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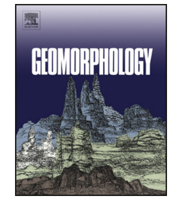

Post-wildfire landscape change and erosional processes from repeat terrestrial lidar in a steep headwater catchment, Chiricahua Mountains, Arizona, USA

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ABSTRACT

Flooding and erosion after wildfires present increasing hazard as climate warms, semi-arid lands become drier, population increases, and the urban interface encroaches farther into wildlands. We quantify post-wildfire erosion in a steep, initially unchannelized, 7.5 ha headwater catchment following the 2011 Horseshoe 2 Fire in the Chiricahua Mountains of southeastern Arizona. Using time-lapse cameras, rain gauges, and repeat surveys by terrestrial laser scanner, we quantify the response of a burned landscape to subsequent precipitation events. Repeat surveys provide detailed pre-and post-rainfall measurements of landscape form associated with a range of weather events. The first post-fire precipitation led to sediment delivery equivalent to 0.017 m of erosion from hillslopes and 0.12 m of erosion from colluvial hollows. Volumetrically, 69% of sediment yield was generated from hillslope erosion and 31% was generated from gully channel establishment in colluvial hollows. Processes on hillslopes included erosion by extensive shallow overland flow, formation of rills and gullies, and generation of sediment-laden flows and possibly debris flows. Subsequent smaller rain events caused ongoing hillslope erosion and local deposition and erosion in gullies. Winter freeze-thaw led to soil expansion, likely related to frost-heaving, causing a net centimeter-scale elevation increase across soil-mantled slopes. By characterizing landscape form, the properties of near-surface materials, and measuring both precipitation and landscape change, we can improve our empirical understanding of landscape response to environmental forcing. This detailed approach to studying landscape response to wildfires may be useful in the improvement of predictive models of flood, debris flow and sedimentation hazards used in post-wildfire response assessments and land management, and may help improve process-based models of landscape evolution.

1. Introduction

Intense rainfall on recently burned landscapes often results in increased flood magnitude, widespread erosion, initiation of debris flows, and sedimentation in stream valleys and on piedmonts in volumes that greatly exceed what is expected from rainfall on unburned landscapes. Post-fire sediment yields have been demonstrated to increase by as much as three orders of magnitude over background erosion rates (Wagenbrenner and Robichaud, 2014). In the western United States, a history of fire suppression and periodic drought has led to increased frequency, extent, and severity of wildfires over the past several years (Stephens, 2005; Littell et al., 2009). Additionally, as human development at urban-wildland interfaces continues, the risk of wildfires and associated hazards increases (Stein et al., 2013). This requires that we improve our understanding of the range of responses that arise from the complex functional relationships among basin morphology, mesoscale precipitation, burn severity, soil characteristics, and the thresholds for runoff and debris-flow generation in order to improve conceptual and physics-based predictive models (Moody et al., 2013).

After a high-severity burn the primary modes of sediment transport on steep, burned slopes prior to the first rainfall include wind erosion and dry ravel (Florsheim et al., 1991; Gabet, 2003; Shakesby and Doerr, 2006; Lamb et al., 2011). However, the most dramatic post-wildfire sediment transport results from intense rain events. Rainsplash and runoff erosion is exacerbated by a combination of the loss of plants and organic ground cover that previously intercepted precipitation and dampened raindrop energy, the decrease in soil shear strength from the burning of roots, and changes in soil hydrologic properties, particularly

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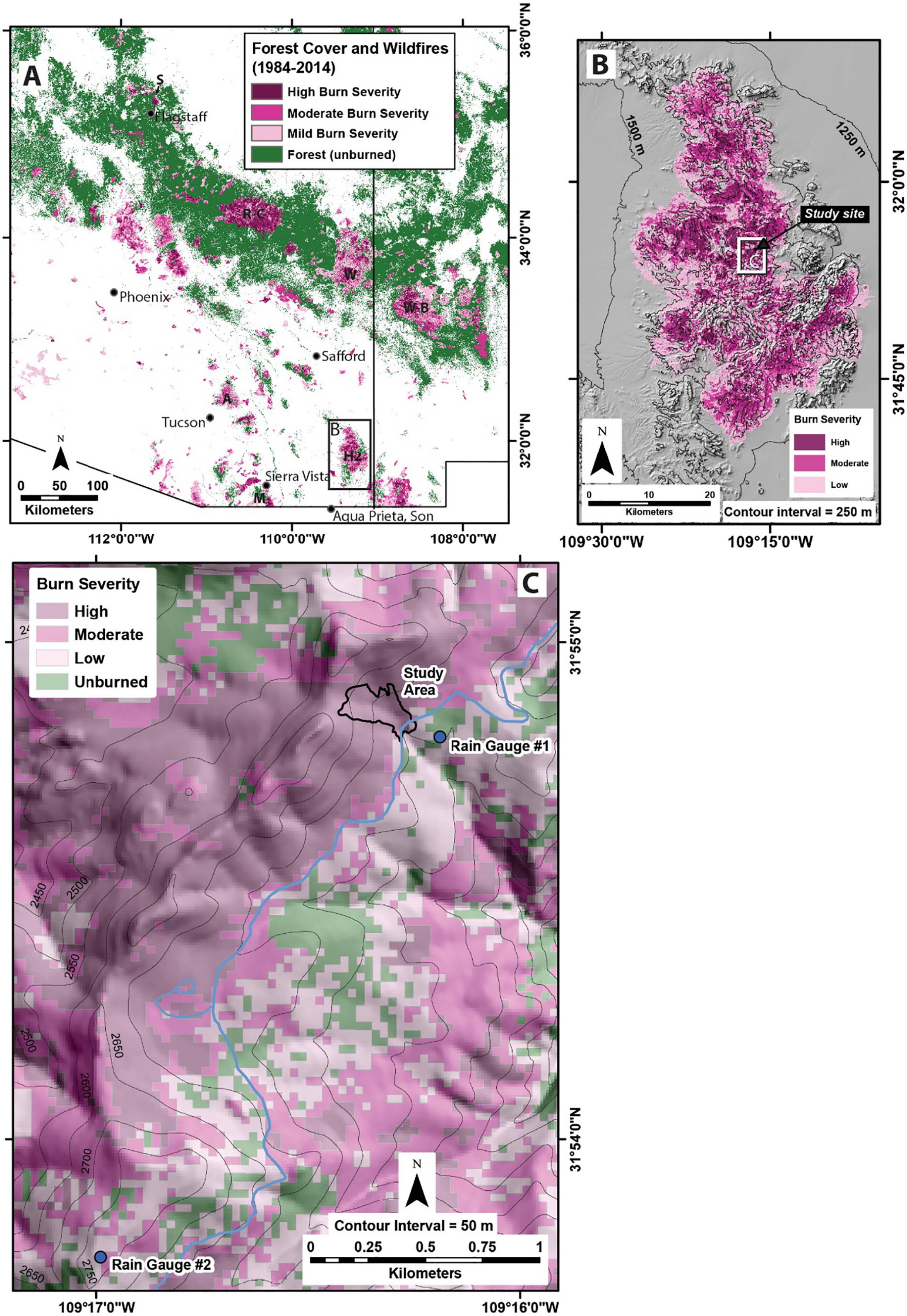
A
Forest Cover and Wildfires (1984-2014)
High Burn Severity
Moderate Burn Severity
Mild Burn Severity
Forest (unburned)
S
Flagstaff
R-C
W
W-B
Phoenix
Safford
A
Tucson
B
H2
Sierra Vista
M
Aqua Prieta, Son
0 50 100
Kilometers
36°0'0"N
34°0'0"N
32°0'0"N
112°0'0"W
110°0'0"W
108°0'0"W
B
1500 m
1250 m
Study site
Burn Severity
High
Moderate
Low
0 10 20
Kilometers
Contour interval = 250 m
32°0'0"N
31°45'0"N
109°30'0"W
109°15'0"W
C
Burn Severity
High
Moderate
Low
Unburned
Study Area
Rain Gauge #1
Rain Gauge #2
Contour Interval = 50 m
0 0.25 0.5 0.75 1
Kilometers
31°55'0"N
31°54'0"N
109°17'0"W
109°16'0"W