ABSTRACT

Among various terrestrial climate proxies used for reconstruction of the past climate, it is advantageous to use trees for climate reconstruction as they have a wide geographic distribution, are annually resolved, show a continuous record, and are easily dated by ring-counting. Numerous dendroclimatological investigations have shown the efficacy of the ring-width and its isotopic composition ($\delta^{18}O$, $\delta^{13}C$ and δD) studies in reconstruction of past climate. It is further believed that the isotopic records of trees, especially from the tropical area, are more useful than ring-width records in reconstructing past climate.

Unlike stable isotope-based dendroclimatological investigations of temperate trees, the potential of tropical trees is yet to be fully realized, as only a few tropical species, such as teak (*Tectona grandis*), exhibit distinct and clearly datable growth rings. Wide geographical distribution of teak, especially in south and south-east Asia – India, Java, Sumatra, Burma, and Thailand – a region important for tracking the past history of El Nino- Southern Oscillation phenomenon, makes it an important candidate for dendroclimatology. Preliminary isotope studies had shown potential of teak in reconstructing past climate, especially rainfall.

To exploit the climatic potential of teak, it is thus important to know what governs its isotopic composition on annual as well as sub-annual scales. Recently developed plant physiological models help in constraining the isotopic composition of photosynthates produced during the growing season, which, coupled with newly developed, faster cellulose extraction techniques makes sub-annual isotope studies increasingly significant.

In the present study, teak from western, central and southern India were analysed for the oxygen isotopic composition ($\delta^{18}O$) for understanding what governs their $\delta^{18}O$ on annual and sub-annual scales. The understanding of this formed the basis for reconstruction of past rainfall.

The first chapter introduces the field of isotope dendroclimatology. It starts with stating importance of trees in reconstructing past climate and how isotope studies in general and $\delta^{18}O$ studies in particular are more advantageous than ring-width studies for deciphering past climate. The importance of a tropical tree species, teak, in understanding past tropical climate is then described. This is followed by a general discussion regarding processes governing $\delta^{18}O$ of trees, described under the atmospheric, soil water and plant physiological processes. This is followed by a brief review of experimental isotope dendroclimatology in which details regarding cellulose extraction and its isotope measurement using mass spectrometer is given. Subsequently, previous isotope dendroclimatological investigation in the tropical region is reported. The chapter ends with describing the statement and rationale behind the present study.

The second chapter describes experimental procedure followed in the present study. Initially, information about climatic setting of the sample sites has been described. An account of $\delta^{18}O$ data of rainwater observed at various stations in the peninsular India is also reported. This is followed by a detailed description of individual samples and their chronology. Method of cellulose extraction followed in the present study is described. Details of the mass-spectrometric measurements of the cellulose samples have been dealt with subsequently.

For sub-annual studies selected rings of various widths were manually sub-divided into various equal parts along a radial direction; the separated parts represent wood formed during various times of the growing season. The sub-annual cellulose $\delta^{18}O$ record of the separated parts was used to constrain factors governing $\delta^{18}O$ of cellulose during the growing season.

Cellulose was extracted using the recently developed faster cellulose extraction techniques with some modifications. The modification introduced in the present study helps to solve the problem of acetylation of cellulose reported in the literature.

The results of the sub-annual $\delta^{18}O$ analysis are described in Chapter 3. For sub-annual analysis, 10 to 17 rings from trees from central and southern India were selected and further divided into various equal parts. To identify what governs the $\delta^{18}O$ of photosynthates during growing season, a plant physiological model was employed and sub-annual $\delta^{18}O$ profiles were constructed using available local meteorological data. The comparison of modeled and actually observed values was done to understand relative importance of rainfall amount and its $\delta^{18}O$ and relative humidity in deciding $\delta^{18}O$ values of tree rings.

Sub-annual $\delta^{18}O$ analysis of several annual growth rings of three teak trees from central India revealed a seasonal cycle with higher values in the early and late growing seasons and lower values in the mid growing season, with amplitudes of 1.9 to 5.0 ‰ and upto 6.8 ‰ in coarse and fine resolution samplings, respectively. Relative humidity rather than the amount of rainfall appears to control the sub-annual $\delta^{18}O$ variations. Further, a comparison of the $\delta^{18}O$ profile of a ring (year 1971 A.D.), analyzed with the highest resolution, and a model profile based on concurrent local meteorological data reveals the possibility of achieving a resolution of ~20 days in monsoon reconstruction by sub-annual $\delta^{18}O$ measurements.

High and coarse resolution sub-annual analyses of $\delta^{18}O$ of teak cellulose from southern India, receiving both rains, the south-west (SW) (summer) and the north-east (NE) (winter, more depleted in ^{18}O) monsoons, show a seasonal cycle, with some degree of incoherence. The amplitudes vary between 1 to 3 ‰, with lower $\delta^{18}O$ values at the early and late growing seasons and higher values at the middle. The observed pattern is opposite to that reported for teak trees from central India, where the annual rainfall is unimodal, with much less NE monsoon rains. Comparison of the observed and modeled profiles reveals that the observed pattern of sub-annual $\delta^{18}O$ variation can be explained only if the tree sampled rainfall from both the monsoons. Thus it appears possible to detect excess NE monsoon years in the past by analyzing the $\delta^{18}O$ of cellulose from latewood of teak trees.

The fourth chapter deals with inter-annual $\delta^{18}O$ variations observed in various teak trees analyzed in the present study. The relationship observed between rainfall and cellulose $\delta^{18}O$ of the corresponding years depends upon the location within India. The trees from western and central India show a positive relationship (r ~0.4) with the amount of rainfall while teak tree from southern India shows a negative relationship (r ~ -0.5). The former could be explained by invoking lengthening of the growing season as a consequence of higher rainfall. The plausible reasons for the negative correlation in the case of the latter could be the presence of relatively strong amount effect in rainfall in the region, higher rainfall during the north-east (NE) monsoon, one depleted in ^{18}O, and relatively lesser effect of lower relative humidity conditions in deciding tree $\delta^{18}O$.

Based on the relationship observed between $\delta^{18}O$ record of teak from southern India and rainfall record, past rainfall record of Palakkad, Kerala and southern India was reconstructed back to A.D. 1743. The cellulose $\delta^{18}O$ based rainfall record extends the existing record back in time by 128 and 70 years for Palakkad and southern India, respectively. One of the conspicuous features of the extended record is higher precipitation during 1743-1830 as compared to the later period.

The fifth chapter summarizes the present work, discusses its implications and ends with recommendations regarding possible future work. To deconvolute climate signal from non-climate noise in cellulose $\delta^{18}O$ record, better understanding of physiological processes of teak is felt necessary.