BOGGS MOUNTAIN DEMONSTRATION STATE FOREST POST-FIRE RESEARCH AND EFFECTIVENESS MONITORING

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Background and Purpose

High-severity fires generally remove all of the organic forest floor layers leaving the soils susceptible to runoff and erosion. Wildfires, especially areas burned at high severity, can greatly increase the risk to downstream water quality (Smith et al., 2011), and the spatial extent of high severity fires has been increasing due to increased fuel loading and climate change (Miller et al., 2009). The risk of elevated sediment yields generally are greatest in the first few years after the fire until vegetation recovers.

Forest managers are increasingly faced with the task of recovering the value of burned timber while providing for water quality protection. Very little information is available regarding the effectiveness of post-fire management in meeting resource protection objectives. Recent studies in other areas in the western U.S. have indicated that post-fire forest management may increase local surface runoff and erosion rates because of soil compaction, surface disturbance, and delay of vegetative recovery related to heavy equipment traffic (Slesak et al., 2015; Wagenbrenner et al., 2015). By assessing water quality responses to post-fire management treatments, we can provide managers with tools to help mitigate potential water quality impacts. This project will quantify the responses of runoff and sediment delivery to wildfire and post-fire logging and reforestation activities, as well as evaluate and demonstrate the effectiveness of different BMPs for post-fire logging.

The primary purpose of this project is to quantify the effects of post-fire salvage logging and common post-salvage site preparation techniques including mechanical and herbicide-assisted reforestation on soil properties controlling runoff, hillslope erosion rates, and vegetative recovery ***(Task 1)***. Responses in burned and logged sites will be compared to burned, unlogged control sites to determine the best strategies to minimize the effects of post-fire salvage logging and post-salvage assisted reforestation techniques on runoff and erosion. Since herbicides may impede post-fire vegetative recovery, a non-herbicide treatment and two different herbicide treatments will be evaluated to determine whether the variations in herbicide use will produce different water quality impacts.

A secondary purpose is to understand processes occurring at small-catchment scales so that small-plot results can be extrapolated to sizes of specific interest to land managers and watershed stakeholders ***(Task 2)***. When combined with the results of different treatments on runoff, hillslope erosion rates, and vegetative recovery, the small catchment, process-focused results can be used to assess the impacts of post-fire management at the watershed scale and thereby help predict and minimize post-fire and post-salvage water quality degradation. We will use the data collected to validate a commonly-used erosion prediction model and assess and develop guidelines for the sizing of watercourse crossings in burned areas.

The third purpose of the project is to develop and demonstrate alternative BMPs used to reduce runoff and erosion from post-fire salvage logging ***(Task 3)***. We plan to focus on controlling runoff from skid trails, as this has the greatest potential impact on erosion rates and sediment delivery to streams (Wagenbrenner et al., 2015). After a short test period, we will install the alternative BMP(s) in a salvage-logged unit as a longer term assessment and demonstration project.

In September 2015, the Boggs Mountain Demonstration State Forest (BMDSF) was burned during the Valley Fire. BMDSF is managed by CALFIRE and offers an unparalleled opportunity to explore the effects of wildfire and post-fire forest management on water quality. We will rely on established techniques for quantifying the runoff and erosion responses to post-fire forest management. This work on the BMDSF provides a unique opportunity to supplement the few studies of salvage logging, which have been conducted on National Forest or private land, and will therefore provide some much-needed information on the effects of post-fire salvage on land outside of National Forest jurisdiction. Results from this project have broad applicability across State Responsibility Areas. Site selection began in October 2015 and the proposed work will expand the scope of work to include a rigorous assessment of the impacts of post-fire salvage logging on runoff, erosion, and surface cover (***Task 1***), more detailed analysis of processes in the existing sites (***Task 2***), and development and demonstration of alternative BMPs for post-fire salvage operations (***Task 3***).

Linkage to the EMC Strategic Plan's Critical Questions and Priorities

The three study tasks are linked to Theme 2 (Watercourse Channel Sediment) and Theme 6 (Wildfire Hazard) of the Effectivness Monitoring Committee Strategic Plan (2015). Specifically, they relate to the following critical questions:

1. ***Are the FPRs and associated regulations effective in minimizing management-related sediment delivery from forest management activities to watercourse channels at the watershed and sub-watershed level in managed watersheds (Section 2.3; Theme 2; pg 16)?***
2. ***Are the FPRs effective in protecting water quality with respect to herbicide application and post-treatment ground cover (Appendix D; Theme 6; pg 63-64)?***

The EMC Strategic Plan also identifies infrequent disturbance events (e.g., wildfire) as priority for testing rule effectiveness (Section 4.2.3). As such, we seek to test rule effectiveness in the context of post-fire forest management.

Tentative Scope of Work

Task 1: Post-Fire Forest Management Study

a) **Objective –** To quantify the effects of post-fire logging and site preparation on runoff, erosion, soil carbon, and vegetation.
b) **Methods -** We will place hillslope-scale plots (~800 ft^2) in pre-identified areas of high burn severity that will be used to quantify the effects of different post-fire management practices on runoff rates, sediment delivery, organic matter transport, and soil properties. Sediment production will be measured using sediment fences. We will measure controlling factors on hillslope-scale processes including infiltration rates, soil bulk density, soil disturbance, surface cover, soil water repellency, and precipitation. Sediment samples will be sent to a certified lab for moisture content, organic content, and particle size analysis as per ASTM protocols. Treatments will be assessed using five replicated blocks, and each of the five treatments will be represented by one plot in each block. Treatments will consist of standard salvage logging, subsoiling, and a combination of pre-emergent or foliar herbicide application. One plot per

treatment will also collect high resolution runoff data using an e-tape stage monitoring instrument and a v-notch weir.

c) **Timeline –** Five control plots were constructed in October/November of 2015, and have been collecting data. Plots locations have been pre-identified for the treated sites and will be logged in the summer of 2016. Sediment fences will be constructed in the summer of 2016. We intend to monitor these sites a minimum of 3 years following treatment.

2) **Task 2 - Catchment Study**

a) **Objective -** To quantify the effects of different soil burn severities on catchment scale runoff rates, sediment delivery, changes in channel and rill networks, and organic matter/soil carbon transport

b) **Methods –** Six sediment fences and v-notch weirs were constructed in zero-order catchments ranging in size from 0.4 to 1.6 acres, and across a range of soil burn severities (i.e., 2 catchments each on low, moderate, and high soil burn severity). We are measuring rainfall magnitude and intensity (tipping bucket), sediment yield, runoff rates (1-minute frequency), surface cover, canopy cover, soil properties (e.g., water repellency), rill mapping and characterization. Sediment samples will be sent to a certified lab for moisture content, organic content, and particle size analysis as per ASTM protocols. Data from this study will be used to validate the GeoWEPP model.

c) **Timeline –** Sites have been collecting data since October 2015 (see Figure 1), and preliminary results have already been presented at the Geological Society of America Cordilleran Section Meeting in Ontario, CA. We plan on monitoring these sites a minimum of 3 years.

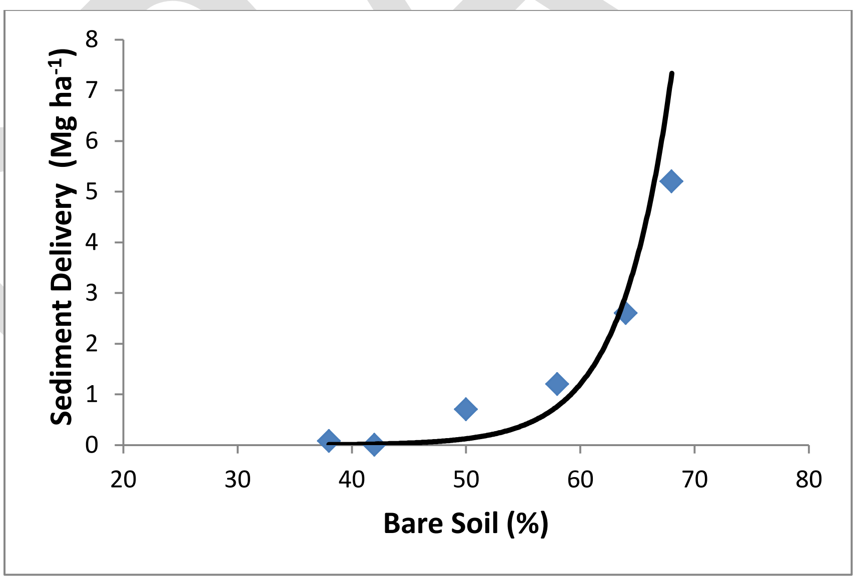

Figure 1. Sediment delivery from the six monitored BMDSF catchments as a function of initial bare soil (%). Data are current to March 4, 2016. We estimate the maximum delivery rate has increased by 150% due to the March 2016 storm events.

3) **Task 3 - Post-Fire Demonstration Study**

a) **Objective -** To develop and demonstrate alternative BMPs for post-fire salvage operations.

b) **Methods** - We will assess current BMPs as installed at BMDSF by salvage logging contractors to develop alternative designs. We anticipate modifying BMPs intended to control runoff from skid trails and reduce sediment delivery to streams. Possible modifications may include: more frequent drainage structures; armoring or slashing outlets to protect soil from incision; and increasing infiltration capacity in skid trails. We will establish a test site where alternative BMPs are installed and monitored over about a 6 month period to determine their effectiveness at reducing rill density and the proportion of rills connected to stream channels.

c) **Implementation –** This task will be implemented in the Summer/Fall of 2016.

<u>Specific Tasks</u>

Rainfall will be measured using tipping bucket rain gages near each block and catchment (nine gages, two installed fall 2015).

Runoff and sediment production rates will be measured using silt fences in all plots and catchments (Robichaud and Brown, 2002), with V-notch weirs in one fence per treatment and in all of the catchment fences. Pressure tapes (Milone Technologies, Sewell, NJ) will record water level every minute. Water depth will be converted to volumetric flow rates using standard weir equations. The sediment stored in the silt fences will be weighed in the field and sub-sampled for laboratory soil moisture analysis (loss on drying) to determine dry sediment production rates (Robichaud and Brown, 2002). Silt fences will be emptied and sampled on a storm-by-storm basis as much as feasible.

Organic matter and carbon analyses will improve understanding of long-term site productivity and carbon storage. The organic matter content in all sediment samples will be determined using the loss on ignition method at 400 °C. The total carbon content in approximately 10% of the sediment samples will be determined using a Shimadzu TOC-V analyzer (Shimadzu Corporation, Tokyo, Japan). The relationship between total carbon and organic matter content will be determined for the subset of sediment samples and used to estimate the carbon export for the remaining sediment samples. All laboratory analysis will be done at MTU.

Cover will be measured at the start of the project and repeated after the first growing season and then annually. Surface cover will be measured with point-intercept methods (Chambers and Brown, 1983) using three 1-m quadrats in each plot and along three transverse transects in each catchment. Cover categories will include mineral soil, litter, woody debris (>0.5 inch diameter), gravel (>0.2 inch), rock (>2 inches), and live vegetation. Understory canopy cover and species will be identified and the frequency and extent of each species will be recorded using estimates of canopy cover (Daubenmire, 1959) at annual intervals during the growing season. Canopy cover will be measured using upward-looking hemispherical photos in each plot and along each transect (Rich, 1990).

Soil characteristics will be measured in each transect of each catchment and in paired undisturbed and disturbed locations in each plot. All measurements will be done at the beginning of the project and repeated each year to assess changes over time. Surface soil samples will be analyzed for soil texture using sieve and hydrometer methods (American Society of Testing and Materials, 2007). Texture samples will also be analyzed for carbon content as described above. Bulk density will be measured by core sampler, or where feasible, the sand cone method (Page-Dumroese et al., 1999). Soil strength will be measured at each location using a cone penetrometer. Soil water repellency will be measured under dry soil conditions at depths of 1 and 3 cm using the water drop penetration time (WDPT) test (DeBano, 1981). Field-saturated hydraulic conductivity will be measured using a dual-head infiltrometer (Decagon Devices, Pullman, WA).

The disturbed area in each plot and catchment will be mapped using a high-precision (~ 1 m) gps. Disturbance classes will include: undisturbed, skid trails, recreation trails, roads, and ripped.

Photo points will be established in each plot and catchment. Photographs with the same field of view will be repeated every 6 months through the duration of the study. Remote cameras (game cameras) will be installed near the silt fence in all of the runoff-monitoring plots and catchments. Remote cameras will be programmed to take photos every hour or for several minutes following rainfall. The photo points will assist in documenting site changes over time, while the remote cameras will help identify runoff processes and the amount of area contributing to runoff and sediment delivery.

Rill networks and connectivity to stream channels will be surveyed at the start of the project and annually thereafter to determine changes in rill density and volume. Surveys will be conducted on hillslopes with similar treatments as the plots to allow for rill network development. Surveys will also be conducted in each catchment. Longitudinal surveys will be conducted in the stream channels in each catchment to determine geomorphological changes over time resulting from the fire.

Collaborators

Dr. Joe Wagenbrenner (Michigan Technological University) has designed the study. Dr. Mary Ellen Miller (Michigan Technological University) will be conducting model validation work. CAL FIRE, California Geological Survey, and the Central Valley Regional Water Quality Control Board are providing in-kind staff logistical support.

Funding

Funding is being pursued through the State Water Resources Board's 319(h) non-point source funding program. Study proponents do not request direct monetary assistance from the EMC. Rather, we seek support for this project to provide a rationale for in-kind staff support. A final scope of work will be formalized during the contract negotiation phase when/if the grant is awarded.

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