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Modeling the effects of ash, water repellency and macropore flow on infiltration during recovery from wildfire

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Infiltration in forest soils can be important as a source of variability in post-fire erosion responses across landscapes. Wildfires produce ash and can cause i) extreme soil drying, ii) increased water repellency and iii) reduced soil structure, thereby reducing infiltration into the soil. High severity wildfire often results in a non-repellent layer of ash, charcoal and burnt soil overlying a water repellent soil matrix. In these conditions the hydraulic parameters can vary across discrete layers in the soil profile, making the infiltration process difficult to measure and model. In this study we use small scale infiltration measurements to untangle the relationships between initial soil moisture conditions, water repellency, hydraulic conductivity and absorption in burnt soils. A two layered infiltration model was used to parameterize and analyze key properties of a soil recovering from wildfire. Laboratory experiments with intact soil cores showed that the soil contained a region of strong water repellency that was inactive, slow to take on water, and ultimately restricting flow through the matrix. Under field conditions, soils remained water repellent throughout the 3 year post-fire measurement period across small headwater catchments, but the strength diminished exponentially during wet conditions. An exponential increase in hydraulic conductivity with decreasing critical surface tension meant that weather dependent repellency led to temporal variability in infiltration. When scaled by macropore availability, the macropore flow increased linearly with time since fire for various soil types, indicating that changes in soil structure during recovery leads to increased flow potential. Surface storage was initially high ($\sim$ 4 mm) after wildfire, then declined exponentially for 24 months. Overall the study shows that the two layered soil can be represented and parameterized by partitioning the infiltration process into surface storage and flow through partially saturated soil. Ash, water repellency and macropore flow are key characteristics of burnt forest soils in general and the proposed model may therefore be a useful tool for characterizing fire impact and recovery in other systems.