Numerous Papers

1) Parise, M., and Cannon, S. H., 2012, Wildfire impacts on the processes that generate debris flows in burned watersheds: Natural Hazards, v. 61, no. 1, p. 217-227.

Wildfire contributes to the generation of debris flows in a burned area. The effects of wildfire include the consumption of vegetation (soil mantling material), ash deposition, changes to physical properties of soil and rock, generation of hydrophobic soils, and ultimately debris flows.

There are many ways soil can be physically and chemically altered by wildfire. The removal of soil mantling material, which consists of vegetation and duff, leads to more rainfall reaching the soil, as well as to exposure of the bare soil to the impact of raindrops and entrainment into surface runoff. Ash deposited on the soil provides a surficial reservoir for water, leading to decreased runoff. Fungus and microbial life can be destroyed by fire, both of which, under normal conditions, help to stabilize soil with anchoring fungal root systems and the secretion of cohesive compounds by microbes. Additionally, the heat of the fire can physically transform soil, by fusing clay and silt particles into coarser grains, leaving the soil with higher sand content than before. Temperatures higher than 460 degrees C have been found to drive off OH from clay soil, which can increase erodibility. Decaying roots of destroyed vegetation leave cavities in the soil, which add additional instability. Another chemical alteration of soil, resulting from the burning of vegetation and other organic material, is the generation of hydrophobic compounds that discourage infiltration. Burning of bare rock can lead to cracking and spalling, which add increased potential material for entrainment by runoff. All of these effects of wildfire lead to increased erosion rates, which have been calculated to increase 50 to 870 times following fire.

The amount of material exceeds the carrying capacity of streams, and leads to immediate aggradation of larger sediment, the carrying of suspended sediment to great distances, and deposition of terraces and alluvial fans. The most commonly documented post-fire debris flows are runoff driven, due to the increased amount of material that can be entrained. The process of debris flow formation involves the erosion of hill slope and channel material by runoff, until the concentration of entrained material is such that the flow can be considered a debris flow. Post-fire, infiltration triggered landslides are more difficult to correlate with fire, but are speculated to continue up to 30 years following a fire. The processes that initiate this type of failure are thought to be the lack of vegetation to absorb and transpire soil moisture, the decay of soil anchoring roots, and accelerated bank erosion. There is still a lack of understanding of post-fire induced debris flows in varying geographic and climatic regions that needs to be explored.

2) Ohlmacher, G. C., and Davis, J. C., 2003, Using multiple logistic regression and GIS technology to predict landslide hazard in northeast Kansas, USA: Engineering Geology, v. 69, no. 3–4, p. 331-343.

Generally, there are two approaches to landslide hazard mapping: deterministic modeling, which relies on physical measurements that are difficult to obtain over large areas, and a statistical approach that relates the occurrence of past landslides to measurable characteristics of the broader landscape. The purpose of this study was to develop a statistical approach to landslide hazard mapping for areas that are difficult to access. Multiple logistic regression was employed to define the relationship between debris flow occurrence and a set of independent variables and then weigh them in a conditional probability function.

A digital geologic map provided numerical values for geologic characteristics such as the strength of different rock types, and a DEM provided slope characteristics. A landslide inventory map was made during the course of previous research. Using the inventory map, the authors assign “1” to cells where a landslide is present, and “0” where a landslide is not present. The multiple logistic regression estimates the probability that an observation will fall into one of the two mutually exclusive categories, 0 or 1.

P(Y=1) = alpha + betaX

Where P(Y=1) is the probability of a debris flow occuring, alpha = y-intercept, and betaX is the slope. The authors also do odds and logit transformations, which both represent the same thing as probability estimations, but logit makes it possible to use regression in a predictive model. The authors state that it is necessary to use maximum likelihood, which finds estimate for alpha and beta that maximizes the resulting conditional distribution. This results in the coefficients for each variable giving them a weight corresponding to how much they contribute to debris flow hazard probability. The process is repeated until the increase in likelihood is negligible from one step to the next.

The final landslide hazard map contains the probability that each cell contains a landslide, given the slope and geology (fig. 7). The authors did not seem to discuss the amount of overlap of predicted probabilities and landslide inventory map. They mention good agreement between figure 7 and 3, but they do not superimpose the two in a new figure. The results of their sensitivity calculation reveal that slope accounts for almost 100% of the probability for a landslide occurring. They do mention a potential limitation that as you move to steeper slopes, soil thickness decreases and thus LS probability decreases. They also recommend that soil can be used in place of geologic unit for areas where geologic maps are too coarse in resolution. They conclude that logistic regression is a viable way to perform hazard mapping, but depending on location, parameters may have to be altered.

**perhaps soil thickness map can be incorporated into my project.

3) Rupert, M. G., Cannon, Susan H., Gartner, Joseph E., Michael, John A., Helsel, Dennis R., 2008, Using logistic regression to predict the probability of debris flows in areas burned by wildfires, Southern California, 2003-2006, U. S. Geological Survey, Reston, VA, United States, Open-File Report – U.S. Geological Survey, 9 p.:

In this report, the development of logistic regression models specifically for debris flows following wildfire in Southern California is described. In a study of erosion response to wildfire, Cannon (2000, 2001) made the distinction between sediment-laden flooding and debris flows in that certain characteristics occurring coincidentally resulted in the generation of debris flows. Following this study, Rupert and others (2003) began a pilot project intending to determine the probability of debris flows in recently burned areas via logistic regression models. These models were effective and further developed by Cannon and others (in press) for the Intermountain West, but were not applicable to Southern California due to different geologic, geomorphic, and climate characteristics.

The logistic modeling approach incorporated 28 independent variables that described the basin morphology, burn severity, rainfall, and soil properties. Basins where debris flows did and did not occur were delineated using the National Elevation Dataset (NED). The relationship between the occurrence or absence of debris flows with the different variables was then defined for the logistic regression:

$P = (e^{x)/(1+e}x)$.

Where P = probability of debris flow occurrence and x is the sum of weighted variables. To ensure the success of the model, P-values were assessed at the 90% and 95% confidence interval. Independent variables with values over 0.1 were not included. The success of the model was evaluated by determining the percentage of correctly predicted events and the percentage of correctly predicted non-events, both of which were plotted using a decile-of-risk calculation to plot the percentage of actual debris flows with predicted probability of debris flows for each burned area. The closer the points plot to a 1:1 trend line, the more accurate the model. Prior to performing the logistic regression, the independent variables were evaluated for skewness. If any were skewed, the data was transformed using a natural log function. Probability maps were constructed using GIS data. The different models were built by sequentially adding variables, and those that did not increase the effectiveness were discarded. All five models produced varied minimally, so can all be used effectively and selected based on data availability for the region of interest. These models were developed based on a specific areas burned by specific fires, so ideally it would be validated using an independent set of burned basins in S. California; however, at the time of this report, one did not exist, so the authors used the decile risk calculation.

These models intend to show the likelihood for a debris flow occurring in different basins following sufficient intensity of rain within 3 years of fire. The authors acknowledge that there may be more variables affecting the presence of debris flows, and the variables included in this study are simply those that are most readily available.

4) Grant, A., Wartman, J., and Abou-Jaoude, G., 2016, Multimodal method for coseismic landslide hazard assessment: Engineering Geology, v. 212, p. 146-160.

Infinite slope analysis modeling does well for shallow soil disruption, but is not effective at conveying the whole range of coseismic slope failures styles. A new method of landslide hazard mapping for varied terrain where slide inventory maps may not be available is presented. The authors use a multimodal approach where 1) susceptibility based on topography and 2) hazards assessed with mode-specific models for: (1) rock slope failures (2) disrupted soil slides (3) coherent rotational slides (4) lateral spreads (table 1).

(1) For rock slope failures, including block slides and falls, were modeled as Culmann wedge-

like masses, which captures planar structural controls that give way to failure (fig.1). In order to prevent under- or overestimation of coseismic hazards, the authors only counted the upper quarter of a slope based on previous observations from past earthquakes. (2) The authors used infinite slope analysis for disrupted soil failures modified to account for root cohesion. The authors used LandSAT and NDVI to define a relationship between landslide occurrence and degree of vegetation. They found that only 1% of landslides occurred on slopes with the highest degree of vegetation while 73% of landslides occurred in minimally vegetated slopes (fig. 3). Based on previous research, the authors assumed a failure depth ~2 m. They used the factor of safety equation: FS = (C+Cr/ytsinB) + (tan(phi)/tan(B))

Where Cr = root cohesion, t = thickness, y = soil unit weight, B = slope angle, phi is friction angle of soil mass, and C is the cohesion of soil mass.

(3) For coherent rotational slides, the authors modeled the radius of a circular failure plane through a dry homogenous hill slope as 1.5 times the local relief (fig 1c). Since lateral spreading is related to liquefaction and pore water pressure, the authors used the Youd and Perkins (1978) PGA thresholds for susceptible slopes based on depositional conditions, ages, and sand-clay gravel contents. Topography assessed from 15m resolution DEM. Coseismic hazard assessment is performed using probabilistic seismic hazard analyses (PSHA).

The authors performed field verification of ~30 sites where the models predicted presence of all four modes as well as locations where the authors suspected over- or underestimation of susceptibility. Upon verification the authors determined that the multimodal assessment methods is capable of defining locations of susceptibility and differentiating the specific mode for that location. Being able to differentiate different modes at different locations allows for more cautious hazard and risk assessment.