TITLE: Drought-related mortality and growth decline in aspen forests

LOCATION: Northern Minnesota and Colorado Front Range

DURATION: Year 1 of 2-year project **FUNDING SOURCE:** Base EM

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PROJECT OBJECTIVES: Our overall goal is to understand stand-level responses of aspen forests, including growth decline and mortality, to weather fluctuations, particularly drought, using a multi-scale approach that will examine differences in forest responses between regions as well as the importance of site conditions within each region. Specific questions to be addressed include:

- What weather conditions result in growth decline and predispose aspen stands to mortality?
- How severe or long must a drought be to cause mortality?
- Do wet years allow aspen stands to compensate for growth decline and mortality in drought years?
- Is mortality preceded by declining growth, and does mortality lag behind drought events?
- Under what abiotic (soil, aspect, long-term climate) and biotic (age structure) conditions are aspen forests most susceptible to drought?

JUSTIFICATION:

a. **Linkage to FHM Detection Monitoring –** Aspen mortality has been observed by the Forest Health Monitoring program in both Colorado[1] and Minnesota[2]. Drought has been proposed as a mechanism behind mortality in both regions, often as part of a suite of stressors that exacerbates the effects of pathogens or other drivers of aspen mortality. However, the overall impact of drought on aspen growth and mortality remains unclear because few studies have explicitly examined the stand-level responses of aspen to drought in terms of both mortality and growth declines/recovery.

b. **Significance in terms of the geographic scale** – The extent of aspen mortality stretches across multiple regions of the United States and Canada, and thus understanding the causes of aspen decline requires examining aspen forests in more than one geographic region. By examining how drought influences aspen forests in two distinct regions, this study will provide insight into the general susceptibility of aspen to weather extremes. Moreover, such a multi-scale approach – examining stand-level responses to drought across various site conditions within a region as well as across regions – will allow generalized predictions of aspen response to drought conditions which are expected to increase in as climate changes[3].

c. **Biological impact and/or political importance of the issue –** Aspen forests have substantial biological and economic importance in both regions examined in this study. In the central Rocky Mountains, aspen stands create structural and biological diversity and contribute significant value for tourism. In the northern Lake States, aspen forests are a major contributor to the forest products industry. Aspen mortality therefore has critical economic, ecological, and social implications, and aspen forests are closely scrutinized by the news media, forest managers and the general public.

d. **Scientific Basis/Feasibility** –This project will build upon previous aspen studies by the project leader and cooperator to save significant time and expense by utilizing existing, established plots in aspen forests in both Minnesota and Colorado. Leveraging these previous studies will allow us to carry out a

unique and important research approach across regions that will provide insight not attainable in other studies of aspen decline or mortality.

e. **Priority Issues addressed from Request for Proposals** – This study will address three of the priority issues: climate change, drought, and tree mortality. One of the primary predictions for climate change is that weather extremes will become more frequent[3], reinforcing the need to understanding how drought conditions influence forest growth and tree mortality.

DESCRIPTION:

a. Background: Previous studies on aspen decline throughout the southern Rocky Mountains and the Lake States have suggested a general loss of vigor in aspen stands related to a suite of various ecological factors [4-6]. Those studies suggest that many, but not all, aspen stands are experiencing a reduction in tree growth and vigor. Notably, many stands not previously observed to be "declining" have experienced rather sudden, extensive canopy tree mortality over the last decade that corresponds to a relatively dry period over the last two decades [5]. Although factors such as site-pathogen interactions have been speculated as a driver of aspen mortality [4], no studies have examined its relationship to drought. If drought causes aspen mortality, it likely reduces aspen vigor and growth, which means that drought may be adversely affecting many more aspen stands than previously realized and may increase the susceptibility of aspen to insect and disease infestations. However, few studies have directly examined the relationship between weather fluctuations and aspen growth and vigor. Understanding the relationship between drought and aspen mortality is especially important because future climatic conditions are expected to include greater frequency and severity of drought events[3].

Other ongoing studies of aspen mortality in the Rocky Mountains (Worrall et al., INT-EM-07-01 and Allen et al., INT-EM-08-01) are providing valuable insight into causal factors behind sudden aspen death, but these studies neither directly examine the effects of drought on aspen growth nor do they do so at multiple scales or across multiple regions. This proposed study will explicitly examine drought effects on aspen growth in both space (multiple conditions within each region and across multiple regions) and time (short- and long-term responses of aspen at the stand level). Rather than simply assessing the extent of current aspen mortality, understanding the long-term, species-related growth and mortality responses of aspen stands to drought will allow us to predict future aspen mortality in the Rocky Mountains as well as the Lake States. Such information is critical for proactive rather than reactive forest management.

b. Methods: We propose to use field measurements of long-term tree growth to characterize the relationship between weather fluctuations and aspen growth and mortality across a range of tree ages and site-quality conditions in Colorado and Minnesota. Building on previous studies, we will quantify annual, stand-level growth in aspen stands that represent the range of site conditions and tree ages. In Colorado, site condition is a function of elevation and aspect, and we will examine stands from prior work in the Arapahoe-Roosevelt National Forest that capture this variability in elevation and aspect[6]. In Minnesota, site condition is primarily a function of soil quality and we will examine aspen stands (already utilized in other studies) on low- and high-productivity soils on the Chippewa National Forest [7].

In each region (Southern Rockies and Lake States), we will examine approximately 30 stands, selected to encompass a range of tree ages. Within each stand, we will collect increment cores for all living and dead trees on 3 circular plots. Cores will be cross-dated and analyzed to quantify the annual ring widths for individual trees, which will be combined with allometric equations to estimate biomass and annual tree growth. We will integrate these individual tree growth measures with plot-level data from the entire stand to quantify stand-level growth for each year over the past ~40 years. In addition, cross-dated cores from dead trees will identify the year of mortality. Using nearby weather stations, we will compile a record of annual and seasonal weather fluctuations over the same time period. We will use linear and non-linear regression techniques to relate weather conditions to stand-level growth and mortality. 100% of this work will be completed on National Forest land (sites already established).

c. Products: We anticipate two peer-reviewed publications from this work, one focusing on how weather fluctuations impact tree growth and one focusing on the impact of growth declines for mortality and regional-scale implications. In addition, we will produce and publish a technical report, aimed at forest managers and policy makers, that presents the practical implications and management application of our results.

d. Schedule of Activities:

- Summer 2009: Relocate all plots and sample in Colorado.
- Fall-Winter 2009-10: Analyze data and draft results from Colorado.
- Summer 2010: Sample plots in Minnesota.
- Fall-Winter 2010-11: Data analyses and syntheses, and manuscript writing and submission.

e. Progress/Accomplishments: We have established plots and collected basic stand structure information in all stands. Increment cores have been collected for a subset of these stands, and need to be measured for ring increment. These data will be incorporated into this study to facilitate preliminary comparison of regional trends in aspen growth and mortality as it relates to drought.

COSTS: For each year, field sampling, core preparation/analysis, and statistical analysis will require salary/fringe for a full time research technician for 9 months ($29,651). One summer field technician will assist with field measurement (~ $6,390). Travel and vehicle expenses will cost ~ $6000. Contributed costs include one month of salary and fringe for each investigator, $2000 in travel expenses, equipment (tree ring laboratory at Wayne State University) and field supplies. USFS overhead is 8% on incoming funds ($3,363).

	Item	Requested FHM EM Funding	Other-Source Funding	Requested FHM EM Funding	Other-Source Funding	Source
Year		**2009**	**2009**	**2010**	**2010**	
Administration	Salary	$ 36,041	$ 17,829	$37,302	$18,453	USFS/WSU
	Overhead	$ 3,363	$ -	$3,481	$ -	
	Travel	$ 6,000	$ 2,000	$6,210	$2,070	USFS
Procurements	Contracting	$ -	$ -	$ -	$ -	
	Equipment	$ -	$ 3,350	$ -	$3,467	WSU
	Supplies	$ -	$ 450	$ -	$466	WSU
Total		$ 45,404	$ 23,579	$46,993	$24,404	

[1]Anonymous, 2004 *Forest Health Highlights - Colorado.*

[2]Anonymous, 2008 *Federal Conditions Report – 2007.* Minnesota Dept. of Natural Resources, Forest Health Unit.

[3]IPCC, 2007 *Summary for policymakers*, in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, et al., Editors., Cambridge University Press: Cambridge.

[4]Worrall, J.J., et al., 2008 *Rapid mortality of Populus tremuloides in southwestern Colorado, USA.* Forest Ecology and Management. **255**(3-4): p. 686-696.

[5]Bigler, C., et al., 2007 *Drought induces lagged tree mortality in a subalpine forest in the Rocky Mountains.* Oikos. **116**(12): p. 1983-1994.

[6]Kashian, D.M., W.H. Romme, and C.M. Regan, 2007 *Reconciling divergent interpretations of quaking aspen decline on the northern Colorado Front Range.* Ecological Applications. **17**(5): p. 1296-1311.

[7]Bradford, J.B. and D.J. Kastendick, In preparation *Age-related patterns of carbon storage and sequestration in Populus tremuloides on high and low productivity soils in Northern Minnesota.*