Research design for hydrologic response to watershed treatments in the mixed conifer zone of California’s Sierra Nevada

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Background

Water quantity response to forest management is of concern in California’s Sierra Nevada, owing to shifts in the rain-snow transition elevation associated with climate change, increasing value of hydropower from high-elevation dams, and the re-examination of adaptive management strategies for wildfire mitigation.

In 2006 we initiated a multi-disciplinary research program to inform adaptive management for USDA Forest Service lands in the Sierra Nevada. Management actions involve forest thinning based on disconnected, overlapping fuel treatment patches to reduce the rate of spread and lower the intensity of fire. As little as 30% of the area in a given catchment will be treated.

Study Design

The study is designed to collect data using a BACI approach (Before and After Treatment data collection in Control and Impact sites). It is designed to last seven years and includes:

- 2 years of pre-project data collection
- 2 years of implementation and data collection
- 1 year of ecosystem recovery and data collection
- 2 years of post-project data collection

Unlike traditional paired watershed studies where statistical comparisons or traditional hypothesis testing is employed, we will measure the support in the data for our a priori expectations using mechanistic models.

Adaptive Management Framework

This hydrologic study is part of a joint research effort designed to measure physical and natural processes at the relevant management scale, in this case the firesheds (10,000-20,000 ha). Research teams have been formed to study the ecosystem and management parameters of fire, forest health, water quantity and quality, wildlife (focusing on two key indicator species – Pacific Fisher and California Spotted Owl), and public participation of stakeholders in the management decision making process.

Hydrologic Modeling & Scaling

Hydrologic modeling will use the Distributed Hydrology Soil Vegetation Model, which was chosen because it is fully distributed and physically based. It will also be used to simulate sediment yield.

In addition to the treatment and control catchments at Last Chance and Sugar Pine, data from other watershed studies in the Sierra Nevada will be used for estimation of model parameters, sensitivity analysis, and scaling to other, unmeasured catchments.

Snowpack estimates will be scaled across the larger areas of interest using satellite-derived snow water equivalent and snow covered area. The study catchments are in the rain-snow transition zone, and estimation of error across the larger study area remains a challenge.

Soil moisture estimation across the landscape will follow that for snow water equivalent, based on topographic and vegetation properties derived from LIDAR and high-resolution satellite data.

In order to extend the results to additional management actions, elevations and landscapes in central and southern Sierra Nevada forests, we have identified the need for additional and member catchments and instrument clusters to support modeling and prediction.

Public Participation

Participation of stakeholders is critical to the success of any adaptive management effort. In order to extend the results to additional management actions, elevations and landscapes in central and southern Sierra Nevada forests, we have identified the need for additional and member catchments and instrument clusters to support modeling and prediction.

Change Detection

We hypothesize that as Leaf Area Index (LAI) decreases with the thinning treatments prescribed by Forest Service SPARTS, snow accumulation on the ground will increase, while evapotranspiration (ET) and snow retention in late spring will decrease. A change in snow accumulation may be seen in the stream hydrograph as a change in the magnitude of the peak flow during peak snow melt. Changes in snow retention, may translate to a change in timing of the recession limb of the hydrograph and the soil moisture curves. Note that soil moisture is a key response variable linking the hydrologic and forest health modeling. Changes in ET may effect both the timing (how quickly base flow is reached or soil dries out) and the magnitude of late season base flow in the streams.

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Infrastructure

Water balance instrument clusters include wind (speed and direction), solar radiation (incoming and net), temperature, relative humidity, precipitation and spatially distributed soil moisture and snowpack. Two clusters were established per site, stratified by elevation, but extending over both north and south aspects.

LIDAR and high-resolution satellite data.

We are using the distribution of annual survival probabilities of trees (called vulnerability profiles) to detect changes in forest health. These profiles are developed from analyses of long-term records of tree growth obtained with tree cores.

The BACI design provides the means to detect shifts in vulnerability profiles (see diagram at left) due to the management treatments.

For example, the summer drought in the Sierra Nevada poses a severe stress on trees. Thus any lengthening of the drought length due to changes in snow pack retention or soil moisture availability can lower the survival probability of vulnerable trees.