Landslide Susceptibility Assessment After Wildfire in Montecito, CA.

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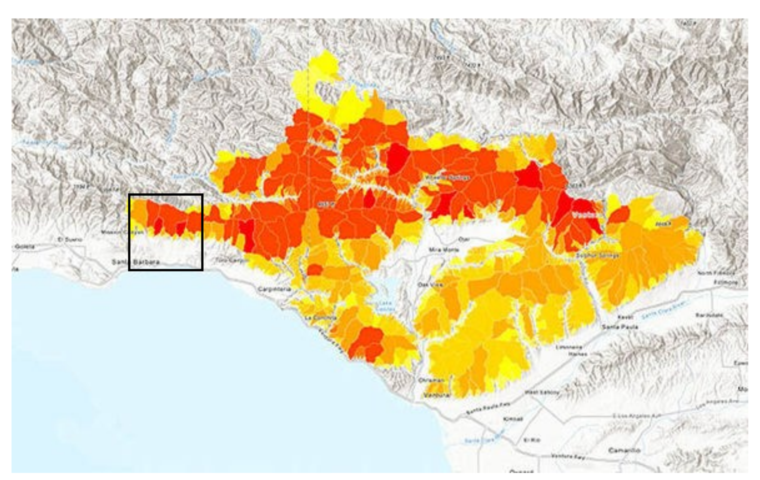
ABSTRACT

Debris flow is a landslide with a quick velocity of displacement that involves risk and damages to life and property. It can be triggered by periods of intense rain usually on steep slopes. Also, a second triggering factor is the influence of wildfire. Wildfire can increase drastically the probability of this type of landslide because the fire burned the vegetation which helps to stabilize the soil and the slope. The research uses geographical information system (GIS) for the development of mapping landslide susceptibility, with a particular interest in the evaluation of areas vulnerable to debris flow natural hazards that may be triggered after a wildfire, with the effects of intensive periods of precipitation. The method has been applied to Montecito city, which was exposed to a massive mudslide in January 2018. The spatial landslide susceptibility response in this study area is correlated to different factors, such as vegetation, lithology, slope gradient, and distance to streams networks which are considered the control of the probability of incidence of a landslide event in this area. Obtained by using the methodology of the multi-criteria decision evaluation (MCE) model. The results obtained from this study indicate that the GIS-based model is valuable and appropriate for the scale used in this study. The model helped to identify areas that still are affected by the wildfire, which can be vulnerable to a new process of debris flow impacting the population closer to the rivers downhill.

BACKGROUND

The City of Montecito is located in Santa Barbara County, CA. Has suffered a massive mudslide triggered by a suddenly intensive period of rain that falls in the burned area from the Thomas Fire. The wildfire increases dramatically the likelihood of debris flow events due to the remotion of the healthy vegetation on the steps slopes, increasing the runoff effects. The presence of vegetation on slopes increases its stability, roots serve as the anchor to prevent erosion and improve the saturated soil-water system. The Montecito population resides downstream of mountains where the flow occurred, leading to human casualties and economic losses.



Montecito spatial location (left). Thomas Fire extension in California and spatial location of study area (right).

Montecito debris flow devastation. Mud flow, death vegetation and blocks of rocks destroyed houses

OBJECTIVES

The purpose of this research is to evaluate areas that were affected by the Thomas fire and to still had no vegetation recovered by Summer 2021, which may lead to a new landslide event by:

- Detecting areas not vegetated by the Normalized Difference Vegetation Index (NDVI).
- Selecting the most vulnerable geology that may lead to a landslide.
- Classifying the deepest slopes in risk.
- Determining areas closer to stream networks that can be affected.
- Performing a GIS-based analysis to create the landslide susceptibility and population in higher risk.

DATASETS

Dataset/Source	Technique used	Purpose
DEM 30 m resolution	GIS integration	Support for slope and drainage network analysis for LSM
Multispectral Landsat 8, 20210611	Normalized Difference Vegetation Index (NDVI)	Support for vegetation analysis
Geology and faults (1:750.000)	GIS integration	Support for LSM analysis

METHODOLOGY

Integrated approach that uses multi-criteria decision evaluation (MCE) methods to generate the landslide susceptibility map of the area. That will provided information for the drainage with higher risk to be involve in a new landslide event that could affect the community of Montecito.

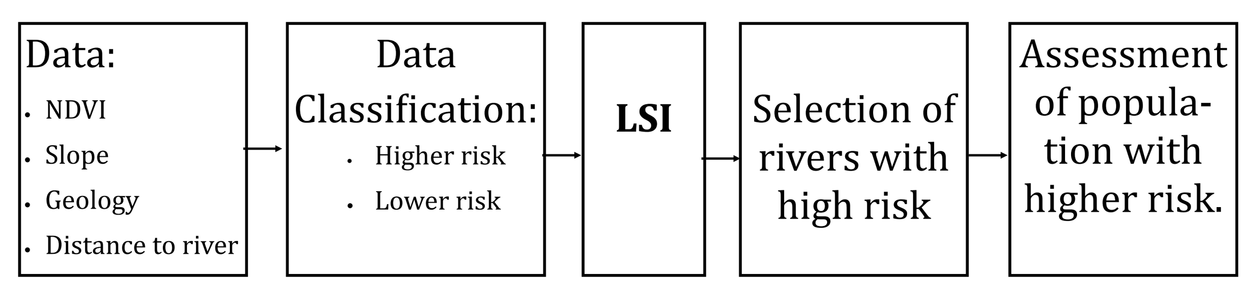


Figure 1: Flowchart of main processes for this study

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

NDVI values range from -1 to 1

Figure 2: Normalized difference vegetation index calculation.

Slope (S) (degrees) 40%	Vegetation (V) 30%	Geology (G) 20%	Distance to Drainage (DD) (m) 10%	Rating (R)*
0 - 15	Vegetated Areas	Mudstone	<200	1
>15	Unvegetated Areas	Sandstone	>200	0

$$R_S(W_S)+R_V(W_V)+R_G(W_G)+R_{DD}(W_{DD})/2$$

*R= Rating based on 1 being most susceptible and 0 being the least susceptible

Figure 2: Factors and computation of landslide susceptibility index

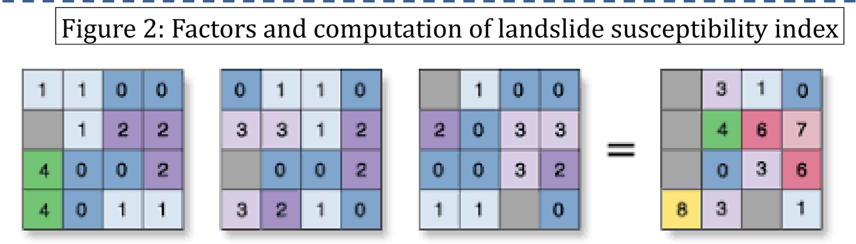
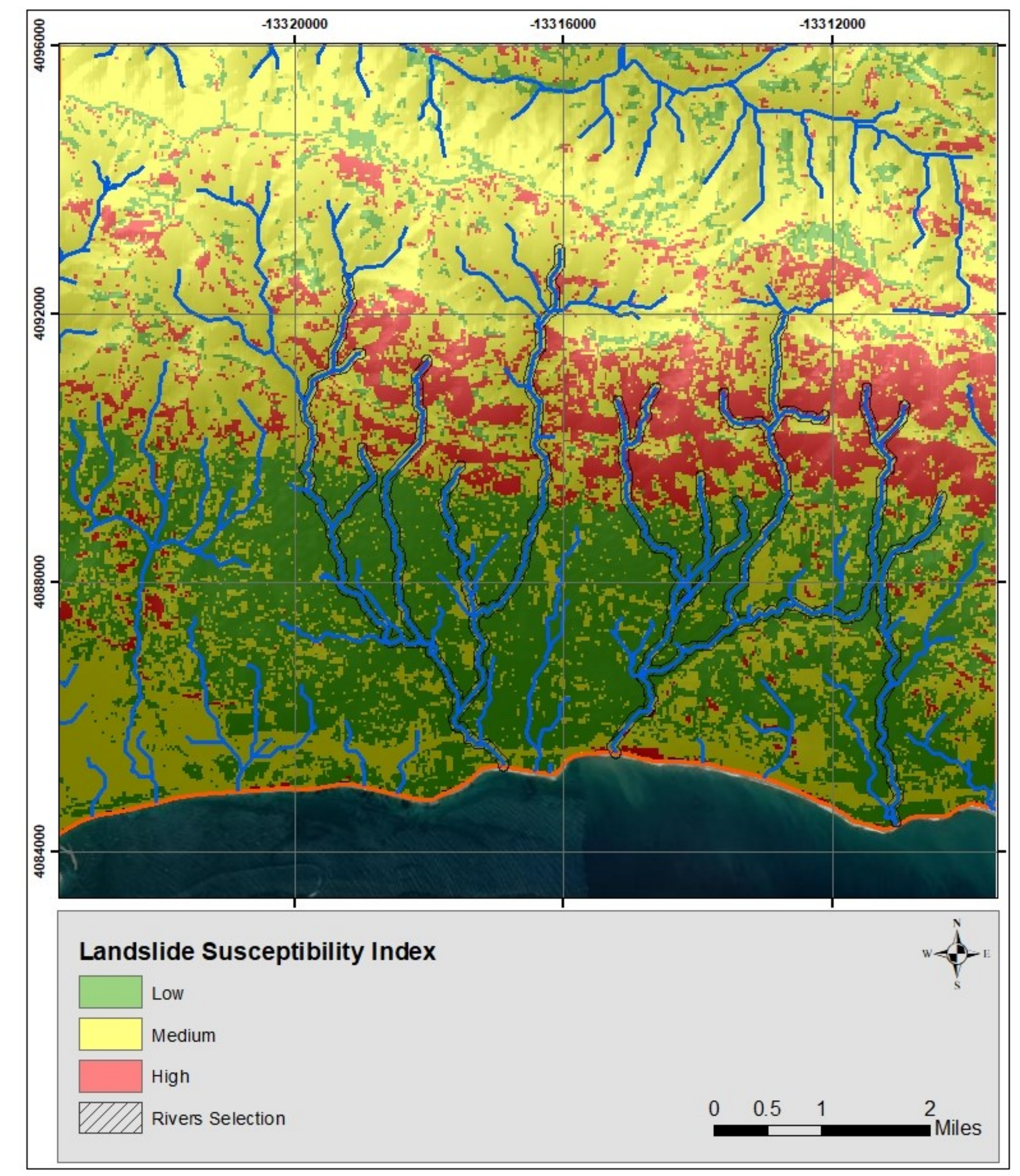
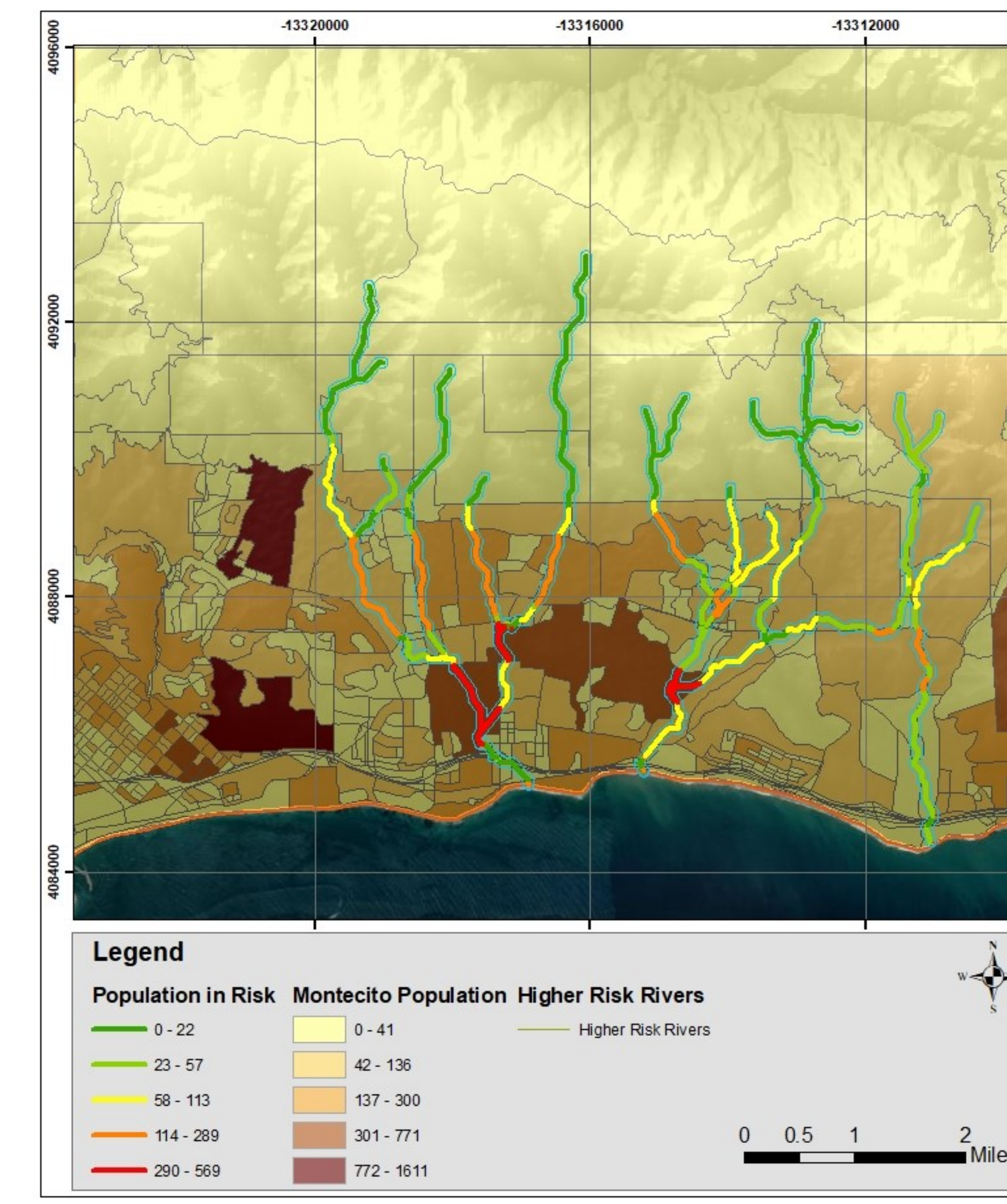


Figure 2: Graphic representation of landslide susceptibility index calculation

RESULTS AND DISCUSSIONS





- The study area was classified into two susceptibility categories based on the LSI values: low, medium, and high. The LSI analysis calculation involved key triggering factors known for inducing the previous landslides that occurred in the area as slope, absence of vegetation, geology, and distances to drainage.
- The model assigned higher weight values to steep slopes and unvegetated, followed by the weakest geology affected by fire, and the stream network areas within 200 m are the higher affected. After the fire, the soil on a steep slope becomes unconsolidated increasing its risk to overcome the shear strength influenced by intense raining periods and resulting in a landslide failure.
- The LS map shows that the northern region of Montecito, on the mountain range has the greater potential for a new landslide occurrence. This area is characterized by steep slopes that its vegetation hasn't been recovered after more than 3 years. Leading bare slopes vulnerable to new slop failures.
- Areas closer to drainage within the 200 m perimeter in the steep slopes, can serve as a discharging channel transporting fast-moving slurries of water, soil, and rock. Merging it with the streams sediments and water, moving down the hills, and rising the settlement on the base of the mountain.
- Heads of rivers and creeks affected by the fire with low or no vegetation recovery are the most susceptible.
- The population closer to the rivers selected is at risk to suffer more debris/mudslides in the coming future with the current conditions of the soil in the burned areas.

CONCLUSION

- The GIS-based assessment for this research, was able to identify areas that still are affected by the Thomas Fire and its potential for a new slope instability that again, may again affect the Montecito population.
- This analysis mapped out the study area based on the susceptibility of the areas to the occurrence of a new landslide as higher risk and low risk by considering the most important factors that influenced the previous landslide.
- The headwater's river with higher susceptibility can be the channel to transport the debris/mud material and impact the population downhill.
- The location of the population on the alluvial fans from the mountain range and the continuous climate change leading to more wildfire, storms with extreme precipitation, and the high degrees slope are the environments for mudslide generation.
- The importance of this research and its modeling is applicability for effective land use management and making the population aware of the imminent hazard.