

# Assessment of the 1998-2001 drought impact on forest health in Southeastern forests: an analysis of drought severity using FHM data



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## Introduction

Analyses of forest health indicators monitored through the Forest Health and Monitoring (FHM) program suggested that weather was the most important cause of tree mortality. Drought is of particular importance among weather variables because several global climate change scenarios predicted more frequent and/or intense drought in the Southeastern USA (Neilson et al. 1989). During the years of 1998-2001, extensive forest areas within the Southeastern USA experienced severe drought conditions (defined by the Palmer Drought Severity Index (PDSI)) (Palmer 1965). In this study, we used FHM data to examine the effect of drought induced moisture stress on forest growth, mortality and changes in crown condition at a regional scale.

## Objectives

Our objective was to investigate changes in growth, mortality, and crown condition across the Southeastern USA under various drought conditions using 1991-2005 FHM plot data. Specifically, we examined how drought severity influenced the rates of annual growth, mortality, and change in crown condition using PDSI as an indicator of drought severity. Drought effects were examined for three species groups (pines, oaks, and mesophytic species).

## Methods

We obtained FHM plot data for the Southeastern area through 1991-2005. The 307 plots selected for this study were located in Alabama, Georgia, and Virginia since plots were not established in other states in the Southeast prior to 1998. Tree data were obtained at the subplot level from a total of 936 subplots. Within each subplot, all trees with diameter at breast height greater than 5 inches were measured. Suppressed trees were removed from growth and crown condition analyses. Annual relative growth rate ( $\text{in}^2 \text{in}^{-1} \text{yr}^{-1}$ ) was calculated for each tree re-measurement by dividing the basal area increment by the initial dbh and the number of growing seasons between measurement intervals. The time interval between measurements varied because the FHM program measurement protocols were revised during the study period. Among the many crown condition indicators monitored through the FHM program, only crown density, crown dieback, and foliage transparency were measured throughout the entire study period. These crown condition indicators are visually assessed for each tree (dbh  $\geq 5.0$  in) during plot measurement and are recorded in 5 percent increments from 0 to 100 percent. Crown density is the amount of branches, foliage, and reproductive structures that blocks light visibility through the projected crown outline (Randolph 2006). Crown dieback is the amount of recent mortality of branches with fine twigs from the terminal portion of the branch and progresses inward towards the stem (Randolph 2006). Foliage transparency is the amount of sunlight visible through the live foliated crown excluding dieback, dead branches, and large gaps in the crown (Randolph 2006). Mortality rates were calculated at the subplot level whereas growth and changes in crown condition were calculated at the tree level. Annual mortality rates within a subplot were calculated for each genus and were expressed as percent removed per year ( $\% \text{yr}^{-1}$ ). The total basal area removed between measurements was calculated for each genus. Trees defined as dead and those not re-measured were considered removed due to mortality. Monthly PDSI values during the study period were obtained for each of the plots from NOAA. Growing season averages (May-Sept) were calculated for each year. Preliminary analyses indicated that the minimum PDSI between measurement intervals was a better drought indicator and was more correlated with relative growth rates than the mean PDSI. Drought conditions were assigned to each interval of plot measurements based on the minimum PDSI using a classification similar to that used by NOAA: 1) no drought, 2) mild drought, 3) moderate drought, and 4) severe drought (Table 1).

Table 1. Drought severity classification based on the minimum growing season PDSI.

| Drought Class | Severity         | PDSI        |
|---------------|------------------|-------------|
| 1             | No Drought       | > -1.9      |
| 2             | Mild Drought     | -2.9 - -1.9 |
| 3             | Moderate Drought | -3.9 - -2.9 |
| 4             | Severe Drought   | < -3.9      |

## Methods continued

Due to limitations within the data, three species groups were identified for subsequent analyses: 1) pine (*Pinus*), 2) oak (*Quercus*), and 3) mesophytic species. The mesophytic species group includes maple (*Acer*), birch (*Betula*), beech (*Fagus*), sweetgum (*Liquidambar*), yellow poplar (*Liriodendron*), and magnolia (*Magnolia*). These three species groups were identified to represent an array of site moisture gradients with pines typically occurring on dry ridges and mesophytic species typically occurring on moist lower lying areas. The mixed model procedure PROC MIXED in the SAS/STAT software (SAS Institute Inc. 1990) was used to examine the relationship between the dependent variables (i.e., the rates of relative growth, mortality, and change in crown condition) and drought severity and stand condition variables. Five stand condition variables were included in the analyses to account for varying stand conditions: total basal area ( $\text{ft}^2 \text{ac}^{-1}$ ), total tree density ( $\# \text{trees ac}^{-1}$ ), tree species richness ( $\# \text{spp subplot}^{-1}$ ), slope (%), and stand age (years). The means were calculated for each dependent variable by drought class and species group. The LSD test was used to determine differences among the drought classes for each of the dependent variables.

## Results & Discussions

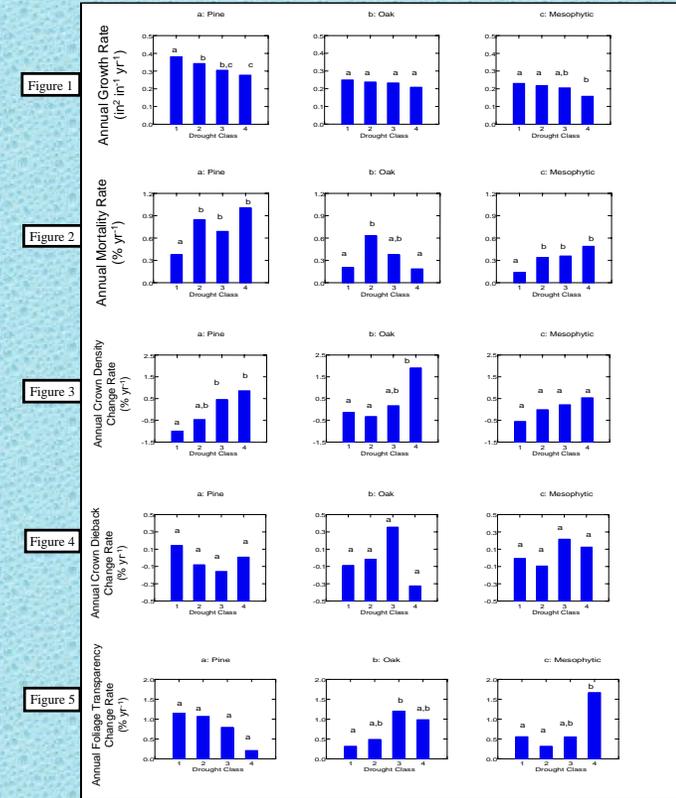
The mean annual relative growth rates by drought class for each of the three species groups are presented in Figure 1. A general decrease in mean relative growth rate was observed with increasing drought severity. However, mean relative growth rates were not significantly different among drought classes for the oak species group, indicating that oaks exhibit drought tolerance and can maintain growth rates during drought episodes, regardless of drought severity. The pine and mesophytic species exhibited a significant reduction in growth rate when exposed to mild and moderate drought. These findings, similar to those reported by Elliott and Swank (1994), suggest that oaks can maintain growth rates during drought episodes but pine and mesophytic species cannot.

The mean annual mortality rates by drought class for each of the species groups are presented in Figure 2. A general increase in mean mortality rate was observed with increasing drought severity for the pine and mesophytic species groups. This result is similar to the findings reported by Olan and Palmer (2003). Mean mortality rates within the no drought class were significantly lower than those within the other three drought classes, among which no significant differences in mean mortality rate were observed, for both the pine and mesophytic species groups. The pine and mesophytic species groups appear to be sensitive to drought and suffer higher mortality rates during drought episodes, regardless of drought severity. However, mean mortality rates were not significantly different among drought classes for the oak species group, indicating that oaks exhibit drought tolerance and can avoid mortality during drought episodes, regardless of drought severity.

The mean annual crown density, crown dieback, and foliage transparency change rates by drought class for each of the species groups are presented in Figure 3, Figure 4, and Figure 5, respectively. A general trend of increasing mean crown density change rate was observed with increasing drought severity, which is unexpected as trees usually shed foliage in an attempt to conserve water and increase water use efficiency during drought episodes. No general trend of mean crown dieback and foliage transparency change rates were observed with increasing drought severity. Our analyses failed to show any negative effect of drought on the change of crown conditions, suggesting that detecting changes in crown condition indicators over a relatively short plot measurement interval using visual measures at 5% increments may be unrealistic.

## Conclusions

- (1) Pines and mesophytic species exhibited a significant reduction in growth rate and increase in mortality rate with increasing drought severity, suggesting they are sensitive to drought.
- (2) Oaks exhibited no significant change in either growth or mortality rates with increasing drought severity, suggesting that they are tolerant of drought (even under the most severe drought class).
- (3) No realistic change in crown condition was observed. Therefore, change in crown condition in relation to drought severity may require different data and/or analyses.
- (4) The observed differential growth and mortality rates among different species groups in response to drought severity may alter the composition of Southeastern USA forests if drought episodes become more frequent and/or intense due to climate change. The potential shift in forest composition should be considered in current forest management in order to sustain these forests in the future.



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