A GIS-BASED VOLCANIC HAZARD AND RISK ASSESSMENT OF ERUPTIONS SOURCED WITHIN VALLES CALDERA, NEW MEXICO

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ABSTRACT

The objective of this study is to evaluate the spatial extent of a possible future eruption using a GIS-based volcanic hazards tool designed to simulate pyroclastic fallout and density currents (PDCs) as well as lava flows [1] and to assess the social and economic vulnerability of the area at risk. Simulated pyroclastic fall deposits originating from the El Cajete crater are calibrated to isopach and lithic isopleth maps of the Lower and Upper El Cajete as constructed by [2]. The calibration of PDCs is based on the distribution and run-out of the Battleship Rock Ignimbrite. Once calibrated, hazards are simulated at two other vent locations determined from probability distributions of structural features. The resulting hazard maps show the potential distribution of pyroclastic fall, PDCs and lava flows, indicating areas to the S/SE of Valles Caldera to be at greatest risk.

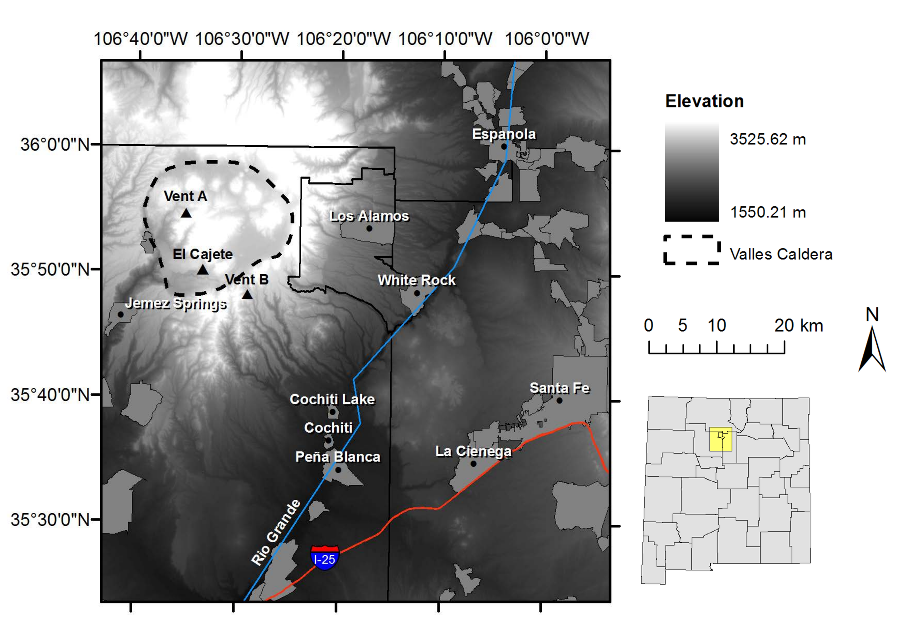
To assess hazard preparedness, social vulnerability is evaluated for all census-designated places (CDP) within the study site. Based on methods by [3], twenty-four variables were selected as proxies of social vulnerability and a principal component analysis is used to generate eight components, which accounts for 64% of the total variance. The eight component scores are summed into a final score for each CDP, and the standard deviations from the mean of the scores is mapped with the CDPs, allowing for an easy visualization of areas considered more socially vulnerable.

Economic vulnerability is evaluated through a multi-criteria evaluation of population, infrastructure, road types and land use [4]. Each variable is categorized and assigned a value representing relative vulnerability based on cost and importance. The variables are assigned weights relative to one another through a pairwise comparison and summed together into a final map showing the distribution of economic vulnerability, which is useful when used with the hazard maps for targeting areas for mitigation to reduce economic loss.

In order to evaluate the overall risk, the hazard maps and vulnerability assessments are aggregated through weighted linear combination and pairwise comparison matrices, creating a total of five risk maps. Although the actual maps provide greater detail, overall, based on the criteria chosen, the risk maps show that ash fall has the greatest impact, effecting areas up to 50 km S/SE of the caldera, including highly vulnerable cities, such as Los Alamos, White Rock, and Santa Fe. The PDCs and lava flow hazards, however, impact significantly smaller areas, primarily disturbing forested land. The methodology presented in this paper allows for a robust analysis of the risks posed by eruptions sourced from the Valles caldera and is especially useful in focusing mitigation strategies to reduce the loss from such hazard events.

BACKGROUND

- JVF is situated at the intersection of the Rio Grande Rift and Jemez Lineament in north-central New Mexico
- Most recent activity at Valles caldera were the East Fork Member eruptions ~55 to ~40 ka
  - El Cajete Pyroclastic Beds
  - Battleship Rock Ignimbrite
  - Banco Bonito Lava Flow
- Valles caldera is currently dormant



- Valles caldera does not pose an imminent threat, but the nearby populations create great potential for destruction of life, property, and possessions if an eruption was to occur
- Study site (left) is composed of a 75 x 80 km area encompassing 55 census designated places (CDPs), including major cities such as Los Alamos, Santa Fe, Espanola, and White Rock

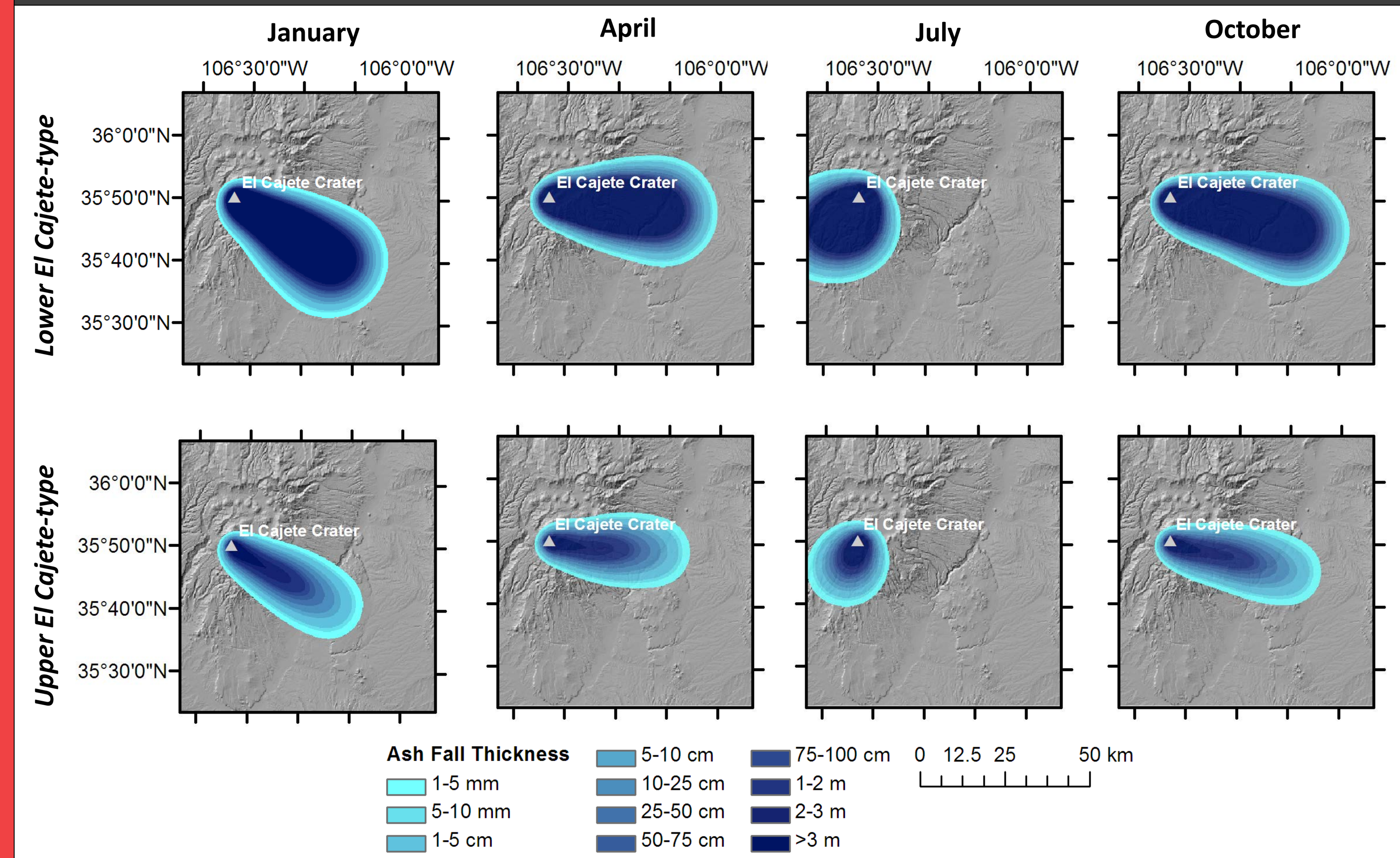
[1] Felpeto, A., 2009. VORIS a GIS-based tool for volcanic hazard assessment user's guide.

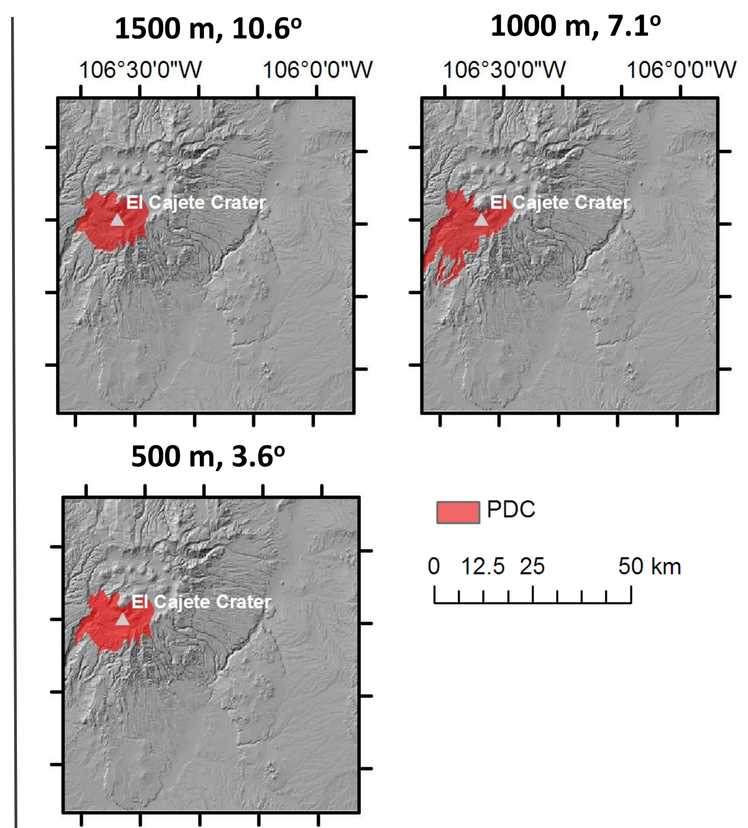
[2] Wolff, J.A., Brunstad, K.A., Gardner, J.N., 2011. Reconstruction of the most recent volcanic eruptions from Valles caldera, New Mexico. Journal of Volcanology and Geothermal Research 199, 53-68.

[3] Hazards and Vulnerability Research Institute (HVRI), 2012. Social vulnerability index for the United States – 2006-10, http://webra.cas.sc.edu/hvri/products/sovi.aspx.

[4] Aceves-Quesada, J.F., Salgado, J.D., Lopex-Blanco, J., 2007. Vulnerability assessment in a volcanic risk evaluation in Central Mexico through a multi-criteria-GIS approach. Natural Hazards 40, 339-356.

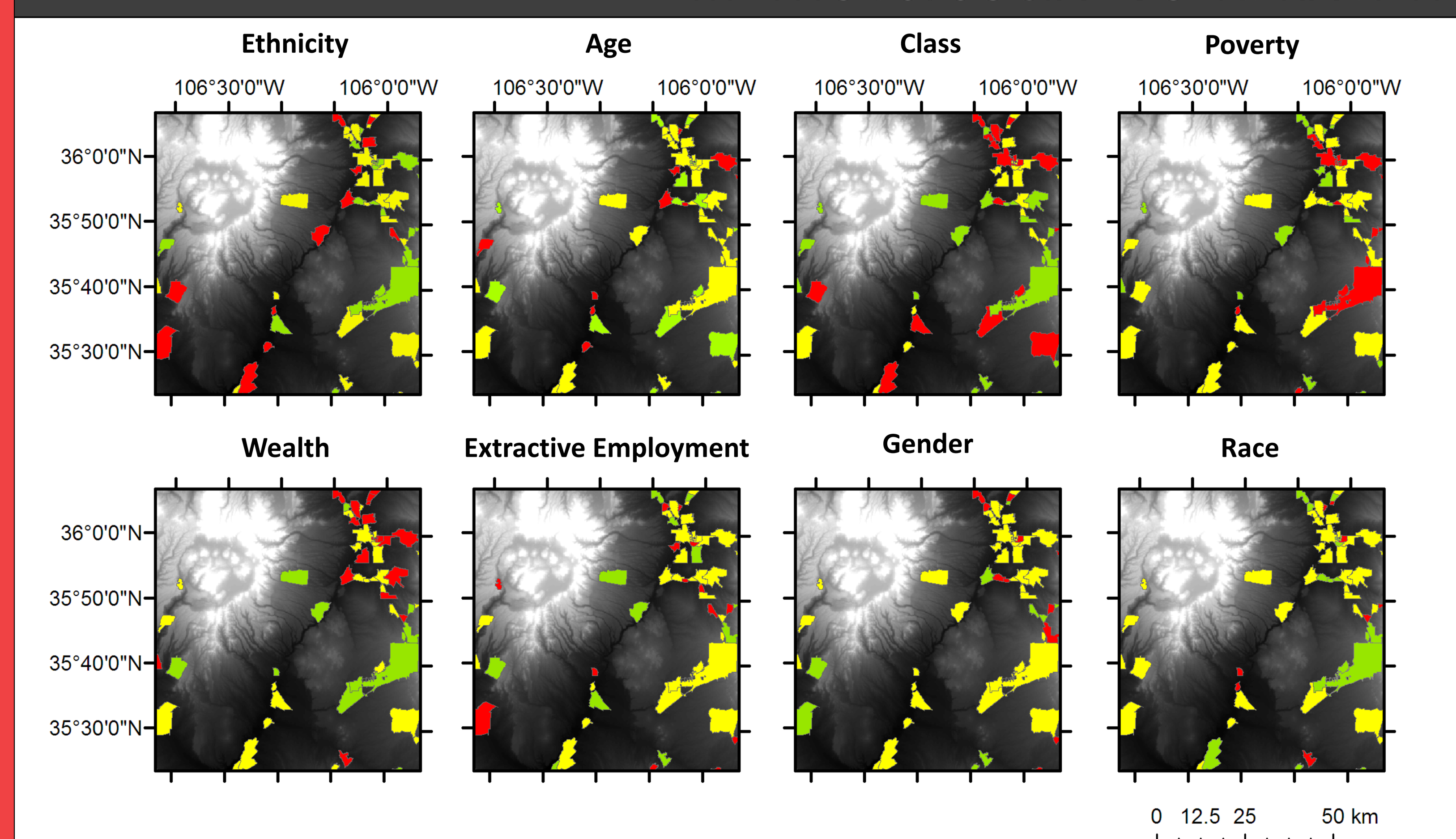
METHODS: VOLCANIC HAZARD SIMULATIONS

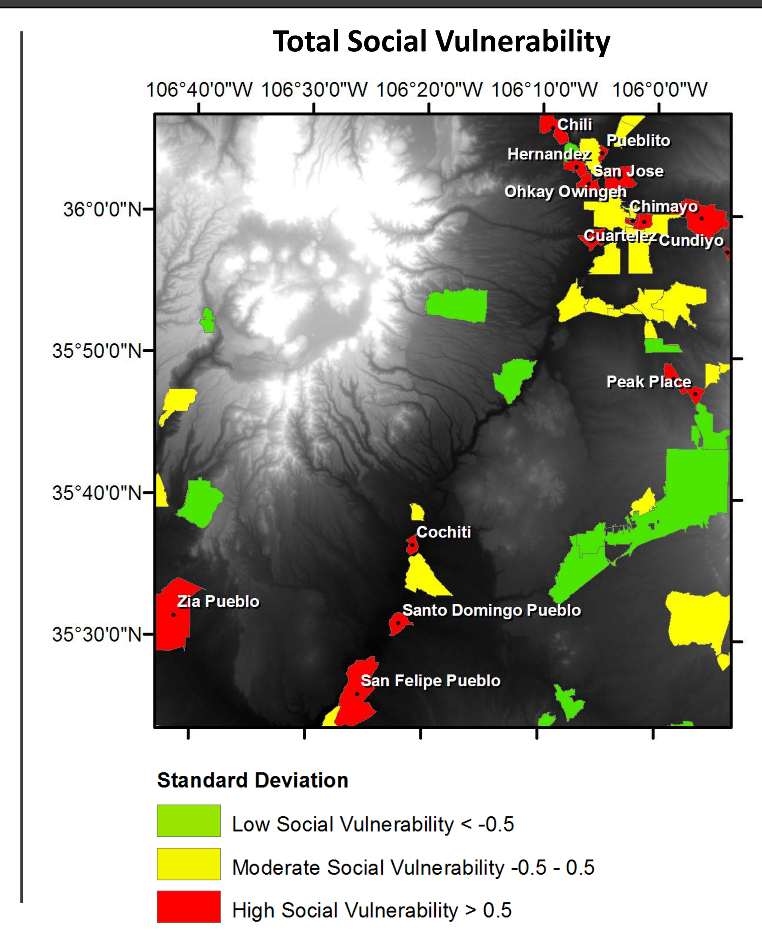




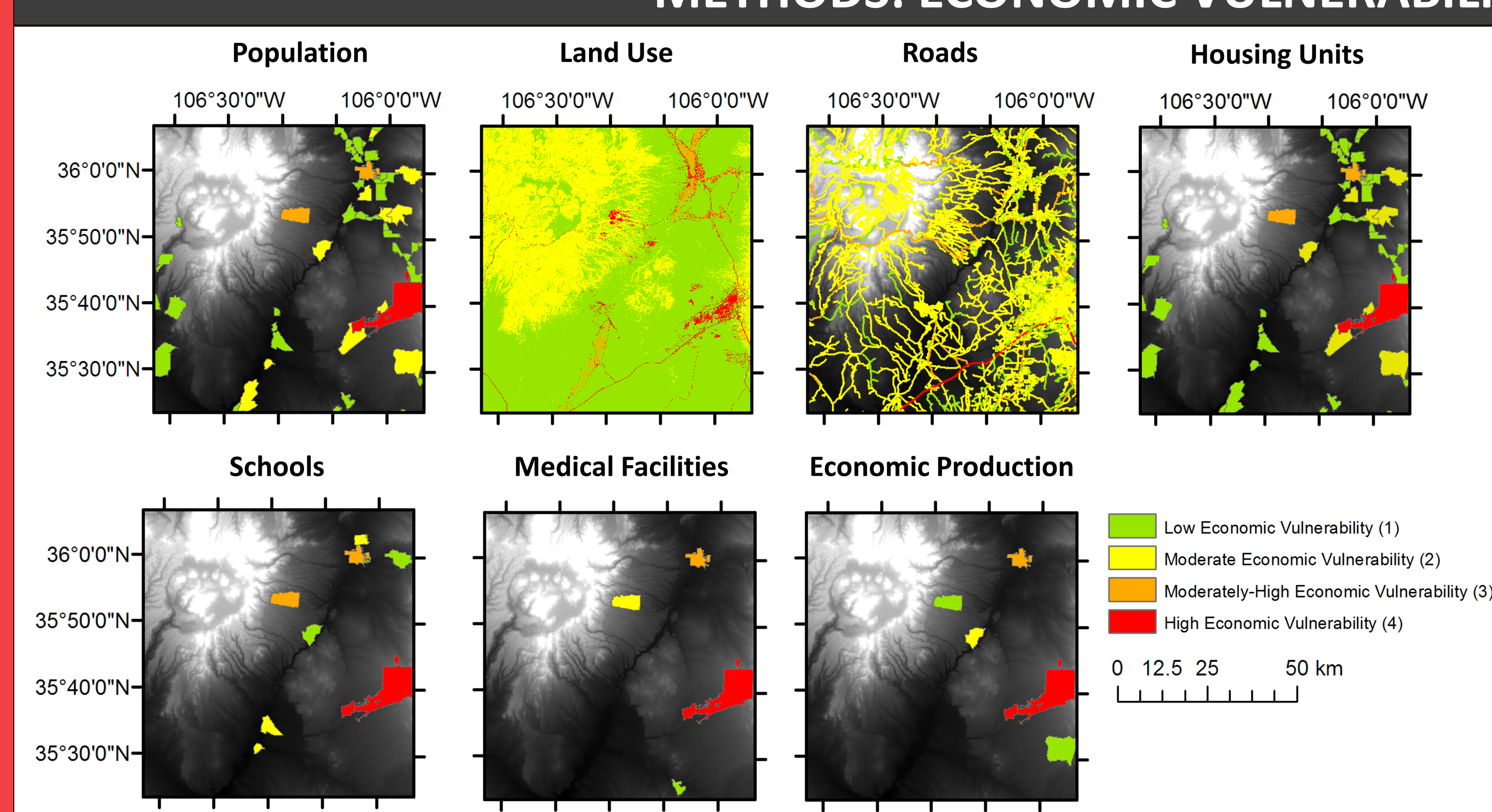
Simulated ash fall calibrated at El Cajete crater within field data from the Lower and Upper El Cajete eruptions and modern wind data (left). Simulated PDCs with varying collapse equivalent heights and angles at El Cajete crater (above). Based on calibration with the Battleship Rock Ignimbrite, a collapse height of 1500 m and angle of 10.6° were used in the final hazard simulations at vents A and B.

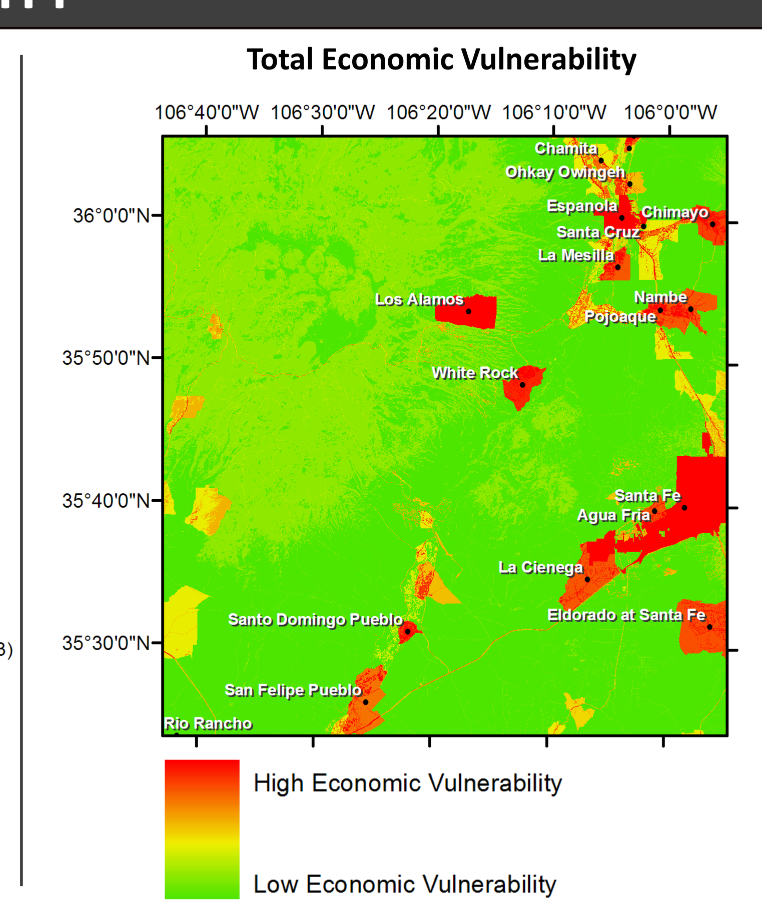
METHODS: SOCIAL VULNERABILITY



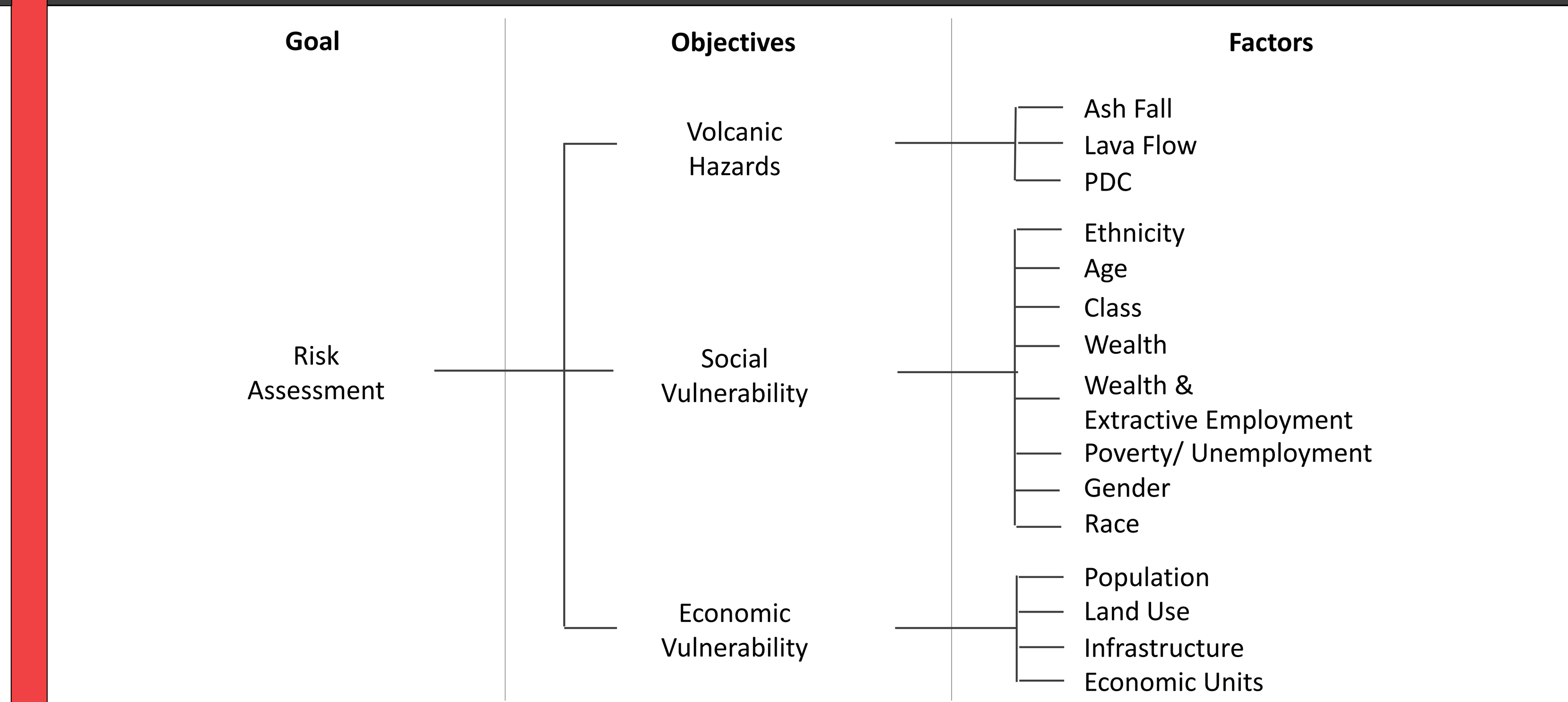


METHODS: ECONOMIC VULNERABILITY

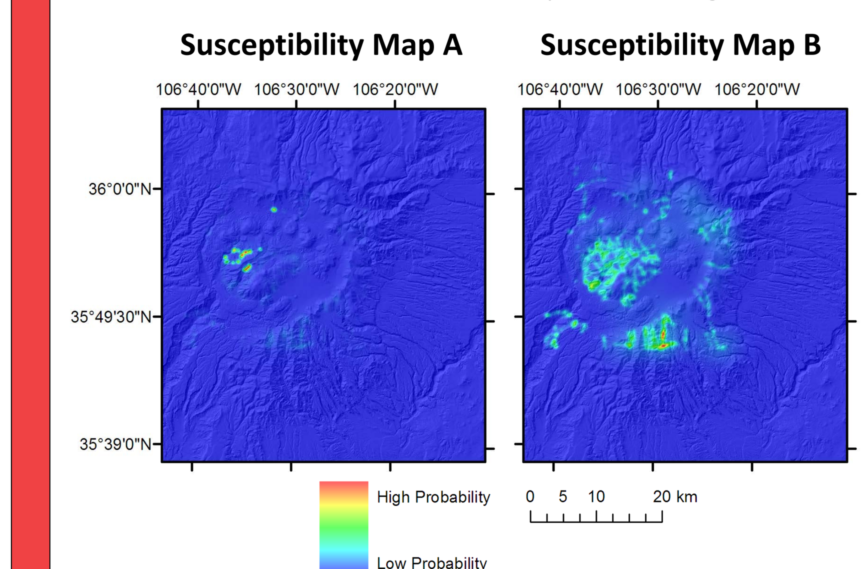




METHODS: CONCEPTUAL FRAMEWORK



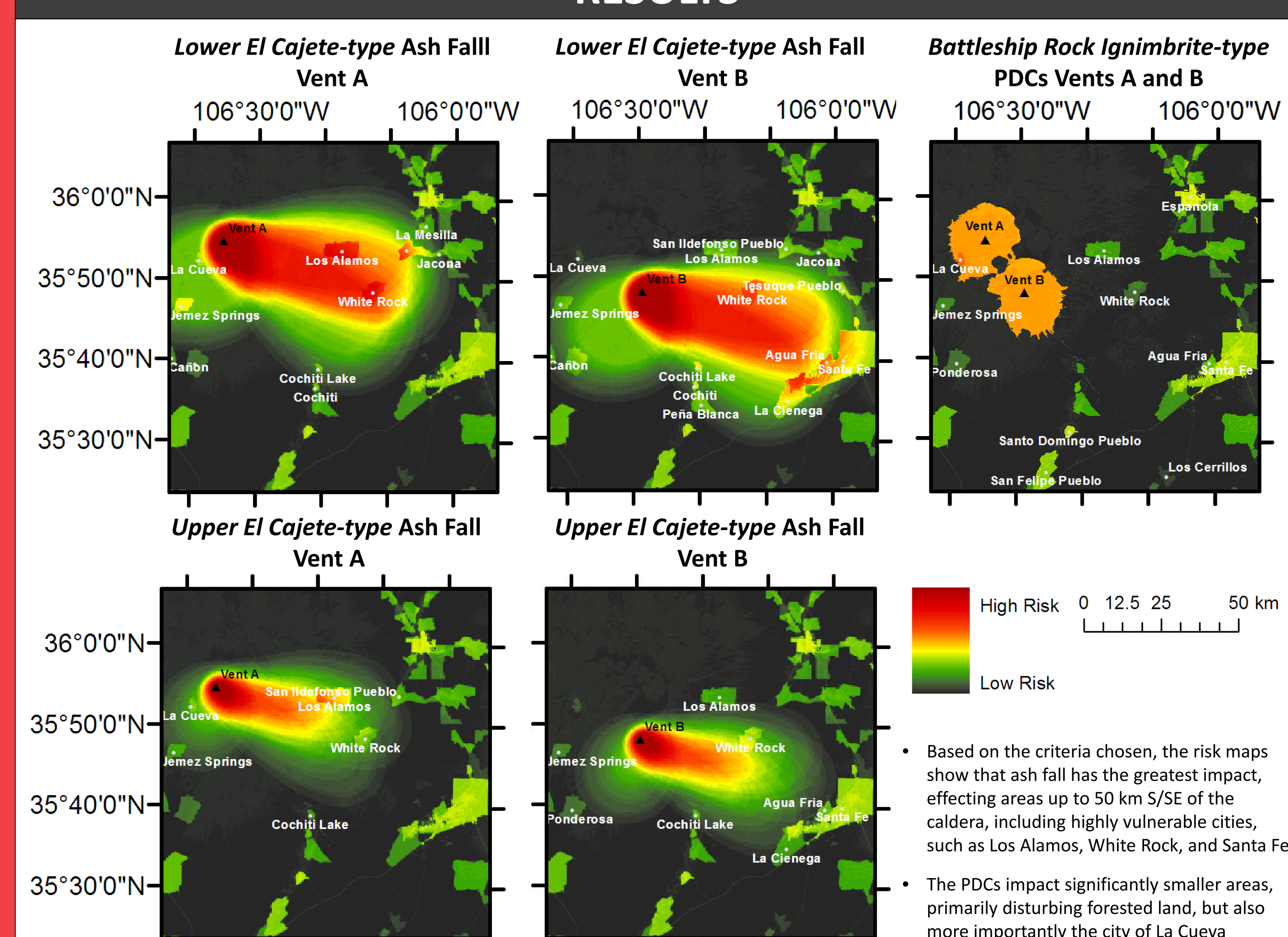
- Risk was evaluated through a multi-criteria evaluation (MCE) of three primary objectives, (1) the volcanic hazards, (2) social vulnerability, and (3) economic vulnerability
- Each objective was assessed through the evaluation of a series defining factors by various methods:
  - The spatial extent of the volcanic hazards was assessed through GIS simulations
  - The social vulnerability of each of the fifty-five communities within the study site was evaluated through a principal component analysis of eight statistically significant components
  - The economic vulnerability was assessed through its own MCE of four economically significant factors (population, land use, infrastructure, and economic production)
- After calibration, each hazard was simulated at predicted future vent locations A and B (below) and aggregated with social and economic vulnerability with a weighted linear combination



	Hazard	Social Vulnerability	Economic Vulnerability	Weight
Hazard	1	-	-	0.6
Social Vulnerability	1/3	1	-	0.2
Economic Vulnerability	1/3	1	1	0.2

Pairwise comparison matrix for determining the weighting of each objective in aggregating the hazards, social and economic vulnerability

RESULTS



- Based on the criteria chosen, the risk maps show that ash fall has the greatest impact, effecting areas up to 50 km S/SE of the caldera, including highly vulnerable cities, such as Los Alamos, White Rock, and Santa Fe
- The PDCs impact significantly smaller areas, primarily disturbing forested land, but also more importantly the city of La Cueva