IAWA Journal, Vol. 20 (3), 1999: 249–253

USEFUL STRATEGIES FOR THE DEVELOPMENT OF TROPICAL TREE-RING CHRONOLOGIES

by

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SUMMARY

This paper outlines efficient strategies for the development of long, climatically sensitive tree-ring chronologies in the tropics. Effective strategies include sampling useful temperate or subtropical species that extend naturally into the tropics; sampling species in botanical families that have already provided examples useful for dendrochronology (e.g., Pinaceae, Taxodiaceae, Verbenaceae); targeting deciduous species in seasonally dry forests; and sampling species described in the literature or found in xylaria that have promising anatomical features such as ring porosity and marginal parenchyma. Dendrochronology can also be used to test the annual nature of growth banding in tropical species. The cross-dating of long ring-width time series between individual trees and between multiple sites in a region is strong evidence that the growth rings are indeed synchronized with the annual calendar. This can be confirmed if the ring-width data are also strongly correlated with long annual or seasonalized records of climate variability. Blind cross-dating tests to identify the cutting dates of known-age timbers can provide a final proof that a species produces reliable annual growth rings.

Key words: Annual tree rings, tropics, dendrochronology.

INTRODUCTION

There is a growing worldwide interest in tropical dendrochronology. The successful development of exactly dated tree-ring chronologies of teak (*Tectona grandis*) in Java, Thailand, and India (e.g., D'Arrigo et al. 1994; Pumijumnong et al. 1995; Bhattacharyya et al. 1992) has particularly stimulated interest in the possibilities for annual ring formation in other tropical hardwoods. Development of tropical tree-ring chronologies would have substantial potential benefits to climatology, forest ecology, and forest management. But in spite of encouraging progress with teak, pine, and few other tropical species, the vast majority of tropical tree species do not produce anatomically distinctive annual growth rings that can be used for the development of reliable, centuries-long tree-ring chronologies. Identifying those few species that are indeed useful from the diverse indigenous forests of the tropics remains a major challenge to tropical dendrochronology.

Several previous papers have discussed methods to document annual rings in tropical tree species. Contrary to conventional wisdom in forestry and dendrochronology, Worbes (1989, 1995), Détienne (1989), Gourlay (1995), Devall et al. (1995), and others have produced convincing evidence for annual ring formation in several tropical tree species. Worbes (1989, 1995) is particularly optimistic about the potential for annual ring formation in tropical species from selected habitats. I share this optimism, but emphasize that even with annual banding we are still quite far from the development of centuries-long chronologies that will provide sensitive records of the paleoclimate. A fundamental problem concerns the complex ring anatomy of many species. While annual growth rings may be reasonably evident in young trees with relatively large rings, the anatomical landmarks are often not distinctive enough to identify annual boundaries in suppressed or senescent growth, particularly when attended by false rings, discontinuous rings, and other anatomical complications that are so common in tropical hardwoods (see also Détienne 1989).

In spite of these difficulties, centuries-long chronologies may yet be developed for selected tropical hardwoods, to add to the success achieved with teak. But how do we most efficiently expand the network of long, climatically sensitive tree-ring chronologies in the tropics? This paper attempts to summarize some of the useful strategies that have already been suggested, and explains how dendrochronology can also be used to provide rigorous testing for reliable annual ring formation in tropical tree species.

SEARCH FOR TREE SPECIES WITH DISTINCT GROWTH ZONES

One highly effective strategy is to simply identify those temperate or subtropical species of known dendrochronological value which have a natural distribution that extends into the tropics [e.g., *Pseudotsuga menziesii* in North America, *Cedrela angustifolia* and *Juglans australis* in South America (Villalba et al. 1985)]. While there is no guarantee that the tropical members of a particular species will indeed be useful, this strategy may be quite effective.

A second strategy would be to build upon previous success in a particular botanical family. The annual growth banding in *Tectona grandis* has been known for several decades (Berlage 1931). *Tectona grandis* is a member of the family Verbenaceae, and a few other species of this large pan-tropical family have recently been shown to also produce annual growth rings (e.g., *Vitex keniensis, V. payous,* and *Premna maxima* in Kenya, Stahle et al. 1995). Taxodiaceae includes *Taxodium distichum* of the southeastern United States which is an excellent species for dendroclimatology (Stahle & Cleaveland 1992), and its close botanical cousin *T. mucronatum* (Montezuma baldcypress) has recently provided rainfall sensitive tree-ring chronologies over 400 years long in the tropics of Tamaulipas and San Luis Potosi, Mexico (Stahle et al. 1999b). And, of course, the genus *Pinus* includes many tropical species, some of which are useful for dendrochronology (Buckley et al. 1995).

Borchert (1999) has discussed the important differences in phenology, and by inference moisture relations, of species in moist evergreen and dry deciduous forests in the tropics. The complete deciduous habit, with a clear seasonal segregation of leaf flush and leaf fall, appears to be an important factor in the formation of annual growth bands. This trait is evident in the phenology of several tropical broadleaf species known to be useful for dendrochronology, including *Tectona grandis* and *Pterocarpus angolensis* in Zimbabwe (Stahle et al. 1997, 1999a). Distinct ring formation is probably favored when the period between leaf fall and subsequent flush is quite long. And those species that flush after the onset of the wet season would seem to be superior to those that flush during the dry season (Borchert 1999). Therefore, a third effective strategy would be to target the seasonally dry deciduous forests of the tropics (e.g., Jacoby 1989; Worbes 1995) in the effort to identify useful species, particularly those forests which experience a single prolonged dry season.

Finally, the anatomical descriptions of tropical timbers can be extremely helpful for isolating promising species (e.g., Kribs 1968; many papers on wood anatomical atlases listed in Gregory 1994). Xylaria and wood anatomical slide collections can provide valuable information about the minute anatomy of tropical species and can be crucial for setting sampling priorities. The Forest Research Centre in Harare, Zimbabwe, for example, contains a xylarium with standard-size wood blocks from some 350 species, including most of those described by Goldsmith and Carter (1981).

PROOF OF THE ANNUAL NATURE OF GROWTH BY CROSS-DATING

Once distinctive growth banding has been identified in the minute cellular anatomy of a particular species, whether based on ring porosity, semi-ring porosity, marginal parenchyma, or other structures, it can be very difficult to prove that these growth bands are indeed reliable annual tree rings. Several experimental techniques have been developed to monitor cambial growth rhythms, including periodic wounding or pinning (Nobuchi et al. 1995), anatomical studies of known age trees, bomb radiocarbon analyses (Worbes 1989), and dendrometer studies.

In addition to these techniques, dendrochronology can also provide an exact test of the annual nature of growth banding over the entire life span of tropical species. If the patterns of wide and narrow growth bands identified in a particular tropical species actually cross-date among all trees in a stand for at least 50 to 100 years, and among trees of the same species at different locations in a given climate province, then there is little doubt that the growth rings are indeed annual and are not simply structural features of the xylem that fail to synchronize with the annual cycle. Cross-dating exists because the growth of trees is periodical, tied to the annual calendar by the seasonality of climate, and synchronized among many trees in a region by the interannual variation in the shared regional climate. If the growth banding cannot be strictly linked to the annual cycle, then the width variations will not readily synchronize among trees and the ring sequences will not cross-date. Many tropical hardwoods are obviously quite old and have distinctive banding (e.g., Goldsmith & Carter 1981), but this banding is usually subannual and the time series patterns created by these bands cannot be cross-synchronized among opposite radii of the same tree, much less between different trees. *Guibourtia conjugata* in western Zimbabwe appears to live for 200 to 400 years on rocky semi-arid positions, but the distinctive parenchyma bands unfortunately cannot be cross-dated within or among trees.

Strong region-wide cross-dating is usually enough to convince most dendrochronologists that the growth bands are indeed annual. But this argument can of course be strengthened if the derived chronology is strongly correlated with annual time series of instrumental climate (e.g., Pumijumnong et al. 1995; Stahle et al. 1997).

Finally, blind cross-dating tests can provide a rigorous dendrochronological proof that the rings are indeed truly annual. Once a master tree-ring chronology has been developed for a particular species, that chronology can be used to determine the cutting dates for timbers sampled from the same species where the true felling dates have been previously recorded. If successful, that species will have fulfilled all requirements of the tree-ring dating method, and can be added to the list of species useful for dendrochronology. Wounds of known age, such as a fire scar or pruning event, can also be used in blind cross-dating tests.

These dendrochronological tests for annual rings can be conducted in a relatively short time frame on any particular tropical tree species. As useful as these dendrochronological tests can be, it will always be preferable to include as many independent lines of evidence as possible, including phenological studies and repeated sampling of cambial activity and xylem formation. Our experience in Africa and Mexico suggests that many more tropical species produce reliable annual growth rings than previously suspected. However, complex wood anatomy often greatly complicates the identification of ring boundaries, particularly in old or suppressed growth. Development of centuries-long tree-ring chronologies from tropical hardwoods and conifers therefore remains a major challenge to dendrochronology.

ACKNOWLEDGEMENTS

This paper was stimulated by the discussions at the First International Conference on Southeast Asian Dendrochronology in Thailand. I thank the participants and organizers of the Conference, particularly Orawan Tongjit, Rosanne D'Arrigo, and Brendan Buckley. University of Arkansas tree-ring research in Africa and Mexico has been supported by the National Science Foundation (Grant No. ATM-9528148).

REFERENCES

Berlage, H.P. 1931. On the relationship between thickness of tree rings of Djati (teak) trees and rainfall on Java (translated from Dutch). Tectona 24: 939–953.

Bhattacharyya, A., R.R. Yadav, H.P. Borgaonkar & G.B. Pant. 1992. Growth ring analysis on Indian tropical trees: dendroclimatic potential. Current Science 62: 736–741.

Borchert, R. 1999. Climatic periodicity, phenology, and cambium activity in tropical dry forest trees. IAWA J. 20: 239–247 (this issue).

Buckley, B.M., M. Barbetti, M. Watanasak, R.D. D'Arrigo, S. Boonchirdchoo & S. Sarutanon. 1995. Dendrochronological investigations in Thailand. IAWA J. 16: 393–410.

D'Arrigo, R.D., G.C. Jacoby & P.J. Krusic. 1994. Progress in dendroclimatic studies in Indonesia. Terrestrial, Atmospheric and Oceanic Sciences 5: 349–363.

Détienne, P. 1989. Appearance and periodicity of growth rings in some tropical woods. IAWA Bull. n.s. 10: 123–132.

Devall, M.S., B.R. Parresol & S.J. Wright. 1995. Dendroecological analysis of Cordia alliodora, Pseudobombax septenatum, and Annona spraguei in central Panama. IAWA J. 16: 411–424.

Goldsmith, B. & D.T. Carter. 1981. The indigenous timbers of Zimbabwe. Zimbabwe Bull. For. Res. No. 9, Forestry Commission, Harare, 406 pp.

Gourlay, I.D. 1995. The definition of seasonal growth zones in some African Acacia species – A review. IAWA J. 16: 353–360.

Gregory, M. 1994. Bibliography of systematic wood anatomy of dicotyledons. IAWA J., Suppl 1: 1–266.

Jacoby, G.C. 1989. Overview of tree-ring analysis in tropical regions. IAWA Bull. n.s. 10: 99–108.

Kribs, D.A. 1968. Commercial foreign woods on the American market. Dover Publications, New York, 241 pp.

Nobuchi, T., Y. Ogata & S. Siripatanadilok. 1995. Seasonal chraracteristics of wood formation in Hopea odorata and Shorea henryana. IAWA J. 16: 361–370.

Pumijumnong, N., D. Eckstein & U. Sass. 1995. Tree-ring research on Tectona grandis in northern Thailand. IAWA J. 16: 385–392.

Stahle, D.W. & M.K. Cleaveland. 1992. Reconstruction and analysis of spring rainfall over the southeastern U.S. for the past 1000 years. Bull. Amer. Meteorol. Soc. 73: 1947–1961.

Stahle, D.W., M.K. Cleaveland, G.K. Haynes, J. Klimowicz, P. Mushove, P. Ngwenya & S.E. Nicholson. 1997. Development of a rainfall sensitive tree-ring chronology in Zimbabwe. Eighth Symposium on Global Change Studies, American Meteorological Society, Long Beach, CA.

Stahle, D.W., M.K. Cleaveland, J. Maingi, & J. Munyao. 1995. Dendroclimatology of Vitex keniensis in Kenya. Eos (Suppl.) Nov. 7, 1995, F316.

Stahle, D.W., P.T. Mushove, F. Roig & M.K. Cleaveland. 1999a. Management implications of annual growth rings in Pterocarpus angolensis from Zimbabwe. Forest Ecology and Management 4760: 1–13.

Stahle, D.W., J. Villanueva-Diaz, M.K. Cleaveland, M.D. Therrell, G.J. Paull, B.T. Burns, W. Salinas, H. Suzan & P.Z. Fule. 1999b. Recent tree-ring research in Mexico. In: F. Roig (ed.), Dendrocronología en América Latina. EDIUNC, Mendoza, Argentina (in press).

Villalba, R., J.A. Boninsegna & R.L. Holmes. 1985. Cedrela angustifolia and Juglans australis: two new tropical species useful in dendrochronology. Tree-Ring Bull. 45: 25–36.

Worbes, M. 1989. Growth rings, increment and age of trees in inundation forests, savannas and a mountain forest in the Neotropics. IAWA Bull. n.s. 10: 109–122.

Worbes, M. 1995. How to measure growth dynamics in tropical trees – A review. IAWA J. 16: 337–352.