A Geographical Information System (GIS) Based Evaluation of Landslide Susceptibility Mapped on the Harrison Mountain Quadrangle of the Santa Ana River Watershed

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Executive Summary

A severe storm in Southern California from December 16-23, 2010, produced over 20 inches of rainfall across the southwestern San Bernardino Mountains, which triggered extensive hill-slope failures (e.g., landslides, slumps, debris flows). Erosion scars are recorded in a time-series of high resolution, digital aerial orthophotographic imagery shown on Google EarthTM. Comparison of georeferenced repeat images before hill-slope failure (15 November 2009) and afterward (9 March 2011) allowed detailed mapping of erosion scars as polygons with perimeters delineated by sharp contrast of barren earth to surrounding vegetation (see figure 3). A total of 8,101 polygons were delineated in a 3,220 ha study area spanning Harrison Mt. to Mt. McKinley (see figure 2). Perimeter data were imported into a geographical information system (GIS) for classification of hill-slope failures by susceptibility factors of vegetation types (grassland, coastal sage scrub, chaparral, oak woodland, conifer forest), and terrain characteristics represented by a digital elevation model (DEM) including hill slope steepness, aspect, and elevation. The total number of hours worked on delineating polygons was about 103 and about 30 hours were spent using the detailed GIS mapping.

Project Objectives

The objective of this undergraduate research project was to provide a GIS based internship utilizing ArcGIS 10.1, funded by the CSU Water Resources Institute (WRI), to evaluate how site-specific factors control the geographic distribution of landslides. The results of this study will improve maps of landslide hazards and predictions of susceptibility in the Santa Ana River watershed. This geographic region includes 4.8 million people and is prone to hydrologic disaster processes. For example, December 2010 rains triggered landslides that cost $20.7 million in damage including 58 homes in the city of Highland below Harrison Mt (see figure 2). It will give a better idea of where to build homes in a safe environment to avoid deadly consequences in the future.

The study area is located in the Harrison Mt. 7.5 min USGS quadrangle which encompasses the southern portion of the San Bernardino Mts. in the eastern Transverse range, southern California. This cismontane region is encompassed by the Santa Ana river watershed which covers 6,863 km2 (Figure 1). The area of mapping was defined by Google Earth™ aerial imagery coverage taken on 9 March 2011 after the December 2010 rain event. This available true color photography spans from the San Bernardino Valley at the city of Highland to the summits of Harrison Mt. and Mt. McKinley. Elevation ranges from 448 m to 1,445 m (Figure 2), where precipitation was rainfall in the storm. The climate of this region is characterized as a Mediterranean type, with cool wet winters, warm dry summers, and mean annual rainfall of 43 cm (17 in) registered at the nearby City Creek weather station. Orographic lift results in increased precipitation up the mountain slopes compared to the valley. The study area vegetation is predominately shrubland of sage scrub and chaparral which burned in the "Old Fire" of October 2003. Regenerating vegetation successions in shrublands include abundant cover of non-native invasive annual grasses (e.g., *Bromus diandrus*).

Project Approach

Erosion scars of landslides were mapped using Google Earth™ imagery taken 15 Nov 2009, and 9 Mar 2011 (Figure 3); the before and after comparison between the two images made it possible to outline every landslide which occurred after the storm. The "add polygon" tool of Google Earth™ was used to delineate polygon perimeters directly on imagery at boundaries where light tone and rough texture of erosion scars sharply contrasted with surrounding vegetation. Eye altitude of 2,000 m above the land surface was used for consistent scale as well as elevation altitude between 1,000 to 3,000 ft. Historical imagery timeline was used to check images before and after December 2010 to confirm landslides resulted from the storm. Delineated polygons were saved as KML files, and imported into ArcMap 10.1 as shapefiles for GIS analysis with a 10 m resolution DEM from the USGS, and a pre-fire vegetation map produced in 1997 for the California Forest Resource Assessment Project (FRAP- CalFire). Shapefiles for the Santa Ana River Watershed were obtained from SAWPA to make the locator map.

Using ArcToolBox, each dataset was clipped to the boundary of the study area. The Spatial Analyst "surface tool" was used to produce hillshade, slope steepness, and slope aspect models (Figure 4- A, B, C). Each raster dataset was then converted into a point shapefile, and a spatial join was used intersect it with the landslides polygons by 5 m proximity rule. The resultant attribute table data were summarized and graphed using Microsoft Excel.

Project Outcomes

A total of 8,101 polygons were delineated for erosion scars over a total of 106 hours of visual photo interpretation using Google Earth™. The total area of landslides was 231.3 ha, which equates to 7.2% of the study area landscape surface. GIS analysis shows landslides predominately occurred at lower elevations of Harrison Mt. and Mt. McKinley, on steep south facing slopes which are mostly covered by shrublands of sage scrub and chaparral vegetation (Figure 4-D). A measure of the geographic pattern of landslides in relation to terrain was made by computing cumulative frequency distributions for elevation and slope steepness. Figure 1 explains the landslide distributions; (A) shows that at an elevation of around 850 m almost 25% of landslide occurred. For example, 59.4% of landslides occurred at elevations between 440 m and 700 m. (B) Shows how more landslides were seen at around 35.4 average. For example 57.2% occurred on slopes of less than 33.4 degree angle. (C) Emphasizes that many landslides face south to southwest and (D) most damage was seen were vegetation was mostly chaparral to sage scrub.

During this internship knowledge of the ArcGIS program was gained as well as independence to achieve map making on my own and many hours of experience. In total I spent about 170 hours working on this project which includes the delineation using Google Earth, the GIS approach, the report, and extra research needed to complete the project.

Conclusions

Because regenerating vegetation successions after the 2003 “Old Fire” have been invaded by non-native annual grasses, additional analysis of the vegetation map by air photo sampling is needed to contrast geographic differences between north and south aspect shrub cover in relation to the mapped pattern of landslides. Previous field based study suggests that non-native grasses like *Bromus diandrus* (rip-gut brome) alter patterns of soil rooting, which may reduce infiltration of rainfall, compared to native shrubland vegetation cover, resulting in greater runoff and erosive potential of slopes. Results of this GIS analysis will then be used to test and refine existing predictive models of landslide susceptibility in the Santa Ana River Watershed.

By working on this project from January to August 2014, I now see myself working in the GIS related field, either with a private or government company, with a specific interest for sustainability, the environment, and its resources.

Appendice

Graphics

Figure 1. Locator Map.

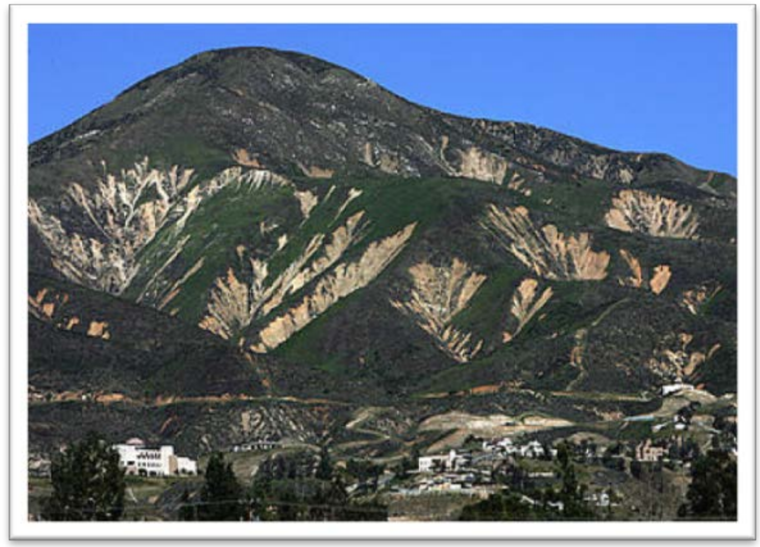

Figure 2. Ground photo of Highland after storm

Figure 3. Aerial images of Harrison Mt. before and after storm. White scale bar= 100 m.

Maps of Study Area

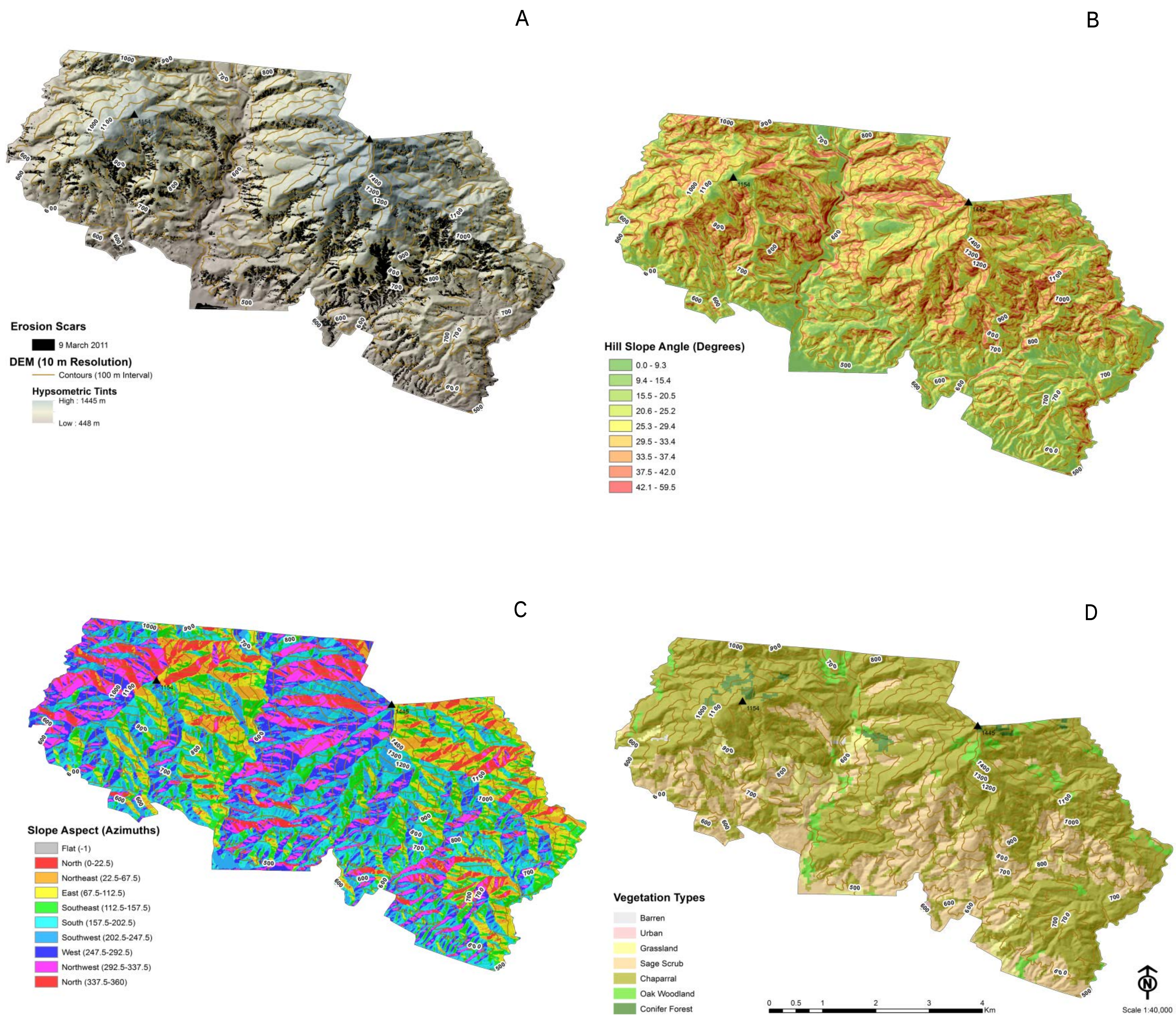

Figure 4. GIS maps of **(A)** landslide polygons, **(B)** slope steepness, **(C)** slope aspect, **(D)** vegetation types.

Graphs (results)

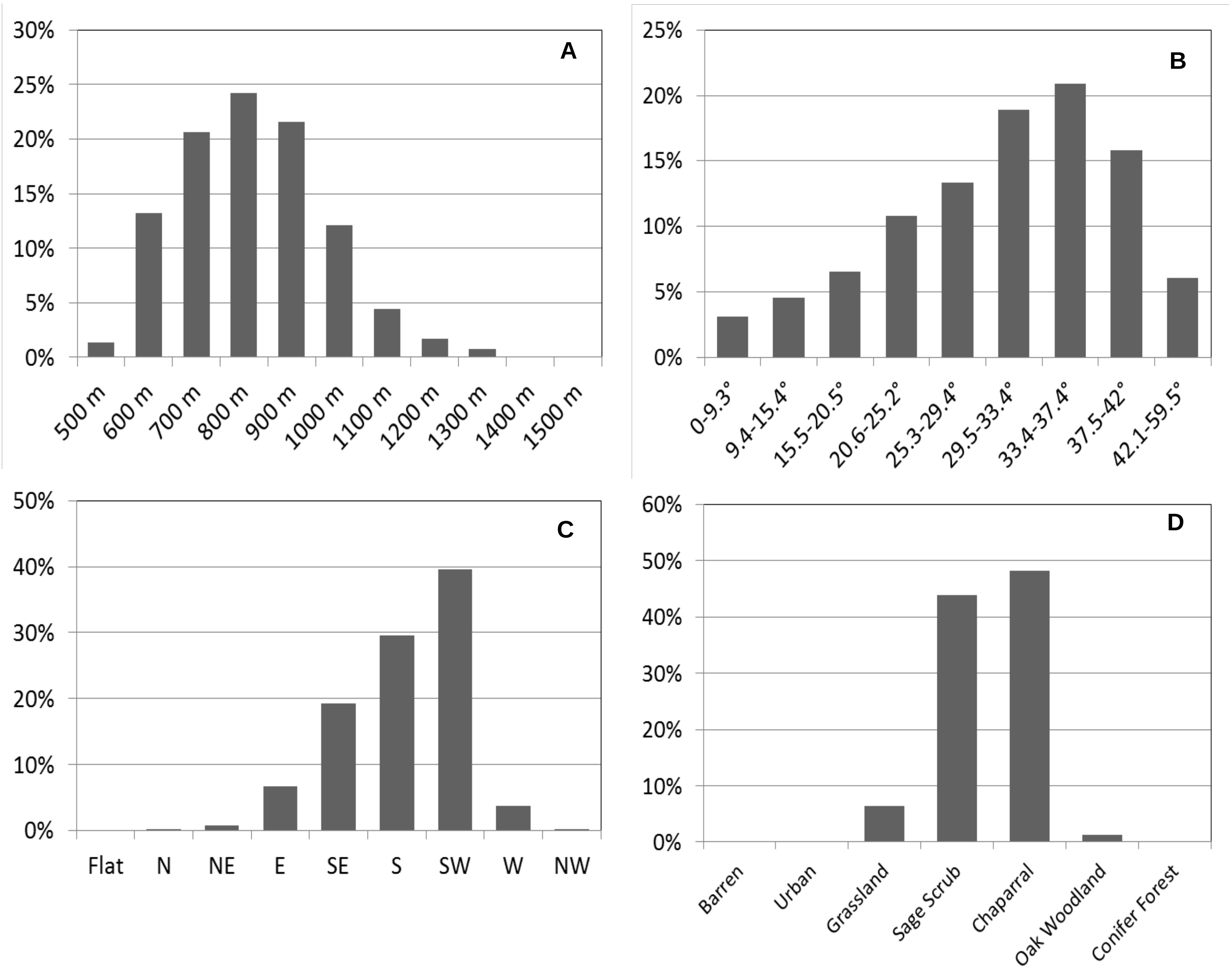

Figure 5. Frequency distributions of landslide classified by intervals of **(A)** elevation (meters), **(B)** slope steepness (degree of hill slope angle), **(C)** slope aspect (azimuths), and **(D)** vegetation types.

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