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# Use of Dendrochronological Methods to Estimate an Ecological Impact Date of the Chestnut Blight

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ABSTRACT

The slope of Bald Knob in Giles County, Virginia, is a former chestnut dominated community that has been the site of two previous forest ecology studies. Analysis of the chronology of basal area increment growth (BAI) of 26 red oaks at least 79 years old clearly shows a dramatic growth release beginning in the mid-1920's. Because of the former chestnut dominance, the timing of its elimination from the canopy, and the extraordinary growth trend of these older red oaks, I attribute the 1920's release to the dynamic changes caused by the chestnut blight. Dendrochronological methods and limitations are discussed.

## INTRODUCTION

The American chestnut (*Castanea dentata* [March.] Borkh.) was a codominant species with red oaks (*Quercus rubra* L.), chestnut oaks (*Q. prinus* L.), and white oaks (*Q. alba* L.) in many of the upland forests of eastern North America (Braun, 1950) until the chestnut blight (*Cryphonectria parasitica* [Murr.] Barr) was introduced in New York in 1904 (Gravatt and Marshall, 1926). The result has been the elimination of all canopy chestnuts in the area. Individuals are now only present in the form of emergent root sprouts with little capacity to grow above the subcanopy.

E. L. Braun surveyed two sites on the slope of Bald Knob, Giles County, Virginia, in 1932. She reported that the canopy (stems > 10 cm in diameter at breast height (DBH)) was composed of 84.6% and 56% of standing American chestnuts at the two sites. Red oaks were the second most abundant species and represented 11.1% and 22%, respectively (Braun, 1950).

Dendrochronological analysis has long been used to uncover climatic and environmental impacts on trees (Schweingruber, 1989). The typical trend of radial increment growth (ring width) of an unstressed tree is thought to be curvilinear, generally following a negative exponential curve (Phipps and Whiton, 1988). Specifically, Phipps (1985) has suggested that the basal area increment growth (BAI) of canopy trees such as oaks are curvilinear. Note that the addition of smaller rings each year could contribute a constant BAI (because the tree's diameter increases yearly).

The application of cubic splines (mathematical functions) to tree ring series was developed to separate the "growth" from "non-growth" components of BAI chronologies (Figure 1) (Cook and Peters, 1981). The "growth" component is the

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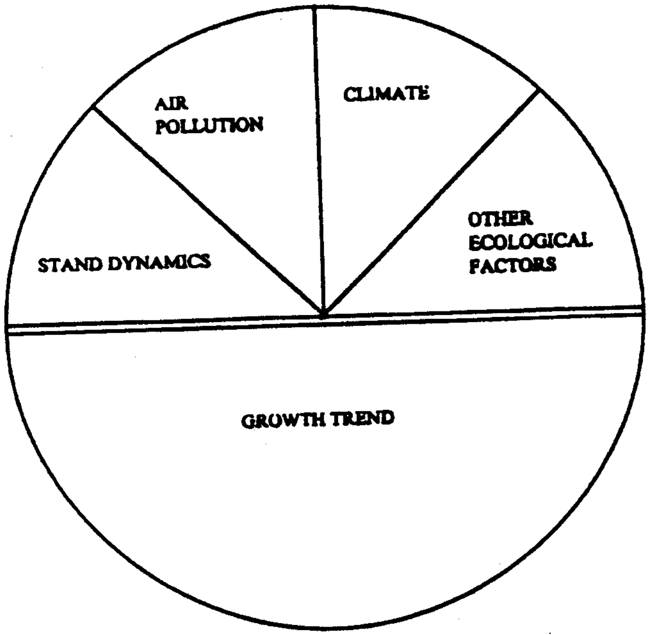


Figure 1. The result of applying mathematical cubic splines to tree ring series: the separation of the biotic growth component (growth trend) from growth related to other ecological factors.

tree's uninfluenced biotic factor, whereas the "non-growth" component is increase or decrease in growth resulting from stand dynamics (including competition and disturbances), climate, and pollution. Although the non-growth component consists of many influences on tree growth, in this study I focus on stand dynamics, which was the most dominant of these effects on Bald Knob. My motive in this project was to examine the response of the now dominant species in individuals that predated the chestnut blight's disturbance.

## METHODS

Codominant tree species present in the area of Braun's survey (as relocated by S. L. Stephenson) were cored 1.37 meter above the ground using a standard increment borer (see Phipps, 1985). Many attempts at coring older white oaks and red oaks were unsuccessful because of center heart rot. A total of 50 cores (1 from each tree) were collected (34 red oaks, 5 red maples (*Acer rubrum* L.), 4 white oaks, and individuals from 7 other species). Cores were dried, glued in grooved blocks, and sanded down with 120, 220, and 400 grit sand paper (Phipps, 1985; Schweingruber, 1989). Ages were estimated by counting rings under a dissecting microscope.

Of the 50 cores, 26 red oak cores predated the blight and were sufficiently old to have shown any response. Each ring of the 26 pre-blight existing red oaks was measured to 0.01 mM with digital calipers. Missing and extra growth rings were checked by overlaying graphs of the BAI trends using the computer program PLOT

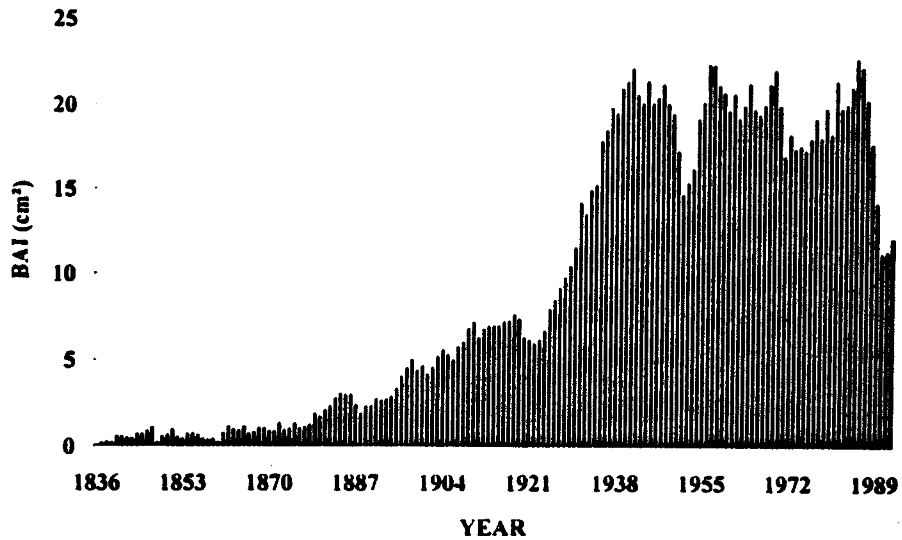


Figure 2. Mean basal area increment (BAI) of 26 red oaks on Bald Knob.

(Phipps, 1989). Where the cores did not hit the center of tree, the pith age and ring widths were estimated by completing the missed concentric rings with a compass (Norton et al., 1987; Arno and Sneck, 1977).

Using the program AREA (Phipps, 1989), time series of the mean BAI, the smoothed (detrended using a cubic spline) basal area increment (SBAI), and the upper and lower 95% confidence limits were created. These results were calculated by applying a cubic spline of 60 years to the data (Cook and Peters, 1981). Additionally, an index of the individual tree responses to the non-growth components was calculated. The ring width index (RWI) was derived by dividing the BAI by the SBAI (Phipps, 1989).

## RESULTS

Of the 34 red oak cores extracted, 26 were at least 79 years old. The other eight had a mean age of 60 years (ranging from 55 to 63 years). I believe, as did Stephenson (1986), that the latter were red oaks newly recruited just after the blight. Similarly, none of red maple cores was older than 65 years of age. Because of the high frequency of center wood rot, the small collection of white oaks could not provide useful information. Thus, I restricted my analysis of tree rings to the older red oaks only.

The 26 pre-blight existing red oak cores ranged in age from 79 to 157 years. The mean age was 103 years. Figure 2 shows the calculated and graphed mean values of BAI for the 26 red oaks. These unmanipulated data show the mean two dimensional wood growth per ring per year. A clear and sustained increase in BAI can be seen during the mid 1920's. Two other sequences of increasing ring widths occurred in the early 1950's and 1970's (see Figure 2).

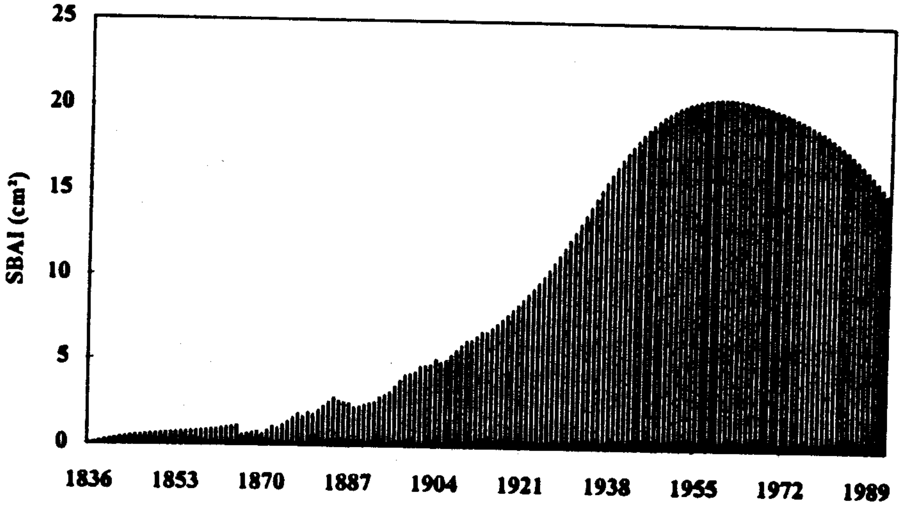

Figure 3. Mean smoothed basal area increment (SBAI) of 26 red oaks on Bald Knob.

By applying a 60 year cubic spline to each core's BAI, roughly 50% of the variance was removed over each 60 year cycle, and a smoothed sequence was obtained for each core (Phipps, 1989). These were then averaged by year of formation to give the mean SBAI values in Figure 3. Although the calculation of SBAI is a representation of the often linear growth trend only (Phipps, 1989), an unusually large increase in SBAI is included here in the 1920's. Figure 4 gives the SBAI with the upper and lower 95% confidence limits. Figure 5 displays the RWI, the ratio between BAI and SBAI (presumably the non-growth components). The average RWI (Figure 5) includes both stand-wide as well as local responses. The index values before 1889 have been removed because fewer than 10 trees were older than 104 years. A small sample size increases variance and poorly fitted curves for young trees, yielding wildly ranging indices.

## DISCUSSION

My results show that there was a growth release throughout the stand in the mid-1920's. This result is not a reflection of averaging strong responses from a few stems with minimal changes in others, because the release (defined by a 5 year sustained increase in BAI) (Canham, 1985) was seen in 81% of the cores. In contrast, the visibly strong responses of the early 1950's and 1970's (see Figures 2 and 5) was seen in only 12% and 4% of the cores, respectively. This suggests that the 1920's release is, indeed, stand-wide, and a response to the chestnut blight.

### Some Limitations of Tree Ring Smoothing

The graph of BAI versus time represents several components of an individual tree's growth: normal biotic growth, stand dynamics (including competition and disturbance), climate, pollution, and other minor factors. The purpose of smoothing the BAI series with splines (e.g., Figure 3) is to identify and separate the normal

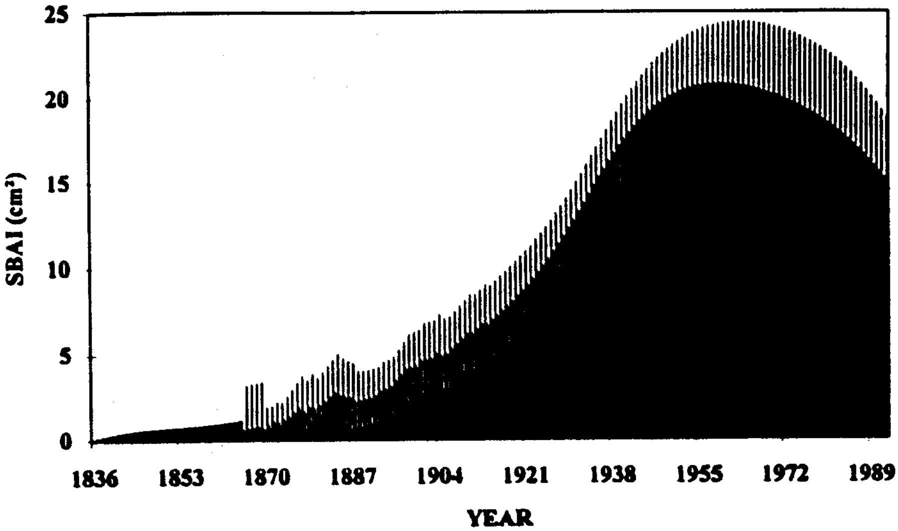


Figure 4. Mean SBAI of 26 red oaks on Bald Knob with the upper and lower 95% confidence limits.

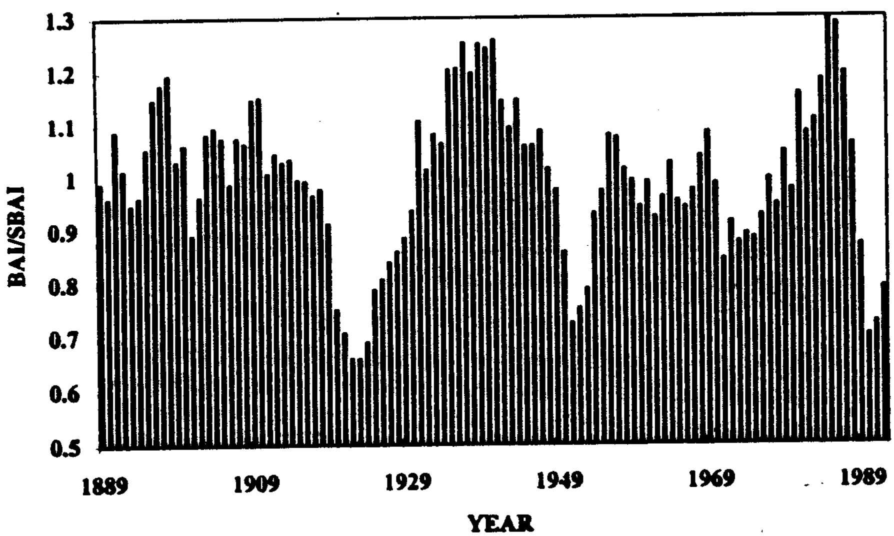


Figure 5. Mean ring width index (RWI) of 26 red oaks on Bald Knob.

growth trend component of the dendrochronological series (Phipps, 1989). However, in the case of this series, the major release of the 1920's was evident in the smoothed trend in a majority of the trees. Thus, part of the response to the non-growth factors is part of the SBAI. Therefore, the RWI underestimates the response of the 1920's release.

An alternate spline length does not solve this problem for these ring series. A stiffer spline length, i.e., greater than 60 years, would produce a more accurate RWI that would better reflect the actual release; however, the RWI would also include components of the growth trend that we would not want to separate from the SBAI. Conversely, a decreased spline length would better represent the growth trend of the trees; however, it would also further underestimate the non-growth component in the RWI. A limitation in the currently available dendrochronological methods is that they were developed mainly for use on open, western forest stands where climate and not pollution or tree-tree interactions are determining the main annual growth fluctuations (Cook and Peters, 1981). Eastern, closed-canopy stands are often affected by factors other than climate. Other smoothing techniques to identify growth trends in stands affected by major disturbances need to be developed.

What Figure 3 illustrates is that the disturbances of the early 1950's and 1970's can be "subtracted" or smoothed, because of their local nature. Also, the larger confidence limits in the mid 1920's than the confidence limits surrounding the subsequent releases (Figure 4) support the hypothesis of a stand-wide release. The sum of all factors other than the growth trend (the RWI), is given in Figure 5. The mid 1920's release, the response of the early 1950's and 1970's, as well as yearly climatic variations are present. Note that the release of the mid-1920's is under-represented in Figure 5 because much of the growth boost remained with the separated growth trend in Figure 3 (owing to the limitations of mathematical smoothing using cubic splines).

I see no other reasonable postulate than to explain the 1920's release in BAI experienced by older red oaks on Bald Knob as a direct response to the death of the American chestnuts. An elimination of 70% of the canopy trees provided the red oaks with favorable light conditions, high nutrient levels, and minimal competition. Thus, I assign an ecological impact date of the chestnut blight on the now dominant red oaks to be between 1924 and 1927.

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