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Teak vessel chronologies as an indicator of Southeast Asian Premonsoon temperature

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ABSTRACT

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The presented dendroclimatological study on Teak (*Tectona grandis* L.) was carried out in northern Thailand by using earlywood vessel density and latewood conductive area and other anatomical variables. The vessel density is determined using an image analysis system. The anatomical variables are used to calibrate and verify temperature during the March period. The regression equation explains about 44% of the relationship among calibrated variances. The study also suggests that more detailed study of El Nino via anatomical variables and tree-ring widths might be possible.

Key-words—Anatomical variable, Teak, Image analysis system, El. Nino.

दक्षिण-पूर्वी एशियाई मानसूनी तापमान के संकेतक के रूप में टीक वाहिका का कालानुक्रम

नासुदा पूमिजुमनांग एवं वोन-क्यू पार्क

सारांश

अग्र दारु घनत्व एवं पश्चदारु वाहिनी क्षेत्र तथा अन्य शारीरीय चरों की सहायता से उत्तरी थाईलैण्ड क्षेत्र का वृक्षजलवायुविक अध्ययन किया गया। प्रतिबिम्ब विश्लेषण सिस्टम की सहायता से वाहिका के घनत्व का भी अभिनिर्धारण किया गया है। शारीरीय चरों को मार्च की अवधि के तापमान को अनुसंशोधित एवं अभिप्रमाणित करने हेतु प्रयुक्त किया गया है। समाश्रयण समीकरण अनुसंशोधित प्रसरणों के मध्य लगभग 44% का सहसम्बन्धन व्याख्यायित करता है। अध्ययन से यह भी प्रस्तावित होता है कि शारीरीय चरों तथा वृक्ष-वलय चौड़ाइयों द्वारा एल निनो का अधिक विस्तृत अध्ययन किया जाना सम्भव है।

संकेत शब्द—शारीरीय चर, टीक, प्रतिबिम्ब विश्लेषण सिस्टम, एल निनो.

INTRODUCTION

TEAK (*Tectona grandis* L.) is one of the few species in the subtropical zone in Southeast Asia that has potential for dendroclimatology. Teak tree-ring width has been proven in various studies to have a significant, positive correlation with rainfall. For example, teak growth in Northern Thailand was positively correlated with rainfall during the beginning of the rainy season (Pumijumnong *et al.*, 1995), teak growth in Myanmar was positively correlated

Observation	Variables	Symbol	Description
Earlywood	EWAREA	V1	Earlywood vessel area
	EWD4	V2	Earlywood conductive area
	EWDD	V3	Earlywood vessel density
	EWDIA	V4	Earlywood vessel diameter
Latewood	LWAREA	V5	Latewood vessel area
	LWD4	V6	Latewood conductive area
	LWDD	V7	Latewood vessel density
	LWDIA	V8	Latewood vessel diameter
Total ring	TWAREA	V9	Total ring vessel area
	TWD4	V10	Total ring conductive area
	TWDD	V11	Total ring vessel density
	TWDIA	V12	Total ring vessel diameter
Ring Width	RW	V13	Ring width

Fig. 1—Twelve anatomical variables and ring width.

with April rainfall, which is during the transition period from the dry season to the wet season (Pumijumnong *et al.*, 2001), just as teak growth in Java was positively correlated with rainfall in the transition period between the dry season and the wet season (D'Arrigo *et al.*, 1994), and teak growth in India was positively correlated with rainfall during the previous October (Bhattacharyya *et al.*, 1992). In contrast to rainfall, temperature seems to have a very weak effect on radial growth of teak in this region.

Image analysis was employed as a new technique to obtain certain anatomical variables of tree rings. Methods have been developed to determine vessel size and vessel density in broad-leaf trees of Temperate Zone using this technique (Eckstein & Frisse, 1982; Woodcock, 1989; Sass & Eckstein, 1992; Sass, 1993). For subtropical trees Pumijumnong and Park (1999, 2000) have applied the image analysis method to Thai teak.

OBJECTIVE

The objective of the study is to explore whether or not anatomical variables can be used to produce a better reconstruction of Southeast Asia temperature, as opposed to tree-ring width.

MATERIAL AND METHODS

Twelve anatomical variables (Fig. 1) were derived from five teak trees and two cores per tree from northern Thailand. These were completely measured for the 50 years 1947-1996 using an image analysis system (Image-Pro Plus, Media Cybertic L.P. 1994). These anatomical variables were detrended by fitting first a negative exponential or straight

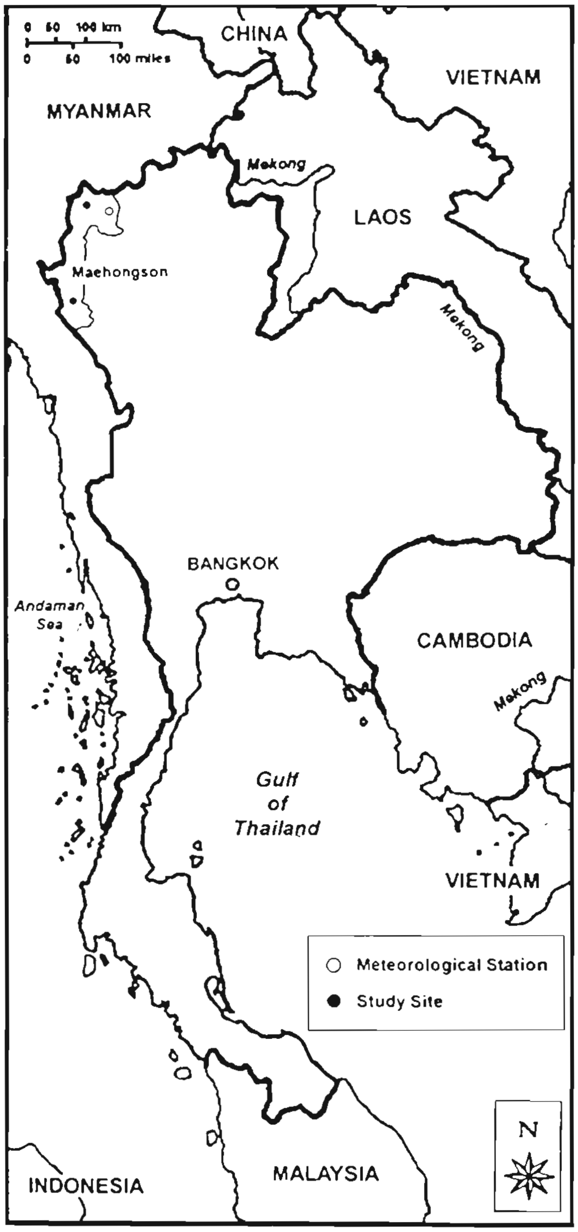

Fig. 2—Map of Thailand and study area. ⟶

line or a cubic spline with a 50% response period of 66 years. An autoregressive model was applied to the detrended series, and the residual series were averaged using the robust mean to obtain the final chronology (Cook, 1985).

Climate data were obtained from the Maehongson Station, situated at a lower elevation (271·68 m a.s.l.) than the tree-ring sites (600-700 m a.s.l.), and about 30 km away from the study site (Fig. 2). Fig. 3 shows a climate diagram of the study area in Maehongson Province. The temperature data extend from AD 1951 to 1997.

These thirteen variables and mean monthly temperature were analyzed by Pearson correlation. We included lagged anatomical variables in $year_{(t0)}$, $year_{(t-1)}$, $year_{(t+1)}$ and $year_{(t+2)}$ in order to consider biological persistence in the series. We finally selected March temperature for reconstruction because it was most highly correlated with ring variables.

Stepwise regression modelling was employed to calculate each significant dependent variable and principal component. Only the significant equations were employed to estimate independent variables. Finally, we calibrated and verified these independent variables. The calibration period was from 1948 to 1972, and the verification period was from 1973 to 1994.

RESULTS AND DISCUSSION

This study chooses temperature data in March as an equation because it showed reasonable relationship among the variables in equation. Although the temperature in May and June revealed a positive correlation with anatomical variables more than data in March, but the results of stepwise analysis using temperature data in May and June were more complicated and hardly to explain such relationship between the variables. Six anatomical variables ($V6_{(t0)}$, $V61_{(t-1)}$, $V3_{(t+1)}$, $V10_{(t+1)}$, $V62_{(t+2)}$ and $V112_{(t+2)}$) were first entered into the equation. The significant variables in the stepwise regression equation for estimated March temperature were ET3 = 260·1150-12·3556 * V61 + 25·6757 * V3 - 11·7864 * V62, where ET3 is estimated March temperature, $V61_{(t-1)}$ is latewood conductive area in $year_{(t-1)}$, $V3_{(t+1)}$ is earlywood vessel density in $year_{(t+1)}$ and $V62_{(t+2)}$ is latewood conductive area in $year_{(t+2)}$. Fig. 5 shows summary statistics for the calibration period and verification period for March temperature.

The percentage of variance (r^2=0·444) that explains the dependent variable of the equation. Pearson correlation indicates the degree of coherence integrated over all frequencies. Calibration and verification periods show a Pearson correlation of 0·4595 and 0·6500, respectively. The reduction of error statistic (RE), a procedure test of the reliability of a climate reconstruction (Fritts, 1976), which can be applied to independent data (e.g., anatomical variables) to measure the association between a series of actual values and their estimates. RE is 0·1789 and 0·4224 for calibration and verification, respectively. Notably, the reduction of error statistic results are all positive, and are equal to or greater than the proposed lower-limit of acceptable RE values. This

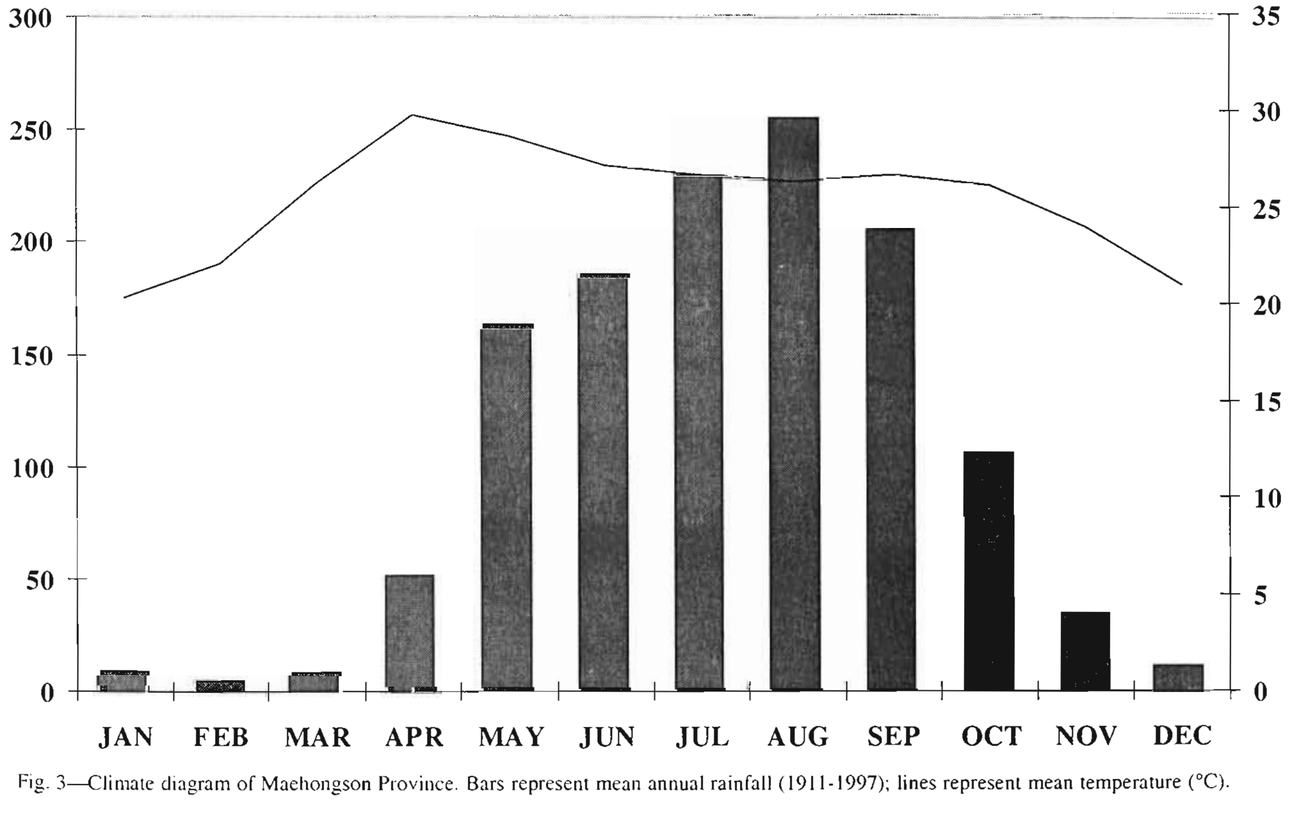

Fig. 3—Climate diagram of Maehongson Province. Bars represent mean annual rainfall (1911-1997); lines represent mean temperature (°C).

Climate	Month	Significant	Variable
Rainfall	Current April	Negative	EWAREA (V1) EWDIA (V4) EWDD (V3) TWAREA (V9) TWDIA (V12) TWD4 (V10)
	Current May	Positive	EWAREA (V1) EWDIA (V4) LWD4 (V6)
		Negative	LWDD (V7) TWDD (V11)
Temperature	Current April	Positive	LWDD (V7) TWAREA (V9) TWDIA (V12) TWD4(V10) TWDD (V11)
	Current May	Positive	LWDD (V7) TWAREA (V9) TWD4(V10)
	Current June	Negative	LWAREA (V5) LWDIA (V8) LWD4 (V6)

Source: Pumijumnong & Park (1999)

Fig. 4—The correlation between climate data and anatomical variable.

Statistic parameters	Calibration (1951-1972)	Verification (1973-1994)
$R^2 = 0{\cdot}444$		
Correlation	0·4595*	0·6500*
Reduction of error	0·1789*	0·4224*
T-value	2·8398*	1·5859>=1·7200
Sign-products	9<=6	5*

ET3 = 260.1150 - 12.3556 * V61 + 25.6757 * V3 - 11.7864 * V62..., where:

ET3, estimated March temperature

V61, latewood conductive area in $year_{(t-1)}$

V3, earlywood vessel density in $year_{(t+1)}$

V62, latewood conductive area in $year_{(t+2)}$

*Significant value at 95% confidence level

Fig. 5—Summary statistics of parameters for calibration and verification periods.

strongly indicates that the calibration and verification are reliable. The T-value, which calculates the products of the deviations and collects the positive and negative products in two separate groups based on their signs. The T-values of the series are 2·8398 and 1·5859. The sign-products test indicates whether or not sufficient similarity exists between the actual and estimated data. For this study, sign-products of calibration and verification periods are 9 and 5.

Fig. 6 depicts actual March temperature versus estimated March temperature derived using the above equation. The estimated March temperature (dotted line) better coincides with actual March temperature during the verification period (1973-1994) than during the calibration period (1951-1972). In 1986, the estimated value exceeds the actual value, although after this their patterns are similar until the year 1973. The calibration period, which has a correlation value of 0·4595, shows some different peaks between the actual and estimated March temperature, such as in 1970, 1967, 1963 and 1955.

The anatomical variables that are negatively correlated with March temperature are $V61_{(t-1)}$ (latewood conductive area in $year_{(t-1)}$) and $V62_{(t+2)}$ (latewood conductive area two years later). The anatomical variable that is positively correlated with March temperature, is $V3_{(t+1)}$(earlywood vessel density in $year_{(t+1)}$). The role that temperature plays in teak growth may be more difficult to determine than that of rainfall due to steady warm temperature in the subtropical zone, combined

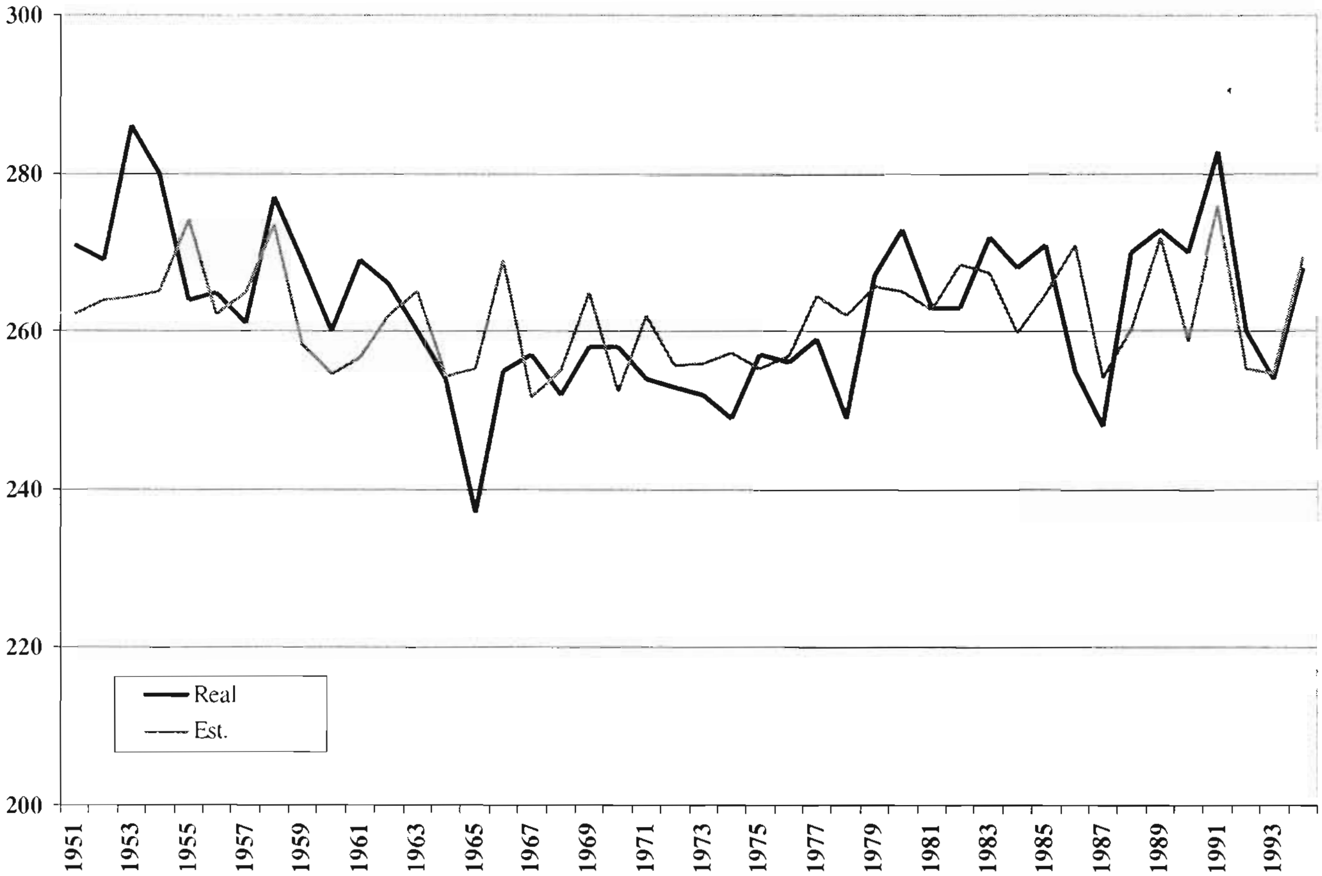

Fig. 6—Depicts current March temperature (thick line) versus estimated March temperature (thin line).

with complex hormonal processes in the tree. Previous studies emphasized that May temperature has a negative correlation with tree-ring width (Pumijumnong 1995). However, in this study tree-ring width was not entered into the stepwise regression model. Still, this may be accounted for, by considering high temperature which usually means less rainfall (i.e., a drought year), causing teak to produce a narrow ring, otherwise containing only a large vessel with one or two lines and no latewood. This coincides with the fact that the regression equation shows a negative correlation between temperature and latewood conductive area (V61). In a normal year optimum temperature combines with adequate rainfall and teak trees form a wider ring, with a large earlywood area and large earlywood vessel density (V3).

Present results using anatomical variables show a correlation with March temperature that we do not see using tree-ring width. Calibration and verification are reliable, as shown by 3 out of 4 statistical measures being at significant levels. The question is: Is it possible that if we examine these variables over a much longer period of time, the statistical parameters will show a higher correlation? Reconstructing March temperatures in Thailand could be important in analysing El Nino events, which begins around the end of December and continues some time into the following year, and warrants further research.

CONCLUSION

In Thai teak, latewood conductive area in year$_{(t-1)}$ and year$_{(t+2)}$ and earlywood vessel density in year$_{(t+1)}$ correlate with March temperature. Drought years cause the teak to have narrow rings with little or no latewood. By contrast, in a year with adequate water and optimal temperature, the teak will develop wide rings with large earlywood and latewood. Further studies will extend these measurements for more years, which will help to reconstruct March temperature for longer period. Besides anatomical variables can be used to determine the effect of El Nino phenomenon on teak growth in Thailand.

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REFERENCES

Bhattacharyya A, Yadav RR, Borgaonkar HP & Pant GB 1992. Growth-ring analysis of Indian Tropical trees: Dendroclimatic potential. Current Science 62 : 736-741.

Cook ER 1985. A time series analysis approach to tree-ring standardization. Dissertation University of Arizona, Tucson 175 p.

D'Arrigo RD, Jacoby GC & Krusic P 1994. Progress in dendroclimatic study in Indonesia. Terrestrial Atmospheric and Oceanic Science 5 : 349-363.

Eckstein D & Frisse E 1982. The influence of temperature and precipitation on vessel area and ring width of oak and beech. *In:* Hughes MK, Kelly PM, Pilcher JR & LaMarche VC (Editors)—Climate from tree rings: 12-13. Cambridge University Press, Cambridge.

Fritts HC 1976. Tree Rings and Climate. Academic Press. New York.

Media Cybernetic LP 1994. Image-Pro Plus. Version 1.3 for Windows. Reference Guild. 8484 Georgia Avenue, Silver Spring. MD 209100 USA.

Pumijumnong N 1995. Dendrochronologie mit Teak (*Tectona grandis* L.) in Nord-Thailand: Jahrringbildung-Chronologiennetz-Klimasignal. Diss. Ph.D. University of Hamburg, Germany 109p.

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

Pumijumnong N, Eckstein D & Park W-K 2001. Teak tree-ring chronologies in Myanmar-A first attempt. Palaeobotanist 50(1). 35-40.

Pumijumnong N & Park W-K 1999. Vessel chronologies from teak Northern Thailand and theirs climate signal. IAWA Journal. 20 285-294.

Pumijumnong N & Park W-K 2000. Reconstruction of Northern Thailand-May Rainfall using anatomical variable of teak tree rings. New horizons in wood anatomy. Edited by Kim YS. Chonnam Nat'l Univ. Press, Kwangju.

Sass U 1993. Die Gefaesse der Buche als oekologische Variable-Bildanalytische Erfassung, dendroklimatologische Pruefung, oekologische Bewertung. Diss. Fachbereiche Biologie. Uni. Hamburg, Germany 172 p.

Sass U & Eckstein D 1992. The annual vessel area of beech as an ecological indicator. Proc. tree rings and environment. Lundqua Report 34 : 281-285.

Woodcock DW 1989. Climate sensitivity of wood-anatomical features in a ring-porous oak (*Quercus macrocarpa*). Canadian Journal of Forest Research 19 : 639-644.