Quick Response Small Catchment Monitoring Techniques For Comparing Postfire Rehabilitation Treatment Effectiveness

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Abstract

Increased runoff and erosion commonly occur after wildfires with the onset of precipitation events. Various erosion mitigation treatments are often used after wildfires to reduce flooding and sedimentation. The effectiveness of these treatments has not been well documented in the literature; therefore we undertook a rapid response approach (within four weeks following fire suppression) to install small catchment monitoring systems to compare treatment effectiveness. A paired watershed approach uses two adjacent and similar catchments (5-20 ac) after wildfires, treating one catchment and using the other catchment as a control. We developed a rapid response monitoring system that can be installed in a few weeks to monitor sediment yield and runoff response. These systems are usually left in place for three to five years.

Each installation has a complete weather station and electronic measuring devices to record streamflow and sediment accumulation in a storage basin. The sediment basins are cleaned out manually after each storm event in order to relate the event (intensity, amount and duration) to runoff and sediment yield. The data is automatically transmitted each day via cell phone or radio transmission to our computer server, thus making the data available daily on our web page. We have installed six paired catchments to date in Colorado, Washington, two in California, and two in Montana. Preliminary results suggest that 1) first year storm events produce the largest runoff and sediment response and 2) treatment effectiveness is less with high intensity short duration storm events. This rapid response protocol allows for quick installation of a monitoring system to provide an assessment of treatment effectiveness.

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Introduction

Soil erosion after wildfires in forest and range environments is often a land management issue due to effects of sediment on water quality and downstream values at risk. Rainfall-induced soil erosion commonly occurs after wildfires. Various methods have been used to estimate sediment yields after wildfire; however, few studies have actually measured postfire erosion (Robichaud et al. 2000). Additionally, postfire mitigation treatments used to reduce runoff and erosion have not been rigorously evaluated to determine if they are meeting treatment objectives (Robichaud et al. 2000, GAO 2003).

Therefore, monitoring postfire treatment effectiveness has been a research focus in recent years. Small catchments (4-20 ac) have been identified as an appropriate size to be able to evaluate the effectiveness of these treatments. These catchments are large enough to generate sufficient runoff and sediment, yet easily measurable. At the same time they are not large enough to include hydrological process such as channel storage and redistribution, which would mask treatment effectiveness.

This paper describes how to install a rapid response measuring system with a paired watershed approach. Study design, installation procedures, equipment and monitoring methods are discussed.

Methods

The study sites, identified during the postfire assessment, usually have high runoff/erosion potential and are reasonably accessible with pickup trucks or ATVs. Generally, treatments are installed before the first storm event following the fire. Also the sites are protected from other disturbances, such as salvage logging or grazing, for the duration of the monitoring period (3 to 5 years).

Paired watershed approach is used to compare a postfire treated to a non-treated control catchment (MacDonald et al. 1991). Site selection is usually made after the fire is controlled by reviewing topography maps, burn severity maps, discussions with local officials, and aerial reconnaissance. Ideally the catchments will have similar topographic features, size, soils, pre-treatment vegetation characteristics, burn severity and are located adjacent to each other. Treatments have included contour-felled logs or log erosion barriers (LEBs), straw wattles, raking, or mulching. By locating the catchments adjacent to each other, isolated thunderstorms will affect both catchments with similar rainfall characteristics.

Each catchment, treated or untreated, contains a sediment basin/storage area and flume/weir. The measurement apparatus for sediment and runoff is robust enough to handle big events (the design storm plus extra capacity), yet sensitive enough to reliably detect small events. Because it is critical to know when storm events occur relative to water and sediment movement, measurement equipment operates continuously.

Sediment Traps

A sheet metal cut-off wall is used to divert all runoff and sediment into a sediment trap area. Sheet metal (4 by 12 ft-16 gauge) is used and buried 8-10 in. beneath the ground surface in the base of the channel and extending up the side slopes (Figure 1). The center sheet (4 by 6 ft) has two wing walls bent at 45 degrees, 1 ft in on each side. Additional metal sheets are added to the top with similar bends to provide for additional storage. Straight sheets are used for each side. The sides extend 5 to 25 ft from the 45-degree bend to define the storage basin.

Wooden posts (4 by 6 in and 4 by 4 in) are used to support the sheet metal. The sheet metal is attached to the wood posts (Figure 2). Lateral supports (4 in by 4 in wooden posts or 2-3/8 in diameter round metal pipe-chain link fence posts) and dead man anchors are used to stabilize the cut-off wall. After the sheet metal and post are in place, concrete is used as a footing along the bottom edge and around each post. Generally about 2 yd^3 of concrete is used per installation. Additionally, silicon caulk is used for all sheet metal overlaps and joints to make the sediment basin watertight.

Figure 1. Sheet metal cut-off wall installation.

Figure 2. Sidewalls of sediment trap.

A 90-degree V-notch (15 in deep) weir is located from the top center of the cutoff wall as a weir for measuring runoff (Figure 3). A trash/debris screen (chain link fencing) is located about 3 ft upstream of the V-notch. A splash apron is located just downstream of the notch, made with concrete, rocks, logs or half- round 12 in diameter culvert pipe.

Figure 3. V-notch weir and trash/debris screen.

Instrumentation

A complete weather station (Campbell Scientific Inc., Logan, UT) is used to measure wind speed, wind direction, solar radiation, humidity, peiziometer measures ground water level, flume/weir level, rainfall intensity (tipping bucket rain gauge), soil moisture and sediment/snow depth in sediment basin.

Depth of runoff flow is measured with a magnetic float along a stainless steel rod (magnetic linear actuator) placed inside a 4 in diameter slotted PVC pipe mounted along the cutoff wall. An ultrasonic sensor is mounted above the floor of the sediment basin to measure the height of the water and sediment in the sediment trap (Figure 3). During winter months, the ultrasonic sensor provides the depth of snow.

All instrumentation is connected to a CR10 data logger (Campbell Scientific Inc., Logan UT) that can store the data, as well as transmit the data via cell phone or radio transmission. The data are downloaded daily from the data logger and uploaded to our web server (http:forest.moscowfsl.wsu.edu/engr/weather). All electronics are powered by 12-volt battery that is charged daily by 32-Watt solar panel with a voltage regulator.

Other Measurements

Soil descriptions including physical characteristics of soil horizons, texture, structure, bulk density, and conductivity are determined using standard methods to ensure that the control is similar to the treated catchment. Soil wetability is measured at stratified and randomly selected locations after the fire to characterize the extent and degree of water repellent soils.

Eight to ten channel cross-sectional measurements for assessing sediment loss due to channel scour are completed at the beginning of the study, should the primary measurement systems fail or become overwhelmed. Channel cross-sections are measured at 100 ft intervals or at major slope change above the sediment trap.

Annual measurements of ground cover (e.g., plants, litter, mineral soil, rock) are made following Chambers and Brown (1983).

Since treatments may vary, monitoring/evaluating treatments also vary. For example, contour felled logs are surveyed for size, number, orientation, position and degree of functionality. After each runoff event, the contour-felled logs are evaluated to determine the accumulation of sediment, failure rate and mechanisms. Mulch treatments are monitored/evaluated by ground cover measurements and vegetation response.

Sediment Basin Cleanout Methods

Periodic clean out of the sediment traps is required to obtain reliable measurements of sediment. Cleaning the sediment traps following every storm improves the prediction accuracy of the storms that produce the sediment. Sufficient time is allowed for most sediment to settle before water is drained.

Hand labor is generally used to collect and weigh the small amounts of sediment (under 2000 lbs) (Figure 4). Large amounts of sediment require small equipment (mini-excavator, Bobcat or wheel backhoe) to clean sediment traps. When equipment is used, volumes are first estimated and bulk densities determined, this allows for converting volumes to mass calculations.

Figure 4. Buckets are used for sediment clean out.

The direct measurement of the total weight of the sediment is the most accurate technique for estimating sediment amounts (Robichaud and Brown 2002). The sediment is weighed and recorded in the field using a plastic bucket (5 gal). Place the sediment into the container and weigh in the field with a hanging or platform parcel scale (scale with 0.5 or 1 lb) increments with a maximum capacity of 80-100 lb. Weigh each bucket and place a representative subsample (0.1 lb) into a soil tin or recloseable plastic bag for water content determination in the laboratory. The remaining material can be discarded downhill of the sediment trap.

Data Processing and Analysis

Telemeter data are reviewed and summarized after downloading. Periodic field collected data are reviewed and summarized. Comparisons are made between the treated and untreated catchments on a storm-by-storm and cumulative basis.

Runoff, expressed as area-depth, rate, or volume flow, is calculated for each storm event. Sediment delivery results can be normalized based on catchment's size (weight/area) to compare treated verse control catchments or based on rainfall intensity and amounts. Additionally, various methods are used to compare treatment efficiency.

Results

We have installed six paired catchments after wildfires in Colorado, Montana, Washington, and California. The first sites were installed in 1998 and additional installations have occurred each successive year. Preliminary results suggest that the postfire emergency rehabilitation treatments are effective with low intensity, long duration rainfall events and less effective with high intensity, short duration rainfall events (Table1). The North 25 and West Pine sites had short duration, high intensity rain events occur during the first year after the wildfire, thus annual sediment yields were similar between the treated and untreated catchments.

Table 1. Annual sediment yields from selected research sites.

Site	Year	Untreated (T/ac)	Treated (T/ac)
North 25-WA	1999	0.3	0.5
	2000	No change	No change
	2001	No change	No change
Mixing-CA	2000	0.01	0.2
	2001	0.8	0.04
	2002	0.8	0.06
Bitterroot-MT	2001	0.2	0.07
	2002	0.4	0.2
West Pine-MT	2002	4.5	4.6

Summary

A rapid response catchment installation procedure has been developed and utilized at six locations in the Western States to compare postfire rehabilitation treatment effectiveness. The quick response system can be installed in a few weeks and provides accurate data to be able to make comparison between treated and untreated catchments. These installations can be removed when the studies are complete usually 3 to 5 years after installation. Preliminary analysis suggests that these methods provide reliable results to be able to compare treatment effectiveness. Additionally, these data are at an appropriate scale to valid our erosion prediction models.

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