TITLE: Impact of climate change-induced drought and temperature stress on oak decline/mortality, fuel build-up and fire risk in the Ozarks: Developing a prospective oak decline/mortality and fuel model based on retrospective analyses of the USFS FIA/FHM plots and NOAA historical climate data in the Ozark Plateau

LOCATION: Ozark Highlands in Missouri and Arkansas (Ecological section 222A: Ozark highlands)

DURATION: 3 years **FUNDING SOURCE:** Fire EM

PROJECT LEADER:	**COOPERATOR:**
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PROJECT OBJECTIVES:

- Evaluate the impact of historical drought and temperature stress on oak decline/mortality and fuel accumulation and study how they interact with tree, stand (plot) and site factors to affect current decline/mortality condition and extent and fuel distribution by using the latest available data from the FIA state-wide inventories (Cycle 5 for Missouri, Cycle 8 for Arkansas, and annual inventory (1999-2008) for both states).
- Develop a prospective climate-driven hierarchical (ecological land type association [ELT]) oak decline and fuel accumulation model to predict and map future oak mortality/decline and fire hazard and severity based on FIA plots and forecasted climate/weather data.
- Quantify the effect of timber management (timber harvest and prescribed burn) on oak decline/mortality, forest fuel distribution and fire risk under changing climate patterns.

JUSTIFICATION: Some projections of precipitation scenarios under climate change postulate an increased incidence and severity of droughts in the Midwest. While annual levels of precipitation may remain similar to current weather, the expected fluctuations in rainfall, with a greater frequency of severe rain events, will likely result in lower overall soil moisture availability in the long run. The soil can absorb precipitation up to a

saturation point, after which rainfall is channeled to streams and rivers and unavailable to terrestrial vegetation. Effectively, the annual moisture available to plants decreases. Drought is one of the inciting factors for multiple-contributor forest health problems such as forest declines. Even before the recent concern about climate change, there was considerable apprehension about oak decline and subsequent rapid build-up of fuel and increasing risk of high-intensity fires in the Ozark Highlands of northern Arkansas and southeast Missouri (Guyette and McGinnes 1982, Moser and Melick 2002, Oak *et al.* 2004, Starkey *et al.* 2004, Spetich 2004, 2006; Guyette et al 2006, Moser *et al.* 2007). In the Ozark National Forest of Arkansas alone, at least 300,000 acres have been severely impacted (Starkey *et al.* 2004). Red oak group species (*Quercus* spp. L.; subgenus *Erythrobalanus*) appear to be particularly susceptible, especially those that are large or physiologically mature, in dense stands, and growing on droughty sites (Law and Gott 1987, Starkey and Oak 1989, Johnson *et al.* 2002, Starkey *et al.* 2004). Regionally, evidence suggesting oak decline's influence was present in crown indicator data collected in Missouri between 2000 and 2003 (Randolph and Moser 2008). These data found evidence of crown dieback in species known to be susceptible to oak decline. A number of related agents such as the red oak borer and Armillaria root disease are also involved in the decline and mortality complex (Voelker and Muzika 2004). The aging, oak-dominated forests of the Ozark Highland ecoregion (Ecological section 222A) (Keys *et al.* 1995) are highly predisposed to oak decline in the coming decades (Lawrence *et al.* 2002). Approximately 98 percent of all scarlet oak volume, 83 percent of all black oak volume, 54 percent of all northern red oak volume in Missouri and Arkansas occurs in this ecoregion. One predictable consequence caused by such a large scale oak decline and mortality will be an extraordinary building-up of fuels and an increasing risk of high-intensity fires in the Ozarks. Previous work on oak decline compared regional oak decline-related and regular mortality and survival, identified the tree and stand level risk factors of oak decline and mortality, and built CART models to predict tree mortality for decline-prone red oak group species (Woodall 2005a, 2005b; Fan *et al.* 2006, Shifley *et al.* 2006; Fan *et al.* 2008a, 2008b). Studies have found that oak decline is often incited by regional drought and other extreme climate events and can severely impact stands and trees that are predisposed to decline due to advanced age, higher stand density, and lower site quality. For future decline monitoring and mitigation and fuel management, a prospective oak decline/mortality and fuel model incorporating both climate/weather (e.g., drought) and site/stand predisposing factors will be critical to identify at-risk forest ecosystems.

DESCRIPTION:

a. Background: Previous work compared regional oak decline-related and regular mortality, identified the tree and stand level predisposing factors of oak decline and mortality, and built CART models to predict tree mortality for decline-prone red oak group species based on identified site and stand predisposing factors (Fan *et al.* 2006, Shifley *et al.* 2006, Fan *et al.* 2008a, 2008b). However, our recent analyses on FIA annual plots showed the relationship between tree decline/mortality and site/stand predisposing factors varied significantly along the temporal scale (1999-2006) and was closely related to the historical drought patterns in the Ozark Highlands (Fan *et al.* 2008c). Red oak group species mortality has been increasing since 1999. For instance, the cumulative mortality of blackjack oak reached over 25% by 2005. Even the minimum cumulative mortality among red oak group species (such as scarlet, black, and northern red oak) was over 13%, twice as high as the white oak group and other non-oak species (around 5%). Oak decline will persist and decline-related oak mortality will expand in extent and severity as more frequent droughts spread through the Ozarks in the future. It is expected that fuel will continually build up (Fan *et al.* 2007) and the high-intensity fires will dominate in the Ozarks as oak decline and mortality persist and droughts and extreme temperatures become more frequent. Currently, no prospective oak decline/mortality, fuel loading and fire risk models are available to monitor and forecast future oak decline and mortality events and identify hotspots for oak decline mitigation and fuel removal to reduce fire risk for upland oak-hickory forest types. Missouri Ozark Forest Ecosystem Project and the Nature Conservancy's prescribed burn project have scheduled simultaneous remeasurements in 2009. The timely arrival of these data, in couple of the IA/FHM data will allow us to build a prospective oak decline/mortality and fuel model to characterize the effect of climate change-induced drought and temperature stress, timber management scenarios (i.e., even-aged, uneven-aged, no harvest) and prescribed burning on fuel loading and fire risk.

b. Methods: Previously-identified decline and mortality risk groups based on site and stand predisposing factors (Fan *et al.* 2008a, 2008b, Shifley *et al.* 2006) will be used to develop the prospective models to predict oak decline and mortality by incorporating tree growth and long-term climate datasets (focusing on minimum and maximum temperature, periodic and cumulative precipitation, degree-days, and calculated Palmer drought severity index). Specifically, the relationship between oak decline/mortality and drought and temperature stress will be analyzed based on 1972-1998 periodical FIA data, 1999-2004 annual FIA/FHM data and historical drought and temperature data in the Ozarks through time series statistical analysis. Time series analysis will be conducted for each predisposing factor-based oak risk group by four climate divisions in the Ozark Highlands. We will use 2005-2009 FIA/FHM to validate the prospective oak decline and mortality model for undisturbed stands.

The oak decline/mortality model will be used to adjust the baseline fuel models to quantify fuel loading for different ecological land type (ELT) associations and ELT's. For oak decline/mortality and fuel accumulation patterns in stands burned by prescribed fires and intensively treated by even- and uneven-aged management (e.g., group or individual tree selection) we will use the 1992-2009 Missouri Ozark Forest Ecosystem Project (MOFEP) data and 1996-2009 The Nature Conservancy's (TNC) prescribed fire experiment data to validate and recalibrate the prospective oak decline/mortality and fuel models and compare the effect of prescribed burning and timber harvesting on oak decline, fuel accumulation and fire risk.

c. Products:

- A set of prospective models for oak species and risk groups
- A set of fuel accumulation models for different ELT associations and ELT's.
- A published analysis of historic trends in temperature and precipitation compared to Ozark forest health, along with a documented inter-relationship between severe precipitation events and soil moisture estimates.
- A list of risk maps of oak decline for different oak species based on forecasted climate condition and forest management scenarios.
- A list of fire hazard maps for the Ozark Highlands at different time points in the future.

d. Schedule of Activities:

Based on time from date of award receipt

Year 1 Climate data assembly and initial FIA/FHM data summary
Initial prospective model development for individual risk groups and species

Year 2 Model testing/validating across data sets (2005-2009 FIA/FHM data)
If MOFEP and Nature Conservancy data are available: We will apply our model to MOFEP and prescribed burn data
Final report revision and draft publication.

Year 3 Fuel model development and fuel loading and fire risk estimation and mapping
Application of fuel models to the MOFEP timber harvest data and TNC's prescribed burn data
Final report revision and draft publication.

e. Progress/Accomplishments: Not applicable, this is a new proposal

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COSTS:

	Item	**Requested Funding**	**Other-Source Funding**	**Source**
YEAR 2009				
Administration	Salary and Benefits (Fan, 2 mo.)	18,430	Contributed salary (Moser, Shifley, and Hansen) $20,000	NRS
	Travel	2,000		
Procurements	Supplies	1,200		
TOTAL YEAR 2009		**$21,630**	**(in-kind)**	**$20,000**
YEAR 2010				
Administration	Salary and Benefits (Fan, 2 mo.)	18,430	Contributed salary (Moser and Shifley) $13,000	NRS
	Travel	2,000		
Procurements	Supplies	750		
TOTAL YEAR 2010		**$21,180**	**(in-kind)**	**$13,000**
YEAR 2011				
Administration	Salary and Benefits (Fan, 3 mo.)	27,654	Contributed salary (Moser and Shifley) $13,000	NRS
	Travel	2,000		
Procurements	Supplies	500		
TOTAL YEAR 2011		**$30,154**	**(in-kind)**	**$13,000**
TOTAL PROJECT		**$72,964**	**(in-kind)**	**$46,000**