TITLE: Modeling Drought Effects on Forest Health in the Southeast – An Analysis at the Sub-regional and Regional Level

LOCATION: Southeastern USA

DURATION: Year one of a two-year project **FUNDING SOURCE:** Base

PROJECT LEADER: Dr. William L. Bauerle (Dept. of Horticulture and Dept. of Forest and Natural Resources, phone: 864.656.7433, email: bauerle@clemson.edu) and Dr. G. Geoff Wang, (Dept. of Forestry and Natural Resources, phone: 864.656.4864, email: gwang@clemson.edu) Clemson University, Clemson, SC 29634

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PROJECT OBJECTIVES:
Based on the detection-monitoring phase of the Forest Health and Monitoring program (FHM), the proposed study will address the following three questions: (1) how much does drought affect forest carbon balance over the period 1955-2095? (2) does the drought effect vary with climate?, and (3) which past and predicted climate variable (e.g. precipitation, CO_2, radiation, temperature, etc.) and plant resource (e.g., soil water availability) interactions most affect forest production, tree mortality and poor crown conditions?

JUSTIFICATION:
Results from current analyses of forest health indicators tracked through the FHM program indicated that weather was the most important cause of tree mortality in the Southeast US, more than insect, disease and animal effect combined. Among possible weather variables that affect forest health, drought or deviation from normal precipitation and its effects are of particular interest to the FHM program. The proposed project will assess and predict drought effects on forest health based on analyzing FHM plot data and process-based modeling. It will cover a large geographic area, the southeast US, where a severe drought occurred in 1998-2001 over an extensive forest area. Drought has been an important regulator of forest ecosystems. It can act directly on trees by reducing their growth and vigor or resulting in mortality. It can also act indirectly by predisposing trees to damage from other abiotic (e.g., fire) or biotic (e.g., insect) agents. In the Southeast US, it is predicted that drought will become more frequent and intense under several global change scenarios. Consequently, understanding how drought affects trees of different species and size classes on different sites and different stand conditions is essential to successfully mitigate its negative impact on the sustainability of forest ecosystems.

DESCRIPTION:
a. Background:
In recent history, extensive forest areas of the Southeast US have experienced several severe droughts (1954-1957, 1986-1989, and 1998-2001) as indicated by the Palmer Drought Severity Index (PDSI) (Palmer 1965). The droughts of the 1950's and 1980's significantly affected tree mortality and growth (Buell et al. 1961, Small 1961, Elliott and Swank 1994, Olano and Palmer 2003). Our analysis of the effect of the 1998-2001 drought, funded in a prior FHM project, indicates that growth significantly declined in this period. However, we plan to substantially expand that analysis to include the period 1955-2060, where several pre and post drought stress events have and are expected to occur. In addition, change in climate, especially successions of warmer-wetter winters and drier summers, will impact the hydrological cycle

(Houghton 2004). As described by Houghton (2004), higher temperatures will cause precipitation events to become more extreme and less frequent. Furthermore, the higher temperatures will lead to increases of forest transpiration, thus reducing the amount of moisture at the surface and adding to the drought conditions. This climate impact has raised concerns about drought frequency and/or intensity on forest ecosystems throughout the USA. Under most climate change scenarios, more frequent and/or intense drought is expected in the Southeast USA, where potential evapotranspiration is predicted to increase and already exceeds summer precipitation (J. Sadler, USDA Cropping Systems and Water Quality Research Leader, Pers. Comm.).

The past emphasis on timber management has simplified species composition of many forest stands across the Southeast US with reduced tree species diversity. The ability to understand how forests with different stand conditions respond to environmental stress is a pre-requisite for prescribing forest management options to enhance the sustainability of forest ecosystems. If increased water stress and dieback materialize in Southeastern forests, a release of carbon will occur. On the other hand, more carbon would likely be sequestered in managed forests because of the increasingly higher ambient CO_2 for photosynthesis (Gitay et al. 2001). By utilizing the extensive network of permanent sample plots established by the FHM program and the proposed additional data collection from the easily accessible Clemson Experimental Forest (17,640 acre Southeastern Representative Forest adjacent to Clemson University Campus), it is possible to parameterize and validate our process models to assess the effect of drought and stand condition on tree growth, mortality and other health indicators at a regional scale.

b. Methods:
First, we will quantify the key components of species-specific gross primary production (GPP) and carbon exchange response to climate change using a spatially explicit model (TREESTRESS). The model accounts for physiological response to environment and plant resources (e.g. precipitation, CO_2, soil water availability, temperature, etc.) on a individual tree basis (Bauerle et al. in preparation). We will parameterize and validate the model against increment cores taken from the Clemson University Experimental forest. Tree cores will be taken from species and site characteristics based on the FHM plot data in our possession (1991-2001). Tree cores will be measured and analyzed following the stand procedures of dendrochronology (Chhin and Wang, 2004). Second, we will apply our version of the advanced feedback model MAESTRA to estimate species-specific GPP and carbon exchange response to simulated climate change (Bauerle et al. 2002; 2004a). The MAESTRA model is a stand version of TREESTRESS that will carry forward the TREESTRESS increment core validation. Third, using Biome-BGC, a model developed by Steve Running and others for regional simulation of forest stand development through an entire life cycle (e.g. Running and Coughlan 1988), we will extrapolate simulated responses to provide scaled-up annual estimates of GPP to quantify differences in the amount of carbon flux at the sub-regional and southeastern regional scale. Lastly, we will address which past and predicted climate variables and plant resource interactions most affect forest production, tree mortality and poor crown conditions by applying our version of the MAESTRA model to identify regional impacts of environmental change. To improve the accuracy of the predictions, we have incorporated the latest temperature and water stress physiological functions into MAESTRA, which will be used in conjunction with site characteristics at the sub-regional and regional scale. Predictions will be made using a two-dimensional matrix that covers the range of soil and climate conditions. Modeling and scaling procedures are briefly described below.

Two primary modeling experiments will be performed: (1) A simulation of the annual GPP and carbon over 140 continuous years; and (2) a simulation of complete forest rotations during the four periods 1955-1990, 1990-2025, 2025-2060, and 2060-2095.

Experiment 1 Canopy fluxes over a fixed forest canopy will be modeled over entire annual cycles. Predictions under varying soil and atmospheric moisture availability (related drought effects) will be constrained on a species basis in the MAESTRA model (Bauerle et al. 2004b). Grid based predictions will be made using the model Biome-BGC and maps of annual GPP averaged at four periods centered in 1955-1990, 1990-2025, 2025-2060, and 2060-2095 will be produced. Changes in forcing variables (e.g. precipitation, CO_2, soil water availability, radiation, temperature, etc.) will be obtained to calculate the potential change in energy balance and its resultant change in carbon fluxes exchanged (Wang and Bauerle, 2005).

Experiment 2 The 1950-2100 climate scenarios will be split into four periods for analysis of the end of rotations 1990, 2025, 2060, and 2095 GPP. The experiment will investigate the variation in soil-water holding capacity (W, mm) from the Clemson University Experimental Forest and compare it to the FHM sites (Kern 1995). Scenarios for each Biome-BGC tree rotation will be based on standard silviculture scenarios widely applied in the geographic region of this study.

c. Products:
One Ph.D. will be granted (student already in progress). Several manuscripts will be submitted for publication in refereed journals, a summary of research findings will be published on the website, and a USDA Forest Service technical report will be generated.

d. Schedule of Activities:
The proposed project is for two years starting in January 2006 and ending December 2007. Each major activity and its starting date are listed below:

01/2006	Acquiring climatic data	05/2006	Compiling study dataset
08/2006	Generating model scenarios	12/2006	Analyzing data
06/2007	Writing Dissertation	10/2007	Writing manuscripts

e. Progress/Accomplishments:
To date, we have FHM data from 1991-2001 and are actively collaborating with Sonja Oswalt regarding prior data and soil samples. We have a Ph.D. student who has been working on the FHM data for over 1 year. The student is already versed in modeling and is prepared to incorporate the above project. Together, Drs. Bauerle and Wang have extensive experience in forest predictive and empirical modeling and dendroclimatic analysis. Taken together, they have developed and employ all of the necessary components to successfully complete the project.

COSTS:

	Item	**Requested FHM EM Funding**	**Other-Source Funding**	**Source**
YEAR 2006				
Administration	Salary	$33,923		
	Overhead	$14,969		
	Travel	$1,500		
Procurements	Supplies	$2,000		
Year 2007				
Administration	Salary	$29,507		
	Overhead	$13,203		

	Travel	$1,500
Procurements	Supplies	$2,000

Appendix

Budget Narrative:

Salary: 2 years of graduate assistantship funding for the Ph.D. student = 18,000 per year plus 2% fringe (2% Fringe = $360) = $18,360 per year. Summer salary is budgeted at 1 month of summer salary for project leaders in year 1 = $8,785 plus 22% fringe (22% Fringe = $1,933) = $10,718 and in year 2 = $9,137 plus 22% fringe (22% Fringe = $2,010) = $11,147. Hourly help for tree core sampling in year 1 = 475 hours*$10 dollars an hour plus 2% fringe (2% Fringe = $95) = $4,845. Salary for project leaders includes a 4% cost of living increase for year 2.

Overhead = 40% of total direct costs.

Travel = 1,500 per year for two years.

Supplies = 2,000 per year.

f. References

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