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Effects of post-fire salvage logging and a skid trail treatment on ground cover, soils, and sediment production in the interior western United States

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ABSTRACT

Post-fire salvage logging adds another set of environmental effects to recently burned areas, and previous studies have reported varying impacts on vegetation, soil disturbance, and sediment production with limited data on the underlying processes. Our objectives were to determine how: (1) ground-based post-fire logging affects surface cover, soil water repellency, soil compaction, and vegetative regrowth; (2) different types of logging disturbance affect sediment production at the plot and small catchment ("swale") scales; and (3) applying logging slash to skid trails affects soil properties, vegetative regrowth, and sediment production. Four study areas were established in severely burned forests in the interior western USA. We installed plots at two study areas to compare burned but unlogged controls against skid trails, feller-buncher trails, and skid trails with added slash. Salvage logged and control swales were established at each study area, but only one study area had simultaneous measurements on replicated swales. Data were collected for 0-2 years prior to logging and from 2-8 years after logging.

The skidder and feller-buncher plots generally had greater compaction, less soil water repellency, and slower vegetative regrowth than the controls. Sediment production from the skidder plots was 10–100 times the value from the controls. The slightly less compacted feller-buncher plots produced only 10–30% as much sediment as the skidder plots, but regrowth was similarly inhibited. The relative differences in sediment production between the disturbed plots and the controls tended to increase over time as the controls exhibited more rapid regrowth. Adding slash to skid trails increased total ground cover by 20–30% and reduced the sediment yields by 5–50 times compared to the untreated skidder plots.

The replicated logged swales at one study area generally had higher sediment production rates than their controls but the absolute values per unit area were much lower than from the skidder and feller-buncher plots. Results from the swales at the other study areas indicated that logging did not increase runoff, peak flows, or sediment yields.

Vegetative regrowth and sediment production rates varied widely among the four study areas. This variation was largely due to differences in rainfall and soil properties, with the more productive sites having more rapid regrowth and thereby a more rapid reduction in sediment production. The susceptibility to surface runoff and erosion after high severity fires suggests that areas disturbed by ground-based salvage logging need additional mitigation practices.

1. Introduction

Moderate and high-severity wildfires in coniferous forests often kill nearly all of the trees, and there is a strong economic incentive to capture the market value of the timber before the wood decays. Salvage logging after such fires is a highly controversial activity, as

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there is little consensus on the extent to which post-fire salvage logging can either exacerbate or mitigate the effects of a wildfire on vegetative regrowth, soil water repellency, and/or surface runoff and erosion (McIver and Starr, 2001; Peterson et al., 2009). Previous studies on post-fire salvage logging have found widely varying impacts on physical soil properties, vegetative cover, and sediment production with only limited data on the underlying causal processes. More data and a better understanding of the effects of post-fire salvage logging is essential given the already-observed and projected increases in the number, extent, and severity of wildfires in the western U.S. and elsewhere (Flannigan et al., 2009; Littell et al., 2009).

The primary difficulties in predicting the effects of post-fire salvage logging are that the additional changes are being superimposed on a system that already has been highly altered by fire, and that logging can have counteracting effects on the underlying causal processes. A rapidly growing list of studies have documented the large increases in peak flows, erosion, and downstream flooding and sedimentation that can occur after moderate and high severity wildfires (e.g., Moody and Martin, 2009; Shakesby and Doerr, 2006). The increased runoff and erosion is driven by four main ecosystem state changes (Fig. 1), namely the: (1) reduction in plant canopy; (2) increase in soil water repellency; (3) loss of surface cover; and (4) consumption of soil organic matter. These state changes then cause a series of interacting process changes, such as reduced interception, higher soil erodibility, and increased runoff velocities (Fig. 1). The relative importance of each state and process change is still a matter of debate given the diversity in site conditions and multiple interactions among the observed changes. Our premise is that the net effect of post-fire salvage logging on runoff and erosion can only be understood and predicted by evaluating the incremental effects of the post-fire logging on the state variables and underlying processes.

With respect to the post-fire state changes, the loss of the plant canopy mainly affects the overall water balance and net precipitation, and this is generally regarded as having a smaller effect on post-fire peak flows and hillslope erosion than the changes in surface cover and soil properties (Shakesby and Doerr, 2006). The second state change is the commonly-observed increase in soil water repellency at or beneath the soil surface, and this has often been suggested as the primary cause for the observed increase in post-fire runoff and erosion (Doerr et al., 2006). Some recent studies have questioned the importance of soil water repellency given its extent prior to burning (Doerr et al., 2009), its high spatial variability (Woods et al., 2007), the relatively rapid decay of repellency compared to the duration of the increased runoff and erosion (Huffman et al., 2001; Larsen et al., 2009), and the loss of repellency at a threshold soil moisture content (Doerr and Thomas, 2000; MacDonald and Huffman, 2004).

Regarding surface cover, numerous studies have shown a strong, nonlinear relationship between the loss of surface cover and increase in surface erosion (e.g., Cerdà and Doerr, 2008; Larsen et al., 2009; Morris and Moses, 1987; Wagenbrenner and Robichaud, 2014). A loss of surface cover also will increase overland flow velocities, and this alone can increase peak flows, sheetwash, rilling and gullying (McGuire et al., 2013; Robichaud et al., 2010; Shakesby and Doerr, 2006). The relative importance of surface cover as a controlling process is further supported by the fact that mulching is generally the most effective treatment in reducing post-fire runoff and erosion (e.g., Robichaud et al., 2013a; Wagenbrenner et al., 2006). The loss of soil organic matter is the fourth state change, and this increases soil erodibility and thus

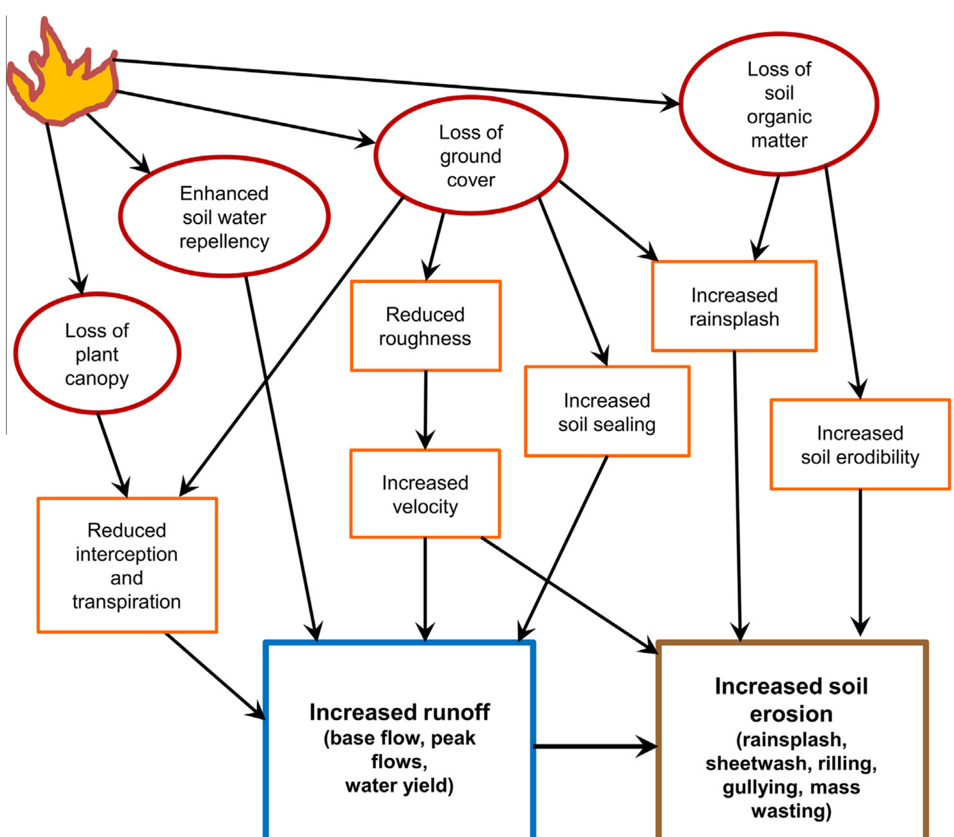

Fig. 1. Conceptual overview of the state changes and processes that can cause increased runoff and erosion after moderate or high severity wildfires. Ovals represent a change in state, and rectangles represent the resulting change in processes.