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A data-driven evaluation of post-fire landslide susceptibility

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Wildfire changes the hydrologic and geomorphic response of watersheds, resulting in a cascade of increased hazards for sediment-laden floods, shallow landslides, and debris flows. This phenomenon has long been studied in regions where landscape evolution is driven by repeated fire-flood sequences such as Southern California. However, comparing mass movement hazards across multiple regions presents a challenge because most landslide inventories are limited to local or regional spatial scales. This study seeks to identify unique triggering characteristics of post-fire landslides through a comparison of the precipitation characteristics preceding landslides at both burned and unburned locations spanning six global regions. Regional inter-comparison was facilitated by selecting landslide events from the NASA Global Landslide Catalog (GLC), and then establishing fire and precipitation histories for each site using MODIS global burned area and CHIRPS precipitation data. In addition, since the GLC did not contain a sufficient percentage of burned locations in any part of Europe, a parallel analysis incorporates nationally maintained landslide inventories from several European countries. Analysis of normalized seven-day accumulated precipitation for sites across all regions shows that post-wildfire landslides are preceded by less precipitation than landslides without antecedent wildfire events. This supports the hypothesis that fire increases the rainfall-driven landslide hazards. A regional examination of landslide susceptibility using normalized triggering storm volumes as a proxy indicator reveals a distinct sensitivity to fire across several regions of the western US. However, in other regions wildfire appears to have a limited or even opposite impact on landslide susceptibility. Unburned locations also tend to see a sharper ramp-up of precipitation leading up to the date of the landslide relative to burned sites in regions of the Western US. In other regions the storm timing is similar or, a in Central America, even longer in burned locations. The landslide-triggering storms of post-fire landslides also exhibit different seasonality from other rainfall-triggered landslides, with a variety of seasonal shifts ranging from approximately six months in the Pacific Northwest of the US to one week in the Himalayas. These results suggest that the apparent inconsistency in the impact of wildfire on landslide hazards may be due to a combination of two factors: interactions between fire and precipitation seasonality and variability in soils and vegetation. For example, in the Intermountain West of the US and Southeast Asia landslides are preceded by a thirty-day or longer dry period while in all other regions there is no difference in the precipitation prior to the triggering storm event, which suggests different landslide mechanisms such as dry ravel, which rely on low rather than high soil moisture levels, may be a factor. Overall, this work offers an exploration of regional differences in the characteristics of rainfall-triggered landslides over a broad spatial scale encompassing a variety of climates, terrains, and ecoregions.