CHAPTER 17

Fire Effects

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In the time covered by this synthesis, researchers of five Evaluation Monitoring (EM) projects under the national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, explored approaches to better understand the role and effect of fire, specific targets for determining the ecological and economic effects of fire, and the relationship of fire to forest health conditions. Since fire is strongly related to forest health in ecological, social, cultural, and political ways, investigations of fire effects must also be multifaceted. Furthermore, quantifying the spatio-temporal association of fire and fire effects represents a constant work-in-progress. Changes in management activity, climate conditions, and stochastic patterns of disturbance in natural forests present challenges to the development of overarching predictive models. As fundamental and applied research efforts contribute results, models will improve and corresponding management decisions will rely on those advancements.

Project NE-F-01-07: An Interactive Web-Based Model for Estimating Fire-Related Characteristics Using FIA Data

The objective of this project was to develop a web-based model that allowed any user to produce estimates based on annualized data by the Forest Inventory and Analysis (FIA) Program of the Forest Service. The user could choose zone of interest, such as national forest or county, by accessing the tool through a web browser. The tool was intended to eventually apply to all areas of the United States with available annualized survey data. It was proposed that by the third year of the project, calculations were to include estimates of FHM phase 3 data, including both fine and coarse woody debris. Fine and coarse woody debris are of particular interest in studying fire behavior and understanding fire risk. These data were expected to be available for public use by the third year of the project. We used open-source software to produce two versions of the tool named the Carbon OnLine Estimator (COLE).

Version 1.0 was based on Java, and, among other features, the graphical interface allowed the user to designate points by clicking on the screen (which featured a map) using their mouse. The user could either develop a polygon or designate the center of a circle, and estimates for all the plots within this defined area was calculated. The tool worked for all States for which data were available. This was an easy-to-use tool, but many users, especially within the U.S. Forest Service, had difficulties using it because of the relative newness of Java applets and relative slowness of Java-based numerical calculations. Because of these issues, version 2.0 was based around the R programming language for statistics with less use of Java. Additionally, a "COLE Lite" non-Java version was developed for those users who had difficulty accessing a Java-based web tool. The version 2.0 and Lite tools produce summary tables of volumes, biomass, and carbon, including carbon in coarse woody debris. Because these survey measurements were still not publicly available, estimates of total carbon (mass) of coarse woody debris were developed for each FIA plot. A version of COLE is available at http://ncasi.uml.edu/COLE. In 2009 COLE remained one of the most reliable, easy-to-use tools available on the web to produce carbon estimates from FIA data.

Project WC-F-03-01: Port-Orford-Cedar Mapping within the Biscuit Fire Area

Port-Orford-Cedar (POC), (*Chamaecyparis lawsoniana*), has a limited distribution, native to the Pacific coast in southwestern Oregon and northern California, within the area of the Biscuit Fire (2002). Much of the area burned experienced severe intensity fire, but the survival of POC had not been documented, and the specific locations of surviving populations of POC were not known. Further, a virulent root pathogen, *Phytophthora lateralis*, causes mortality of POC and can be introduced on firefighting equipment via infested soil or water. This project estimated the pre-fire extent of POC at 89,880 acres, and the amount purportedly infested with *P. lateralis* at 3,022 acres. The post fire extent of POC was

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21,273 acres (23.7 percent of pre-fire acreage), and *P. laterialis* was thought to infest 829 acres. Fire severity caused a stand replacement event on 46,000 acres occupied by healthy POC.

Project WC-F-05-06: Port-Orford-Cedar Mapping within the Biscuit Fire Area–Part 2, Follow-Up

This project followed the initial efforts of POC mapping in the area of the Biscuit Fire. The landscape pattern of fire severity and POC survival relative to soil was examined. According to post-fire mapping, POC was strongly associated with riparian areas. The pathogen *P.laterialis* can be most problematic in such areas where water drainage and transport can infect otherwise healthy POC. Areas of serpentine soils burned with greater severity than non-serpentine areas. Correspondingly, approximately 34 percent of POC acreage on serpentine soils was populated by dead trees, compared with 13 percent of POC acreage on non-serpentine soils.

Project NC-F-04-02: Effects of Prescribed Burning on Indicators of Forest Health in Oak Savannas and Woodlands of Iowa: Implications for Ecological Monitoring and Restoration

Oak savannas and woodlands represent ecologically valuable transition communities between the Eastern Deciduous Forests and the Great Plains. Land use change and alteration of the disturbance regime has compromised these oak and grassland communities. Today, < 1 percent of the original extent of savanna vegetation remains (Nuzzo 1986, Gobster and others 2000). Restoration typically has focused on reducing an encroaching overstory and instituting prescribed burning. This project aimed to establish a protocol for assessing the value of FIA Detection Monitoring (DM) on restoration based management activity. Specifically, the objective of this study was to evaluate the use of DM indicator measurements to quantify and monitor changes in soil quality, productivity, and forest health as influenced by thinning and burning degraded oak savanna ecosystems in central Iowa. Indicator variables identical to those collected on FHM phase 3 plots (i.e., understory vegetation, soils, overstory structure and mensuration growth, down woody material, crowns, damage) were monitored on DM plots following DM measurement protocols. Detection Monitoring and forest health indicators are described in the Introduction chapter of this document.

Restoration of oak woodlands requires opening the mid-story canopy through thinning and reintroduction of fire (McCarty 1998). Thinning and prescribed burning are expected to reduce the presence of both shade-tolerant trees and exotic species and promote the establishment and maintenance of native savanna species in the understory. Long-term monitoring and evaluation are necessary to determine both the extent of these degraded woodlands and the effects of restoration practices on the structure, composition, and function of the targeted vegetation communities. However, little is known about the effectiveness of current indicator measurements to detect ecological responses to specific management practices and progress towards achieving short-term and long-term restoration goals. The investigation examined key ecological indicators of forest health and productivity (e.g., soil quality, growth rates, species composition, structure, water and nutrient cycling) to assess long-term ecosystem function, and to determine the extent of change by management. Variables range from the structural to the physiological for 6 years of regrowth following treatments. The project also aimed to determine the sensitivity of indicator variables to specific management practices in these ecosystems.

Project INT-F-06-04: Monitoring Tree Deterioration Following Stand-Destroying Wildfires

The project evaluated the process, rate, and causes of tree deterioration following stand-destroying wildfires in five tree species of the Rocky Mountain Region. The project evaluated losses of wood quality and economic value following fire-induced mortality associated with the exceptional fire year of 2002. Study areas were established in national forests in Wyoming, South Dakota, and Colorado. Species of interest were Engelmann spruce, subalpine fir, ponderosa pine, lodgepole pine, and Douglas-fir. The field methods included determining log weights for volume calculations, categorizing burn severity, taking samples for wood density determinations, and estimating wood boring beetle damage, amount of decay, and staining.

This 5-year effort provided an opportunity to study deterioration of wood quality and quantity over time. Emergence traps were placed in 2003 for quantification and identification of wood-boring insects. Sampling and isolation of decay-causing fungi important for each species took place in 2006 and 2007.

Decay as measured by decrease in block density from 2002 to 2004 varied among species and with fire. Greatest decrease in log weight was observed in ponderosa pine from the Bucktail Fire at the Uncompahgre National Forest. Log weight decreased the least in Douglas-fir from the Hayman Fire at the Pike National Forest. The decay fungus *Coniophora puteana* was the most frequently isolated fungus from the

wood samples. Area covered by visually detected sap rot was near zero in 2002 and 2003 but increased sharply in 2004 in Engelmann spruce, ponderosa pine, and Douglas-fir. Damage and evidence of wood boring beetles were apparent as early as 2002, and increased up to 4 years following fire.

Project NC-F-05-01: Effects of Prescribed Fire on Oak Pests and Invasive Plant Species

Fire in forests of the Missouri Ozarks has varied from long interval natural fire to prescribed frequent fires that were used as a management tool. Further confounding the role of fire as both a disturbance and as a tool are the years of oak decline, concomitant with or attributed to droughts, insects, and pathogens. Long-term mortality of oaks contributes to increasing fuel loads but an understanding of the etiology of oak decline generates questions about the potential use of prescribed fire (i.e., if prescribed fire had been used in the past, the predisposing factors of oak decline might have been avoided). This project addressed the biological impacts and political importance of fire and how the local landscape features influence fire characteristics. It also aimed to provide understanding of the related factors of hazardous fuel reduction and ecological restoration of the Ozark forest ecosystems.

Despite the use of prescribed fire to achieve various silvicultural goals, the practice of burning in upland Ozark forests raises many questions, (e.g., attaining objectives, indirect impacts, long-term effects and potential damage). This project examined the effects of prescribed burning at the individual species level and the stand/community level by examining fire scars, overstory tree vigor and damage, and ground flora vegetation in the Missouri Ozarks.

For determining the potential damage by prescribed fire, regression analysis revealed that stem bark char height, a proxy for fire intensity, is the most effective postfire predictor of percentage of trees scarred and extent of scarring. Landscape features such as aspect, fetch, and slope steepness were also important predictors of extent of scarring for some species.

Fire influenced structural components of the overstory vegetation primarily through differential tree scarring and losses of vigor. Insect activity, particularly red oak borer (*Enaphalodes rufulus*), was associated with stands that consisted of high density of suppressed trees. Understory vegetation was assessed in forests that had been subjected to prescribed burning. Grass cover was highest in burned stands, and tree seedling cover was highest in stands burned 1 year before sampling.

Summary of Key Findings

NE-F-01-07—The Carbon Online Estimator (COLE) was developed to allow any user to produce carbon and dead wood estimates based on FIA annualized data. It incorporates other ecological data to enhance accuracy. Reports can include statewide and county level summaries. With contributions of additional FIA phase 3 data, e.g., measured down woody debris, a more accurate examination of carbon stocks will be possible.

WC-F-05-06—It is possible to predict potential fire severity and damage to a species of concern (Port-Orford Cedar) based on soil type, i.e., serpentine versus non-serpentine. The project demonstrates the importance of integrated efforts by using GIS, fire date, pathology and botanical reconnaissance, to understand the range of fire effects while focusing on the fate of a species.

NC-F-04-02—Although thinning of oak woodlands modified the stand structure in woodland and savanna restoration, there was no positive effect on oak regeneration. Rather, non-desirable species encroached. Intervention management, e.g., eliminating encroaching species, would be possible but could only be verified by additionally monitoring the restoration status. A modified FIA sampling design was replicated across eight sites, but only then was it possible to document vegetation change. That level of replication was necessary for resolving differences in treatment. Direct effects of fires were not discernable using these methods.

NC-F-05-01—Fire intensity in the Ozark Highlands of Missouri can be inferred by examining bark char, and, therefore, the results can be used to related damage to specific levels of intensity. Post-fire examinations are facilitated through this approach, and bark char and damage can be suitable predictors of subsequent damage. Landscape characteristics also play an important role in extent of damage, presumably because of the influence of topography on fire behavior. Vegetation responses and influences of insect pests are strongly associated with type of fire and frequency of fire. Tree vigor in scarlet oak (*Quercus coccinea*) was negatively correlated with fire injury, but there was no difference in tree vigor in burned and unburned stands. Tree vigor of black oak (*Quercus velutina*) was higher in burned stands, although the difference may not be biologically significant.

INT-F-06-04—In Rocky Mountain tree species of commercial importance, density of wood boring beetles, although present at the time of wildfire, showed increasing trends up to 4 years following fire, when it reached a peak. Over a relatively short time following fire, i.e., under 5 years, up to 50 percent weight loss occurred in some tree species. The degree of deterioration, and consequently value loss, varied among the nine wildfires and with species.

Utilization of Project Results

The interactive Web-based tool developed through this project was successful. In 2006, COLE was named in the Federal Register as the official U.S. Web tool for forest carbon estimates for the 1605b Voluntary Reporting Program Update, an Executive Branch effort led by the Department of Energy. In terms of usage, in November 2008, there were 588 hits on COLE and 100 hits on the COLE User Manual. COLE continues to be updated and used for estimating fire-related forest characteristics and for quantifying carbon stocks. The full version 2.0 and Lite tools produce summary tables, reports, and maps of volumes, biomass, and carbon, including carbon in down dead wood. Summary products from the simulator contribute to economic or ecological modeling and assessment as well as management scenarios.

The mapping of Port-Orford-Cedar within the Biscuit Fire Area revealed the value of using immediate post-fire aerial photos to evaluate the area of unburned forest. This approach created an opportunity to explore soil-fire relationships as well as location of species of limited distribution, providing a fundamental ecological picture of the species and system. Predictions of fire effects on uncommon species and associated pathogens have been rarely explored, and a careful, well-timed effort might enhance predictions. Potentially this approach could be used for the pathogen—host examination alone, even in the absence of fire.

There is critical research to be done in validating indicator variables and determining the sensitivity and utility of such variables. In practice, when using a national monitoring approach, validation needs to be conducted across habitat and vegetation types. The attempts to determine the sensitivity of indicator variables used in FIA data collection, and to validate these indicators for specific management practices in Midwestern oak savanna/woodlands represent one such approach. The findings reveal that standard FIA methodology is useful only if study area is sufficiently large to accommodate subplots.

Fire effects research has described specific losses of economic value of trees when a stand has been managed with prescribed fire. The resulting model includes identifying the trees that are likely to scar and potentially decay, based on species and topographic position (Stevenson and others 2008). Models developed from this study can aid managers in assessing potential injury to trees based on landscape features and fire intensity. Results of this project provide management recommendations for stand improvement thinning and harvesting guidelines. Finally, it contributes to fire effects literature by describing the response of vegetation to varying fire intervals.

Variability of tree deterioration and marketability following wildfire is great, and, therefore, these factors must be assessed on a species level and regional basis. The project examining deterioration of five species in the Rocky Mountains provides an understanding of the economic effects of fire of varying intensities over a wide area. This information provides managers a generalized time frame through which salvage activity can be conducted and a species level opportunity to focus post-fire management practices.

Suggestions for Further Investigation

Suggestions for continued improvement of the COLE web tool include: an outside review of current Web sites that provide access to FHM data to ensure user satisfaction; improved coordination with major partners to focus on timely access to the data and quality resulting estimates; augmentation of the COLE site to use FIA plot-based measurements of down woody data to produce estimates more directly useful about fuels loading; and development of a companion site that allows users to submit their own inventory data with the new tool producing useful statistics on fuels loading and carbon.

Findings from the fire effects field-based research underscore the importance of examining relationships that are not well established, but might be critical for species persistence or for overall forest vigor, e.g., productivity and maintenance of species diversity. Continued research into forest health-related issues, such as the root pathogen associated with Port-Orford Cedar, can be revealing about new perspectives on fire effects. There remains a need for more investigation into fire severity associated mortality and damage relationships.

Continued refinement of FIA-style protocol and indicator variables for non-closed canopy forest ecosystems should occur. Detailed analysis of soil carbon effects from restoration management could be included in these investigations. There is a need to specifically identify the effects of fires and the utility of the FIA style approach for plot design as well as the relevance of specific variables. The project represents only the first step in a long process of understanding the use of FIA or other monitoring data in various ecosystems and under varying practices or natural disturbances.

With increasing importance of prescribed fires, fuel reduction and long-term vigor of overstory trees, there is a need to develop site specific management guidelines, restoration approaches and continual assessment of economic and ecological effects of fire as a management tool. The value of empirical field data cannot be understated, when such data are central to the eventual development of robust models. Related research has yielded a theoretical rotation age

assessment based on insect activity that can strongly apply to much of the Ozark forest (Guyette and others 2007). If combined with fire effects on tree vigor, highly specific management recommendations could be made. Such models are necessary when evaluating fuel accumulation, establishing fuel management guidelines, and conducting fuel reduction practices. Long-term data are necessary for evaluation and demonstration purposes, and to understand larger scale consequences on forest productivity and ecological processes (Voelker and others 2006).

With regard to quality losses of timber caused by wood decay and general deterioration following fire, there are many opportunities to focus specific research efforts. Fungal isolation to determine the identity and colonization sequence of decay fungi would be highly valuable and provide bio-specific targets that can influence timing of salvage activity or can influence whether salvage should be considered. Similarly, continued examination of beetle species (the entire guild) and assessing which species account for population increases in the wood boring beetle community following fire should be conducted. Quantifying the value of resources and economic loss from all these factors would complete an integrated project on post-fire biodegradation and economic loss. Furthermore, a more broadly developed approach to determine species and regional differences with regard to fire effects on wood quality remains critical. There is ample economic and ecological justification for studying which agents of deterioration are active after fire and the duration of their activity. Variation within and among regions is great and this variation might challenge refinement of scientific investigation; however, generalized findings that contribute to improved understanding and management are likely to result from further study.

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