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RESEARCH REPORT

STRESSED TREES PRODUCE A BETTER CLIMATIC SIGNAL THAN HEALTHY TREES

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ABSTRACT

The basis for the selection of trees to be used in the production of dendrochronologies has long been an issue (Douglass 1946; Fritts 1976). In humid regions the common practice has been to use trees that appear to be in good health. As a part of a larger study involving the impact of ice storms on tree-ring increments (Travis 1989), we show that trees stressed as a result of ice damage produced a stronger climatic signal than nondamaged trees.

Die Auswahl von Bäumen für den Aufbau von Jahrringchronologien ist lange Zeit eine offene Frage gewesen (Douglass 1946; Fritts 1976). In feuchten Regionen wurden üblicherweise vitale Bäume ausqesucht. Im Rahmen einer umfangreichen Untersuchung zum Einfluß von Eisstürmen auf die Jahrringbildung (Travis 1989) konnten wir zeigen, daß durch Eisschäden gestreßte Bäume ein stärkeres Klimasignal erzeugen als unbeschädigte Bäume.

Le fondement de la sélection des arbres utilisés pour la production de dendrochronologies est depuis longtemps sujet à débat (Douglass 1946; Fritts 1976). Dans les régions humides la pratique courante est d'utiliser les arbres qui semblent en bonne santé. Parmi les résultats d'une étude plus large portant sur l'effet des tempêtes de glace sur la croissance des cernes (Travis 1989), nous avons montré que les arbres stressés sous l'effet de dommages occasionnés par la glace produisent un signal climatique plus fort que les arbres non endommagés.

MATERIALS AND METHODS

All trees sampled in this study were mature loblolly pines (*Pinus taeda* L.) growing in a naturally regenerated stand of mixed conifers in the Chattahoochee-Oconee National Forest, near Greensboro, Georgia. Records show this geographic area is subject to frequent and occasionally severe ice storms (Bennett 1959). Trees were separated into a damaged set and a nondamaged control group. In this case damage was identified as most likely caused by ice storms.

Permanent ice damage to pines can be recognized in a number of ways. The most obvious signal is a bent stem, which indicates that the tree was subjected to severe bending for an extended period. In this situation, the ice accumulation often occurs late in the winter and the bending is so severe that the tree is unable to return to its original vertical form before the onset of the growing season. The result is new growth increments that are put on asymmetrically. This may continue for a number of years until the tree becomes vertical once again. Another indicator of ice storm damage is a broken crown. This occurs when the wood is brittle, possibly due to old age, inherent wood properties, cold weather or prolonged drought. Crown breakage is normally more severe in open-grown stands than dense stands (Williston 1974). If the tree survives, new growth will be produced. Initially, this growth usually extends vertically from just below the point of breakage. One or more of the lateral branches will eventually express apical dominance resulting in a crooked stem, a lyre-shaped stem or a basket-top. In each case, evidence of ice damage is easily recognized from the ground.

Each damaged tree was paired with a nondamaged partner. Nondamaged control trees were selected on the basis of proximity and similarity in height, age, and stem diameter to damaged trees. In some cases a nondamaged tree was located between a number of damaged trees, and was therefore used as a control for each of the others. This procedure resulted in the selection of a greater number of damaged trees (N=15) than nondamaged (N=10). Since tree growth may be reduced by insects and diseases, great care was taken to select damaged and nondamaged trees showing no signs of pest damage.

Using standard dendrochronological techniques which have been presented in many works, including Graybill (1982) and Hughes et al. (1982), ring-width indices were developed. This process included both the crossdating and standardization of two cores from each tree. The method of core extraction is discussed in Maeglin (1979). Two separate tree-ring chronologies were developed. These were labeled damaged and nondamaged, respectively. Both chronologies extended from 1910 to 1985. Regression techniques were used to test the hypothesis that damaged trees respond to climate stress more readily than nondamaged trees.

Monthly temperature and precipitation data for Greensboro were obtained from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Regionally-averaged data for the north-central division of Georgia were used rather than single station data. The benefits of regionally averaged data are discussed in Blasing, et al. (1981).

Monthly temperature and precipitation variables were regressed against the ring-width values from each chronology. Only the five most significant explanatory variables were allowed to enter each regression equation. To be included all variables had to be significant at the 0.05 level. Stepwise regression provided candidate models, and eventually the most parsimonious model associated with each chronology was determined.

RESULTS

Cores from the set of 10 control or nondamaged trees were subjected to standard dendroclimatic techniques using records of monthly temperature (°C) and precipitation (mm). The best model for the undamaged set is expressed by:

$$\mathrm{RW1} = 2.53 + 0.018\mathrm{CAP} + 0.036\mathrm{MT} - 0.035\mathrm{CJT} + 0.026\mathrm{PNP} + 0.016\mathrm{MP}$$
$$R^2 = 0.35$$

where RW1 is the ring width indices, CAP is current August Precipitation, MT is current March temperature, CJT is current July temperature, PNP is previous November precipitation, and MP is current March precipitation. This equation explains approximately 35% of the variation in ring-width indices. It falls on the upper end of R^2 values commonly reported for humid, Eastern U.S. forests, which range from .17 to .41 (Dewitt and Ames 1978).

In a second analysis, cores from the set of 15 ice storm damaged trees were used to produce a chronology of ring widths. Damaged trees were located in the same area, and often next to nondamaged trees. The best model for the damaged set is expressed by:

$$RW1=5.668 - 0.066GT + 0.035MP + 0.020PDP - 0.018JP + 0.010PMT$$
$$R^2=0.45$$

where GT is the average July and August temperature, MP is current March precipitation, PDP is previous December precipitation, JP is the current January precipitation total, and PMT is the previous March temperature.

These results show that the relationship between climate and ring widths is significantly greater in the damaged versus the nondamaged chronology. The r-squared value of 0.45 for the damaged trees exceeds the average range of correlation in the eastern United States; the value of 0.35 for the undamaged chronology is closer to the results presented by Dewitt and Ames, (1978). This result leads to the hypothesis that damaged trees possess less ability to resist climate stress than healthy trees.

It is noteworthy that the damaged trees responded most significantly to growing season temperature. High temperatures produced smaller rings. All other chronologies of pines in this region have shown a marked response to precipitation totals, with only a secondary response to temperature (Travis and Meentemeyer 1991). It is possible that the physiology of damaged trees may result in a breakdown of transpiration processes. This would result in a reduced ability to remain at a cooler, or more optimum, temperature during very warm periods.

Another possible explanation of the strong relationship between damaged trees and temperature is the fact that damaged trees often contain a higher resin load and less stem electrical resistance (Nebaker, et al. 1982) near the damaged areas. If damage is severe enough, the resin may interfere with growth processes by inhibiting cell development and energy transfer. Periods of warm weather may also intensify this physiological process, resulting in narrow rings.

In summary, the sudden reductions in crown area caused by ice storms may trigger a chain of interactive physiological responses in a tree. The combination of reduced photosynthetic tissue, associated breakdown of transpiration processes, and increased respirational rates caused by high temperatures result in less growth in damaged trees than in nondamaged trees. Clearly, more research is needed to explain the marked response seen in damaged trees. In fact, the use of lagged variables with these data could increase R^2 values to >0.50. It is evident that future dendroclimatic work that requires a high correlation between ring-widths and climate should consider using damaged trees.

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REFERENCES

Bennett, I.
1959 *Glaze--Its Meteorology and Climatology.* U.S. Army Quartermaster Res. & Eng. Cent., Environ. Prot. Res. Div. Tech. Rep. EP 105.

Blasing, T. J., D. N. Duvick, and D. C. West
1981 Dendroclimatic calibration and verification using regionally averaged and single station precipitation data. *Tree-Ring Bulletin* 41:37-43.

Dewitt, E., and M. Ames
1978 Tree-ring chronologies of eastern North America. *Chronology Series IV,* Vol. 1., Laboratory of Tree-Ring Research, The University of Arizona, Tucson.

Douglass, A. E.
1946 Precision of ring dating in tree-ring chronologies. *University of Arizona Bulletin 17(3), Laboratory of Tree-Ring Research Bulletin* 3. University of Arizona Press, Tucson.

Fritts, H. C.
1976 *Tree Rings and Climate.* Academic Press, New York.

Graybill, D. A.
1982 Chronology development and analysis. In *Climate from Tree Rings,* edited by M. K. Hughes, P. M. Kelly, J. R. Pilcher, and V. C. LaMarche, Jr., pp. 21-28. Cambridge University Press, Cambridge.

Hughes, M. K., P. M. Kelly, J. R. Pilcher, and V. C. LaMarche, Jr., Editors
1982 *Climate from Tree Rings.* Cambridge University Press, Cambridge.

Maeglin, R. R.
1979 Increment cores: how to collect, handle, and use them. *General Technical Report* FPL 25, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Nebaker, E., D. M. Moehring, J. D. Hodges, M. V. Brown, and C. A. Blanche.
1982 Impact of thinning on host susceptibility. Paper presented at the Second Biennial Southern Silviculture Research Conference, Atlanta, Georgia.

Travis, D. J.
1989 The Influence of Ice Storms on the Growth Rates of Loblolly Pine (*Pinus Taeda* L.) and Shortleaf Pine (*Pinus Echinata* Mill.) in the Appalachian Piedmont. Master's Thesis, University of Georgia, Athens.

Travis, D. J., and V. Meentemeyer
1991 Influence of glaze ice storms on growth rates of loblolly pine *Pinus taeda* and shortleaf pine *Pinus echinata* in the southern Appalachian Piedmont. *Climate Research* 1:199-205.

Williston, H. L.
1974 Managing pines in the ice-storm belt. *Journal of Forestry* 72:580-582.