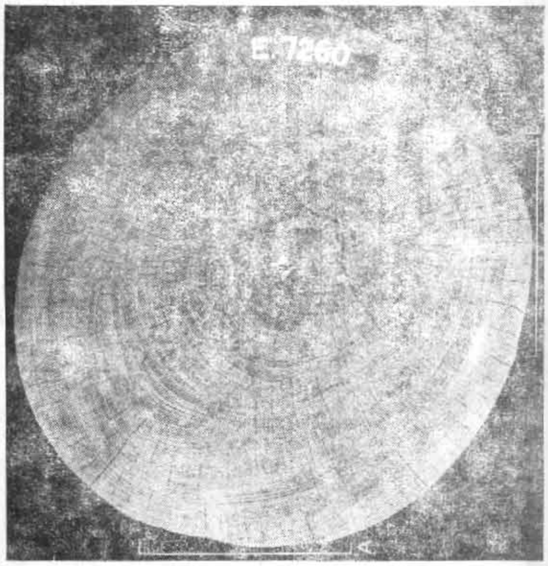

Fig. 2. A complete disc showing distribution of concentric marks in Sal (*Shorea Robusta*) a diffuse-porous wood from Dehradun (U.P.). Notice the growth-marks perhaps not reflecting the true growth-rings abruptly ending at A and B (Photo : K.A. Chowdhury)

leaving prominent marks between the woods of different years. The growth and size of the tree-rings depend on the physical factors such as adequate soil moisture, sunlight and leaf area for photosynthetic production of food material, adequate temperatures for rapid respirational rate and supply of proper minerals from the soil. As the trees depend on their local environment for food and growth a reasonably faithful record of climatic events is expected from the life history of a tree. Certain trees live long enough to preserve the information beyond documented weather records thus providing a valuable bridging block between the recorded weather events and proxy data from the archaeological and fossil samples. Method of assigning dates to different trees on the basis of counting the annual growth rings is known as Dendrochronology. In association with historical samples of known age tree-ring chronology is also being used in the calibration of radiocarbon dates.

In the extratropical and subpolar regions of almost uniform moisture supply throughout the year but a vast winter to spring temperature contrast the seasonal temperature is a dominating factor in tree growth. A number of important studies has been conducted by the Carnegie Institution of Washington and the Tree-ring Research Laboratory of the University of Arizona (Douglass 1914, 1919; Glock *et al.* 1937; Glock 1950; Mac Dougal 1924; La Marche 1974; Fritts 1965; 1971 and 1977). In the drier semi-arid regions, where the factors like sunlight, soil characteristics and the exposure remain essentially constant and adequate for growth throughout the life of a tree, the lack of moisture varying from year to year is a major limiting factor in tree growth. In the regions of warm moist equatorial and tropical forests the influence of climatic factors may not be directly reflected in tree growth. Selection of sites and tree species for climatic studies particularly in the tropical conditions of abundant rainfall and sunshine has to be done carefully. Some of the factors to be considered in site selection are, geographical location, topography, soil characteristics, subsoil water, location in respect of drainage, bed rocks and surrounding vegetations. Name of the plant specie, date of cut, date of sample collection, diameter and height of the sample above the roots need to be recorded along with the details of the site. The trees selected for a set of data should represent an area with uniform climatic characteristics. On the basis of the tree-ring analysis for arid-site conifers Fritts (1974) has stated that the site factors particularly the slope followed by altitude and latitude appear to be most responsible for variations in the growth response. There are fewer differences between species than between the factors of site. Shallow rooted trees with no access to permanent source of water particularly in the semi-arid regions will be dependent on frequent recharge of the soil moisture by rainfall and hence will represent the sensitive rings. Therefore, a sufficient number of suitable sites and species be examined and the data should be cross-matched. Cross-matching is done by comparing the growth-rings of various samples from a locality and only those samples are selected for final analysis which show the common features possibly reflecting the climatological response. Normally a thin slice across the whole tree about a metre above the root level avoiding the buttresses is an ideal sample. A rectangular radial cut across the section including the centre or a 'V' shaped cut are also convenient. Immediately after the blocks are cut from the tree they are fixed in absolute alcohol and the air is extracted from them by means of a vacuum pump. Various methods of chemical treatments are in use to stabilize and preserve the wood and make it fit for ring-width and wood-density measurements. For ring-width determination sufficient number of measurements along different diameters are to be taken. As an example, tree-rings for California Fir (USA) with its ring-width variability across six different diameters are shown in Fig. 1 and a section of less distinct non-concentric growth-marks for Sal tree for Dehradun (India) is shown in Fig. 2.

Two principal advantages using tree-ring records are the accuracy of tree-ring dating in respect of year of formation and a much greater geographical scope permitted by the wide latitudinal distribution of suitable tree species and their abundance over large land areas of the globe. Principal limitations of the method are that on an average tree-rings can provide information for a period of few hundred years. In case of some old trees it may be difficult to read the rings near the centre or very close to the bark. In addition one has to depend on the precut trees or follow the tree cutting operations in accordance

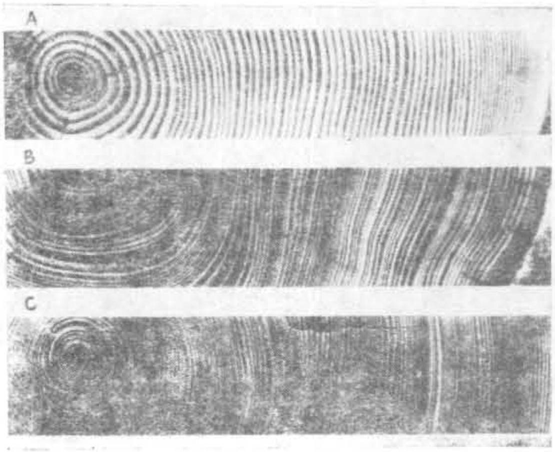

Fig. 3(a). Three types of variability in complecent rings (uniformity in climatic effects) (*After* : Glock)

A : A uniform sequence whose rings decrease in thickness with age.

B : A variable sequence in which adjacent rings vary notably in width.

C : A variable sequence in which adjacement groups of rings vary in width.

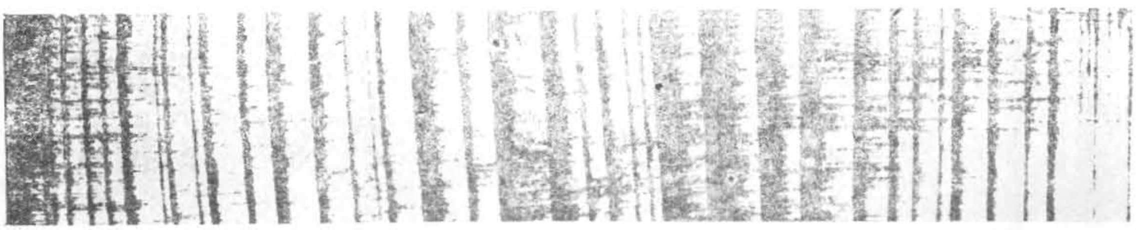

Fig. 3(b). Sensitive rings (Laboratory of Tree-ring Research, Arizona) indicating significant departure from uniformity in climatic effects

with the plans of forest departments, however, some rectangular or 'V' shaped cuts can be obtained with special care without cutting the trees. The tree ring analysis primarily consists of the following four steps :

(1) Rings are read in a sequence, continuity in the sequence is established and the relative ring-widths are evaluated ;

(2) Sequences are cross-matched with other sequences from different or same tree species of the same locality ;

(3) Calendar dates are assigned to individual rings and a master ring-width sequence is prepared ;

(4) Direct or indirect association between the ring-width variability and climatic stress is established and the non-climatic effects are minimised.

In addition to variations in the tree-ring width the ring density is another important parameter of great significance for climatic inferences. Wood density is a function of availability and assimilation of plant food during the growth period of the rings and, therefore, closely associated with climatic conditions. X-radiographs of thin sections of growth samples from the trees are scanned with a microdensitometer to produce a continuous record of wood-density variations. In association with ring-width analysis the densitometric measurements at the same site might also be useful in separating seasonal components of the climatic variation. Some studies have established a high correlation between the densities of different components of the annual rings and total monthly precipitation at different times during the growing seasons. Broadly, there appears to be a direct relationship between the principal climatic variables such as, rainfall and temperature, and the ring-width variability. For example, the narrow rings indicate low precipitation and high

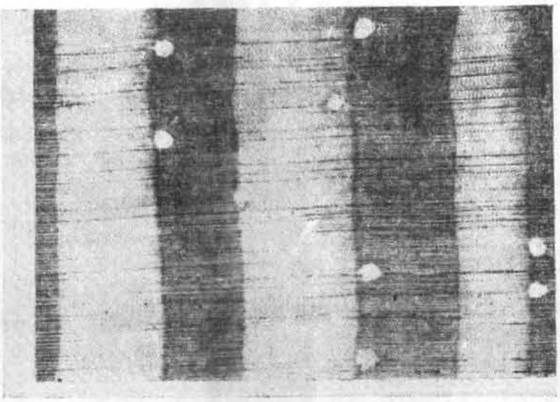

Fig. 3(c). A cross-section of piece of Chir (*Pinus-Longifolia*) wood (Dehradun, India), showing growth-rings (Magnified, *After* : K.A. Chowdhury)

temperatures prior to the end of the current growing season in drier arid forests, whereas, in higher mountains of temperate latitudes the narrow rings are associated with low summer temperatures. Typical examples of ring-structure and variability are indicated in Fig. 3. In practice the relationship is quite complex and analysis involves sophisticated technical means and statistical techniques. Systematic variations in ring size are normally due to the age of the tree, as the central rings are wider than the peripheral ones. Superimposed on these ring-width patterns are the variations due to the climatic abnormalities. The mean growth-ring pattern due to the age of the tree is found to follow an exponential pattern, namely, the ring size diminishes exponentially with the distance from the centre. Superimposition of the actual tree ring width plot with the standard exponential pattern is adopted to adjust the ring series for the age of the tree (Fritts *et al.* 1969). This adjusted parameter is known as the ring-width index. At the Tree Ring Research Laboratory of the University of Arizona, USA the method of finding the ring-width index is fully computerised and a plot of the ring-width index is directly obtained as the sample is scanned. The sensitivity of a tree-ring record is expressed in terms of the variability from ring to ring. The variability index which is a function of the ring-width indices of two subsequent years is another important parameter. Long term variations and periodicities in the data series may be studied by calculating the autocorrelations or lagcorrelations between the ring-width indices within a suitable lag period depending on the length of the series. Cross-dating with the ring series from fallen logs and fossil or dead trees may be used to extend the tree-ring series back in time. An average tree-ring index value obtained from many trees from a site is used to make a master series to be compared with the existing temperature and rainfall series. An extrapolation in time can be done on the basis of the statistical relationships for the periods for which both the climatic and ring-width index series are available. There are some indirect methods of correlating the environmental factors, with tree-ring growth such as the relationship between the sunspot cycle and the ring-width (La Marche *et al.* 1972). Extraction of climatic information from tree-rings has been limited because of the inadequacy of the techniques available to incorporate a large number of environmental variables. Recent advances in multivariate statistical analysis and high speed computers have made it possible to objectively analyse the tree-ring data representing a great diversity of responses to the environmental factors. With the availability of reasonable amount of tree-ring data for trees from extremely cold as well as some arid sites it is possible to establish that highly significant statistical relationships do exist between the tree-growth and climatic data (Blasing and Fritts 1973 and 1976, Fritts 1962, Fritts *et al.* 1965 and 1971). These statistical correlations are supported by reasonable physiological cause and effect relationships between the growth mechanism of trees and the climatic factors.

Without considering the details of the biological and environmental relationships the tree-ring analysis simplifies itself into a problem of relationship between the ring-width and integrated climatic records of annual rainfall and temperature. Some of the recent studies suggest a prominent relationship between monthly and seasonal climatology and the mechanism of tree growth during different periods of the year (for example, Fritts 1974, Brett 1978). A complex model of biological and environmental factors for arid-site conifers is presented by Fritts (1974) and these responses are analysed using multivariate techniques, multiple regression on principal components of climate and a cluster analysis for identifying similarities among the response functions. Some workers think that the moisture from precipitation falling immediately prior to and during the growing seasons is most often the major climatic control of growth (Glock 1950). On the other hand Douglass (1919), Fritts (1965), Fritts

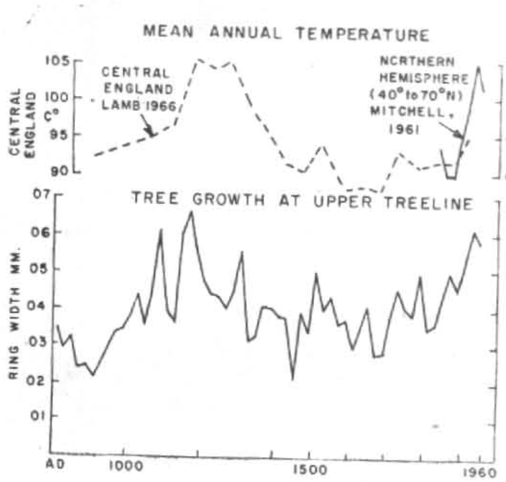

Fig. 4(a). Ring-width (20-yr mean) at upper tree line of Bristle cone Pines of California compared with 50-yr mean temperature values for central England (*After* : H.H. Lamb)

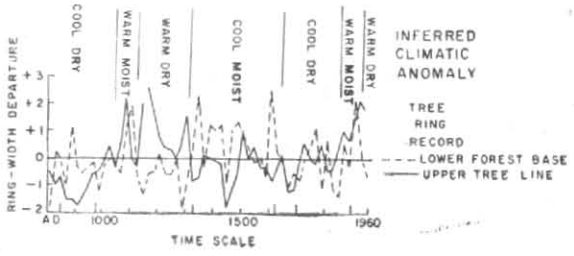

Fig. 4(b). Ring-width (20-yr mean) compared at the upper tree line and at the lower tree line for Bristle cone Pines of California and inferred climatic anomalies (*After* : La Marche)

et al. (1965) and others have stated that the ring-width growth in conifers on arid sites is most often correlated with precipitation falling during the autumn, winter and early spring months than with precipitation occurring during the growing season. Study of Brett (1978) for the Elm trees of England also indicates the importance of the rainfall during the period immediately preceding the growing season. He has further suggested that the climate during previous growing seasons will effect the vigour and extent to which the tree is prepared for the next growing season.

In addition to the analysis of tree-rings, distribution of vegetation zones, leaf shedding in deciduous trees and onset of budding and flowering in some plant species are also used as climatic indicators. Only an excessive change in climate is likely to induce the sudden replacement of one plant community by another. In the regions of rapid change from wet to dry conditions or from freshwater to saline water zones a sharp transition in vegetation is found. In addition to the physical conditions for the survival of particular plant species the environmental conditions also control the seed and pollen dispersal rates which in turn are responsible for the vegetation pattern. The effect of change in climate upon the vegetation may appear in three possible ways : as its adaptation to new environment, migration to neighbouring favourable climatic zones or as a complete extermination. Based on the physiological requirements of the plant species vegetation zones are found to correlate well with present climatic zones. As regards leaf-shedding it is normally believed that low humidity and scanty rainfall are associated with leaf-fall in deciduous trees, hence its relationship with seasonal change of climate seems probable.

3. Studies in India

Though the tree-ring analysis has provided some interesting results and past climatic series for few thousand years are constructed and verified with other documented weather records and information from other proxy data sources (for example, *see* Fig. 4), the analysis is mainly confined to some parts of Europe and North America. Most of the studies relate to polar tree margin where the growth is well marked by strong temperature contrasts and practically all tree-ring work has been done on the conifers. In India this branch of climatology is yet to see its offing. A few scattered studies by wood technologists and forest planners are mainly confined to the growth of tree cells. Few studies which attracted author's attention include the studies of Chowdhury (1939, 1940 a, 1940 b; Chowdhury and Rao 1949 and Chowdhury and Ghosh 1950) of Forest Research Institute, Dehradun and a few references cited therein. Chowdhury collected samples from three sites in India at Dehradun (U.P.), Kaptai (Chittagong) and Nilambur (west coast) for one full year to supplement his earlier study for 3-year period for the trees from Dehradun. Though his study is basically oriented towards the study of tree growth mechanism, some attempts are also made to consider the effect of local environment. Some pertinent inferences of interest to Dendroclimatologists are :

(1) In tropical climates majority of timbers are diffuse-porous and these as a group offer the greatest difficulty in the determination of growth-rings. In Europe and North America the growth-rings are distinctly marked no matter whether the wood is non-porous, ring-porous of diffuse-porous.

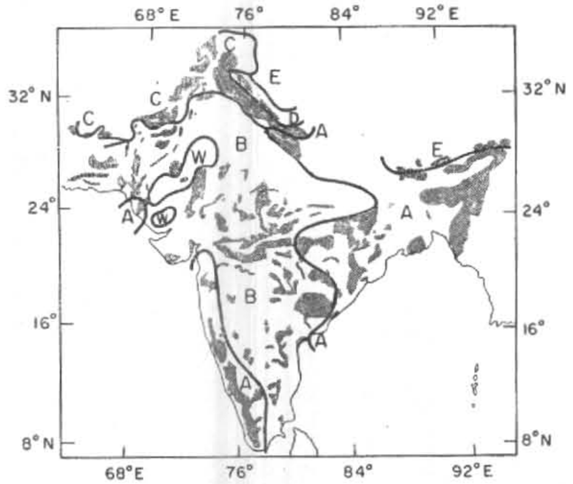

Fig. 5. Broad classification of forest types of Indian region and current distribution of open and dense forest areas (shaded)

(2) The growth-rings are usually distinct and annual in Chir (*Pinus Longifolia*); distinct in Semul (*Bombax Malabaricum*), Laurel (*Terminalia Tomentosa*) and Teak (*Tectona Grandis*); distinct under microscope in Cutch (*Acacia Catechu*) and fairly distinct in Toon (*Cedrela Toona*). Irregular rings are found in Jaman (*Eugenia Tambolana*) and Sal (*Shorearobusta*) and they are not found to be annual. Growth-rings are uncertain in Champ (*Michelia Champaca*). In Sissoo (*Delbregia Sissoo*) the alternate bands of dark and light-coloured tissues present in the heartwood often give the impression of growth-marks but they are not found to be related to true growth rings. No rings are detected in Kokko (*Albizzia Lebbek*). In a later study (Chowdhury and Rao 1949) the growth-rings in Teak (*Tectona Grandis*) and Mahacany (*Swietenia Macrophylla*) are studied in detail and false rings are detected. Among the Indian trees examined so far Chir (*Pinus Longfolia*) shows the most prominent rings. Other trees of Pinus family are believed to show the same characteristics. Some of the important conifers such as blue pine (*Pinus Excelsa*), Deodar (*Cedrus Deodara*), Spruce (*Picea Morinda*) and Silver Fir (*Abies Pindrow*) generally available in Himalayan mountains and Teak (*Tectona Grandis*) from sub-Himalayan mountains and some parts of Rajasthan and Gujarat region (Meher-Homji 1977), may constitute the best samples.

(3) No difference in the commencement of growth was found between ring-porous and diffuse-porous woods or between deciduous and evergreen trees. Trees of the same specie showed a difference of one to three weeks in the commencement of growth. Not a single specie examined had any resting period in the middle of active growth season.

(4) No direct correlation of growth with external factors such as temperature, rainfall and humidity or internal factors such as heredity and cell growth mechanism of tree species is established.

Investigations of Trout (1919), Chowdhury and Ghosh (1950) for the growth-rings of sandle-wood (*Santalum Album*) from Mysore indicate frequent occurrence of false rings and their accuracy in determining the actual growth by counting the rings is doubtful. Other studies on growth activity of Indian trees has mainly been confined to the height growth of seedlings and saplings, and does not have any direct relation to the diameter growth. There has been no recent tree-ring studies in India, in fact none after the preliminary studies of Chowdhury and associates about two decades ago. Following observations in relation to leaf-shedding, leaf-renewal and budding need further examination and extensive sampling of many tree species from all over the country. On the basis of the preliminary information available for Indian trees (for example, Gill 1933, Wright 1901) the deciduous trees normally shed their leaves during the dry periods of the year; though the onset of leaffall may or may not coincide with the first dry months of the year. The trees may also not remain leafless during the entire period of dry months. The exact time of leaf-fall is, perhaps, determined not so much by the local rainfall or temperature as by the state of the internal water balance of the tree. In cold and temperate climates a high temperature may be necessary for opening the dormant buds and starting the activity of growth-promoting substances. But a continuous high temperature does not seem to be essential for keeping up the activity of the cambial cells, though extremely cold temperature and frost may have damaging effect upon the buds in many species. In arid and semi-arid tropical belts availability of appropriate soil moisture may influence the budding. For the Indian tree species, it has been more or less established that the diameter growth starts on the young twigs first and then spreads gradually to the main bole and also the interval between the development of new foliage and commencement of cambial growth are longer in Indian tree species than those in Europe. Interesting accounts of some forest species for northwest, western and central India and their climatic relationships are discussed by Seth (1963) and Meher-Homji (1977). Meher-Homji has indicated that dry deciduous Teak (*Tectonga Grandis*) forest occurs in parts of Rajasthan and Gujarat normally characterised by the climatic conditions of annual rainfall between 80 cm to 230 cm, a dry season of 7 to 8 months duration and temperature of coldest months not dropping below about 15°C.

Himalayan regions constitute the least degenerated forests in India today. There is very little forest area in the higly populated and agricultural areas of Indo-Gangetic plains and much of the forest area of the Peninsula is only scrub-jungles very open or stunted forests. There are ample archaeological and other evidences of forest regimes during the Indus civilization around 2,000 B.C. in the regions of northwest India which are currently devoid of forests or even the vegetation. There are also good historical evidence for large forests in central Punjab during Alexander's time (300 B.C.), in Jamuna basin during Mohmud Gazni (11th century); and the Gangetic plains were also originally covered with vast Sal forests till the urbanisation of Gangetic Doab during the early iron age. Climate is the main determinant of forest types and broadly for the Indian region the rainfall is more important than temperature except in the Himalayan regions. Soil factors, orography and hydrological conditions are secondary for major forest types but they play an important role in deciding the distribution of species within the major forest types. Fig. 5 depicts the very broad classification of forest types of Indian region along with the current distribution of dense and open forest areas. A critical examination of Fig. 5 as well as the detailed characteristics of various tree species of different regions shall serve as an important guide in designing the dendroclimatic field experiments particularly the selection of regions and species with maximum climatic sensitivity. In

TABLE 1

Himalayan forest zonation in relation to growth rings

Classi-fiction	Altitude (m)	Common trees	Growth-rings
Alpine	5,000-3,500	Rhododendrons, Birch, Junipers, Silver Fir,	Prominent rings
Temperate	3,500-1,000	(a) Conifers, Junipers, Rhododendrons, Abies Pindrowi, pinus excelsa, pinus longifolia, cedrus deodara etc	Most of the conifers have prominent growth-rings, growth-rings may aslo be detected in some species of broad leaved trees
		(b) Broad leaved oaks, chestnut, maples, laurels, Alders and Birches	
Sub-tropical and tropical	1,000-400	Mixed deciduous, tropical evergreen; Sal, Teak, Semul, dry Bamboo etc. Riverine Savannal (Terai,) dry thorn and scrub (extreme-west)	Growth-ring characteristics of some species are discussed in the text

the absence of organised field experiments preliminary inferences are drawn on the basis of available literature. Evidences suggest that useful information can be derived form the trees of dry deciduous forest (within the region B in Fig. 5) containing many tree species with established growth-rings and occupying a vast area in central and Peninsular India and also along Sivaliks and Terai from central Nepal to Himachal Pradesh, particularly the rainfall response and in some cases a combined response of moisture and temperature. Trees of the Himalayan zone are most appropriate for well defined growth-rings and probably the most prominent temperature to growth-ring relationship. As a preliminary survey, few species of Alpine, temperate, subtropical and tropical regions of Himalayan zones are listed in Table 1.

4. Remarks and recommendations

The Indian subcontinent enjoys a variety of distinct climatic zones and associated tree species. A considerable variation has been found in the time of leaf shedding and leaf renewal as well as in the characteristics of growth-rings in Indian trees. In view of this response of trees to climatic conditions and a multidisciplinary nature of climatic research it is extremely important to know how far the effect of local climate is reflected on the diameter growth activity and other growth parameters of the trees. Studies so far for the tropical regions in general are so much limited in their scope and extent that the inferences are merely indicators rather than conclusions. For some plant species of Europe and

North America, good correlations are found between the tree-ring indices and local climatic variables particularly the temperature and rainfall. In Indian region no systematic and extensive study has so far been done to comment conclusively on the relationship. On the basis of the inferences drawn in the studies cited above it can be concluded that the external climatic factors and their monthly or seasonal effects may be complex to analyse in many species of Indian trees. A nonlinear interaction between tree-ring growth, temperature, rainfall and other factors is expected. But the climatic abnormalities such as severe droughts and abnormally cold winters shall definitely leave detectable marks on the tree growth which needs an extensive examination. From the tropical trees one can expect to derive tree-ring data normally for a period of 300-400 years whereas in mid-latitudes data is available for about 1000 years for common tree species. As regards fossil trees, under the warm and humid conditions of tropical weather conducive to quick decomposition of organic matter it is almost impossible to obtain fossil woods with descernible growth-rings. It is encouraging that for our region recorded meteorological data is available for about a century. It can be extended backwards qualitatively on the basis of documented historical records so as to have information available for a period of about three hundred years as far as the climatic anomalies, such as droughts, are concerned. Two distinct climatic zones in India where extensive sampling and tree-ring analysis is suggested are the forests of the mountains adjacent to Himalayan snow-line including sub-Himalayan forest belts and the semi-arid regions of the country. A good sample of tree-ring and other growth parameters for large number of tree-species from different climatic zones specially the regions suggested above are essential for such a study to be conclusive and then only a reliable relationship between the tree-growth parameters and the climatic variable can be established. A close cooperation with Forest Depts., Forest Research Institute, Dehradun (U.P.) and the Botanical Survey of India is essential for the collection of samples and preliminary analysis. Laboratory for detailed analysis of tree-rings and climatic inferences need to be established as a first step in this interesting and informative branch of Palaeoclimatology. The tree-ring data collected according to specifications and cross-matched need to be provided to the International Tree-ring Data Bank to help in the understanding of global climatic changes.

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