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Abstract

California is infamously known for its likelihood of environmental hazards such as flooding, landslides, air pollution, and forest fires which can be attributed to the natural climate of the area as well as anthropologically influenced climate change. Air pollution also poses potential threats and dangers to the civilians of California as increasing populations and uses of fossil fuels continue to contribute to the growing issue of climate change. The goal of this study was to examine and analyze the geospatial trends environmental hazards in California such as landslides, air pollution, flooding, and forest fires. A weighted test, zone and slope reclassifications, and quantified tests were conducted in order to study the effects of climate change on risk level in California. It was found that the greatest air quality and fire risk is located within Central Valley while fire and landslide risk showed opposite effects. Areas of high environmental hazard risk and low income were scattered amongst the state but mainly concentrated in the northern and eastern areas of California.

Keywords

GIS, ArcGIS, California, flooding, landslides, air pollution, wildfires, income, risk assessment, satellite

Cover Page Footnote

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Keywords: GIS, ArcGIS, California, flooding, landslides, air pollution, wildfires, income, risk assessment, satellite

Introduction

California has been infamously known for its likelihood of environmental hazards such as flooding, landslides, air pollution, and forest fires which could be attributed to the natural climate of the area as well as anthropologically influenced climate change (Adams et al. 2014; Harris 2017; Montgomery 2018; Hanson 2018). Air pollution also posed potential threats and dangers to the civilians of California as increasing populations and uses of fossil fuels continued to contribute to the growing issue of climate change (Benmarhnia 2017). Climate change additionally worsens air pollution, as ground-level ozone (O3) formed through reactions from sunlight and other air pollutants such as nitrous oxides. Ozone formation further accelerated under higher temperatures as well (Allen 2014). The effects of climate change that lead to dangerous natural events such as wildfires in California oftentimes created positive feedback loops that led to worsened conditions such as drought or inundation depending on regional circumstances (Barnard et al. 2018). Exposure to environmental disasters was also found to increase risk for long-term mental health disorders such as Post-Traumatic Stress Disorder (PTSD) and major depression (Lowe et al. 2015). Evidence suggested that lower income areas may be purposefully placed in locations that exposed them to more environmental disasters as well as lower air quality due to factors like environmental racism and a lack of political change (ESRI and Geiling 2015).

The goal of this study was to examine and analyze the geospatial trends of environmental hazards in California such as landslides, air pollution, flooding, and forest fires. We also compared the risk of these hazards to average income within California census tracts. Two research questions were inquired in this study: Where in California were people exposed to more environmental hazards? Additionally, were California areas with lower overall annual income more exposed to environmental hazards?

Methods

In order to analyze risk of environmental hazards in California on a census-tract scale, we followed modified methods of Carver, Tricker, and Landres (2013) by creating ranks and weights of qualities to create a visual representation of a certain characteristics of the environment. In order to get a holistic perspective of environmental hazard risk, we quantified the risk of air pollution (specifically ozone and particulate matter) exposure, landslides, flooding, and fire by assigning specific properties of the hazards a risk-ranking from 0 (smallest risk) to 4 (highest risk). To finalize overall hazards risk, we did a weighted overlay analysis, combining the four environmental hazards. Finally, we compared individual and overall environmental hazards risk to income to determine if there was a relationship between risk and income.

To quantify flood risk, we reclassified the flood zones of California and assigned them a risk-ranking from 0 to 4 (*Table 2*). For the fire quality, we directly used the fire threat raster from the California Fire Resource Assessment Program (FRAP) that was already classified into five classes based on severity of fire threat (*Table 3*).

To quantify landslide risk, we first reclassified the slope of California into a risk ranking (*Table 4*). To account for the influence of soil compaction and stability, we reclassified each land classification in the National Land Cover Database into five classes (*Table 5*). Because wildfires loosen soil and increase landslide risk (Montgomery 2018), we used the overall fire risk as a quality of landslide risk. To generate a holistic landslide risk character, we conducted a weighted overlay analysis, giving both slope and fire risk a weight of 40%, because a landslide is dependent on slope and fires can significantly increase landslide chances. We gave land cover a weight of 20%.

To quantify risk to exposure of air pollution in California, we quantified the risk of exposure to both ozone and particulate matter $PM_{2.5}$ microns. Ozone and particle pollution were selected as the two indicators of exposure to air pollution due to their direct and severe effects on human health: ground-level ozone can lead to respiratory deficiency and asthma while particulate matter can cause an increase in heart attacks along with other decreased lung functions (Environmental Protection Agency 2018). We assigned both ozone and $PM_{2.5}$ a risk-ranking based on the amount of each in a daily maximum 8-hour period (*Table 6*; *Table 7*). We then conducted a weighted overlay analysis of these two pollutants, giving each equal ranking (50%) due to their high cost to human health.

To quantify the overall risk of environmental hazards in California, we conducted a weighted overlay analysis of all four environmental hazards. Specifically, we gave fire risk a weight of 30% because of the high wildfire frequency of California and flood hazard a weight of 20% because the semi-arid climate results in little precipitation to cause much flooding (Barnard et al. 2018). Meanwhile, we assigned both landslide risk and air pollution risk a ranking of 25%, as they are subject to change but still have a rather impactful influence on the natural disasters that could occur within a given area (Barnard et al. 2018).

In order to analyze the relationship between socioeconomic class and environmental hazards exposure risk, we used GeoDa to generate a standardized scatterplot of income versus overall natural hazards risk within the California census tracts. We selected the census tracts with both average to below-average income and average to above-average natural hazards risk so to evaluate spatial distribution of higher risk, poorer areas. We also created scatterplots of each of the four individual environmental hazards in comparison to income to closely analyze any possible correlations between each of the hazards to income that may affect the overall relationship.

Results

The severity of flood risk varied throughout California, as the greatest amount of risk lies along a vertical medial line of the state from the city of Red Bluff to Rosamond within Central Valley. The lowest areas of flood risk tended to cluster together such as the southeastern region of California as well as several areas along the northern and eastern part of the state (*Figure 1a*.). Areas around the Central Valley between Red Bluff and Rosamond as well as part of southeastern California were least likely to be impacted by landslides and fires (*Figure 1b*., *1c*.). The greatest air quality risk was located within Central Valley and the amount of risk gradually decreased in adjacent areas (*Figure 1d*.).

In regard to overall environmental hazard risks, the areas of the lowest amount of risk included regions of southwestern California and a small number of northern areas at the northern end of Central Valley (*Figure 2*). The eastern edge of the valley and the southern areas of the state had the highest overall natural hazard risks (*Figure 2*). There was not a clear spatial pattern of census tracts with average to above-average risk and average to below-average income (*Figure 3*). There was not a clear relationship between any individual environmental hazard risk and income (*Figure 4*). There was also not a clear relationship between overall environmental hazard risk and income (*Figure 5*).

Discussion

Flood risk and air pollution risk were highest around the Central Valley region (*Figure 1a., 1d*). Fire risk and landslide risk were lowest in this region (*Figure 1b., 1c*.). Overall, the areas in California with the highest natural hazard risk bordered the Central Valley region (*Figure 2*). There was not a clear relationship between income and any or overall natural hazard risk (*Figure 4, Figure 5*).

There did not appear to be a clear spatial pattern of areas with average to above-average hazards risk and average to below-average income (*Figure 3*).

Our results could be generally explained by the topography of the region. The Central Valley, for example, would have had a high flood risk due to its flat elevation (California Physical Map 2018). Its flat elevation also explained the low landslide risk. Additionally, the Central Valley was quite developed, minimizing the number of shrubs, trees, and grasslands that could have otherwise had high fire risk (Hanson 2018). In contrast, high fire risk areas were composed of more grasslands and shrubs that caused a positive feedback event of wildfires (Hanson 2018). Finally, the mountains surrounding the Central Valley could trap ground-level ozone and PM2.5 within its borders. (Irceline 2018). There was less air pollution risk along the western coast due to the strength and high frequency of coastal winds which pushed air pollution eastbound (Adams et al. 2014). In reference to overall risk, the relatively higher weight of fire risk (30%) and relatively lower weight of flooding (20%), may explain the high risk in the areas surrounding the central valley and the low risk within it. With landslide risk also incorporating fire risk, fire risk significantly impacted overall natural hazard risk.

Our overall results were not supported by previous studies. One study by Bolin, Boone, and Grineski (2015) found that affluent populations were oftentimes more exposed to certain natural hazards, such as flooding, as affluent populations could afford insurance to mitigate the risks while enjoying and affording the luxuries associated with water-front property. The study also found that less affluent populations often resided near areas with high air pollution, as there is not any insurance that could mitigate the costs of this hazard (Bolin et al. 2015). Several other studies have found that lower-income communities were more exposed to air pollution, although other factors such as race also play a role in distribution (Brulle and Pellow 2006; Marshall 2008; Clark et al. 2014).

Our study is important because it allows local governments to better prepare and mitigate environmental hazards. It is important to understand the geographic trends of environmental hazards in order to utilize the proper, necessary resources to help high-risk communities. This study was not without limitations. For one, we had to give a ranking of 0 (lowest risk) for areas with no data (such as areas with undetermined flood zones). Additionally, we had to simplify the criteria of risk for each natural hazard as there are an immeasurable number of factors that could influence flooding, landslides, and fires. However, in order to quantify the complexity of these hazards, we had to simplify the factors.

To further this study, further research should include an in-depth analysis into how varying the weights when quantifying individual natural hazards risk (such as flooding) as well as when quantifying the total environmental hazard risk in California will impact the findings. Further research should also incorporate additional environmental hazards, such as drought, to expand upon the current results. It would also be valuable to assess the relationship of risk to natural hazards with other socioeconomic factors, such as race.

Figures and Tables

Table 1. *Data sources*

Name	Who Created	Time Valid	Description
National Flood Hazard Layer	FEMA	2018	Shapefile of flood data for California, including flood zones
California Air Pollution 2018	Office of Environmental Health and Hazard Assessment	2018	Shapefile of California with data of air pollution exposure (including but not limited to ozone and particulate matter 2.5), respiratory health diseases, and income
National Land Cover Database 2011	USGS	2011	Raster of the land use types in California
Fire Threat in California	State of California Fire Resource and Assessment Program (FRAP)	2005	Raster of fire risk in California. Created by combining fire frequency and potential fire behavior.
California Shapefile	State of California	2018	Shapefile of the state of California
California 90m DEM	Data Basin- from NASA and NGA data	2000	(An incomplete) Digital Elevation Model of California at 90-meter resolution
California 90m DEM-Tiles	USGS	2013	Tiles of California and Arizona Digital Elevation Models to complete the California DEM
California Census Tracts	American Fast Finder	2012-2016	Table of census data for census tracts of California, including but not limited to income data.
California Census Tracts Shapefile	US Census Bureau	2010	Shapefile of California census tracts

***Table 2**. Rationale for Reclassified Flooding Ranking (Second Look Flood, N.d.)*

Flood Zone	Rank	Reason
"Area not included"; "D"	0	"D" rankings are possible but undetermined flood hazard areas.
"X"	1	Area of minimal or moderate flood hazard
"A"; "A99"; "AE"; "AH"; "Open Water"	2	Areas with a 1% annual chance of flooding or areas where clear base flood elevations
"AO"	3	Area with a 1% or greater chance of flooding each years with an average depth of 1-3 feet
"V"; "VE"	4	High risk coastal areas

***Table 3**. FRAP Fire Threat Rankings*

FRAP Value	Our Rank	Definition
-1	0	Little to No Threat
1	1	Moderate
2	2	High
3	3	Very High
4	4	Extreme

Table 4. *Rationale for Reclassified Slope Ranking (Clark et al. 2018)*

Slope Degrees	Rank	Reason
0-1	0	Need some slope in order for a landslide to occur
1-10	1	Steep slopes not a necessary prerequisite for landslides to occur. Gentle slopes at 1–2 degrees can also cause landslides
10-20	2	Increasing slope allows for greater chance of mass wasting
20-40	3	Major landslides are often associated with slopes from 20-40 degrees
40-83	4	Extremely steep

Table 5. *Rationale for Reclassified Land Cover Ranking (Montgomery 2018)*

Land Cover	Rank	Reason
Open water Woody Wetlands Perennial Snow/Ice	0	Open water. High tree density in woody wetlands. Overall little soil to mass waste.
Deciduous forest; Emergent herbaceous wetlands; Evergreen forest; Mixed forest	1	High tree density keeps soils compact and prevents mass wasting
Shrub/scrub; Developed High Intensity	2	Shrub/scrub has some roots to stabilize soils; Little soil to mass waste in highly developed areas
Cultivated Crops; Pasture/Hay; Developed Medium Intensity; Herbaceous	3	Herbaceous, Cultivated crops, and pasture/hay lands have little roots to stabilize soils; A little bit of soil to mass waste in medium
Developed Open Space; Low Intensity; Barren Land; Unclassified	4	Developed Open Space, Low Intensity, and Barren land have little to no roots or structures to compact and stabilize soils.

Table 6*. Rationale for Reclassified Ozone Ranking* (ESRI and Geiling 2015)*

Ozone (ppm)	Rank	Reason
0.026- 0.34	0	Equal interval division rounded based on EPA standard of 0.070 as acceptable ozone level, noticeable amounts and respiratory effects, painless
0.3401 - 0.043	1	Uncomfortable patterns of breathing in some individuals
0.04301- 0.051	2	Coughing and throat irritation, more frequent episodes of coughing
0.05101 - 0.060	3	Chest pain, coughing, shortness of breath
0.0601- 0.068	4	Meets upper end of EPA standard - chest pain, intense coughing, difficulty breathing for individuals both with and without asthma

*Based on the amount of each in a daily maximum 8-hour period

Table 7*. Rationale for Reclassified Particulate Matter ($PM_{2.5}$) Ranking* (EPA 2018)*

PM	Rank	Reason
0 - 3.92	0	Equal interval division rounded based on range of 0-19.60 PM2.5 annually in California using 7.89 CA state average- particles linger in atmosphere and are breathed into lungs
3.9201 - 7.84	1	Slightly more acidic waters and possible irritation of throat and eyes
7.8401 - 11.76	2	Acidic waters and hazy air, depletes nutrients in soil
11.7601 - 15.68	3	Exertion experienced by sensitive individuals with increased possibilities of the following: nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms
15.6801 - 19.60	4	Lack of oxygen intake along with nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, and premature death

*Based on the amount of each in a daily maximum 8-hour period

Figure 1. *Four Risks of Environmental Hazards in California*

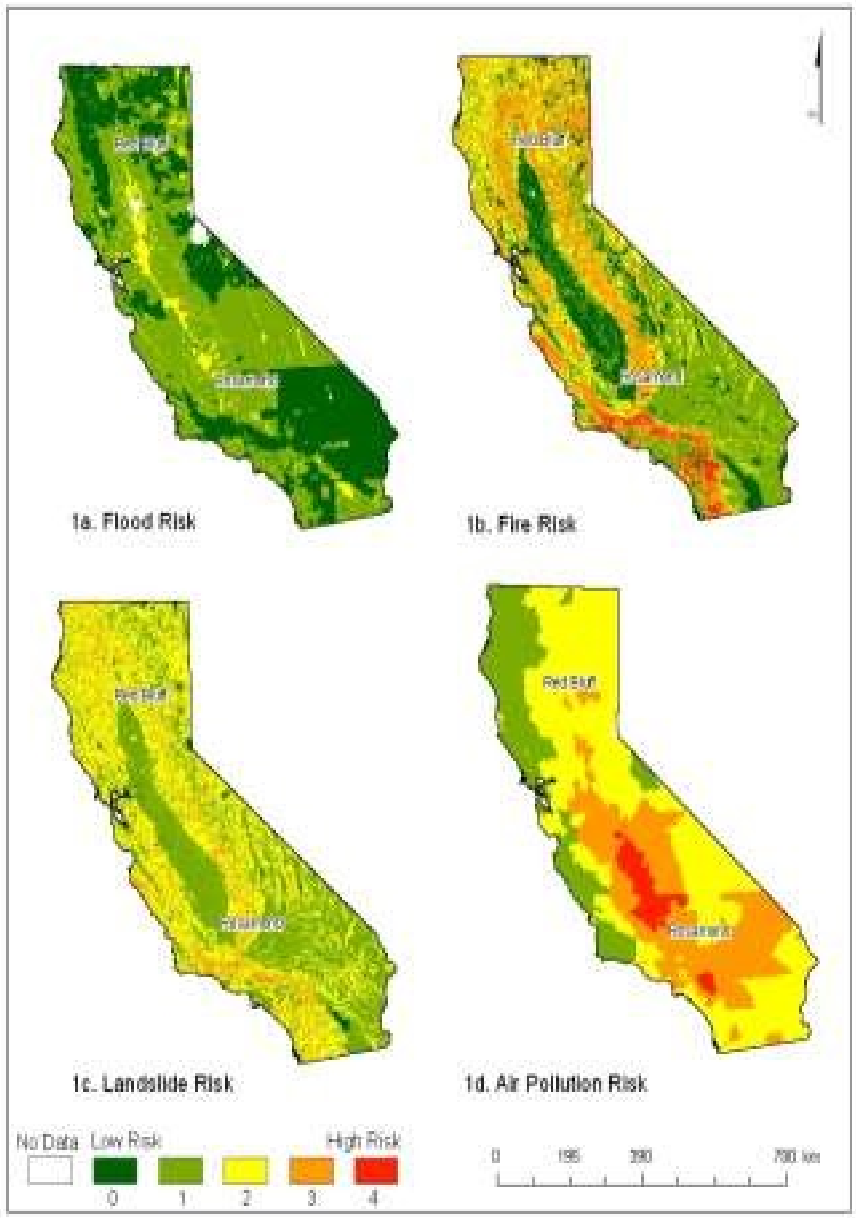


***Figure 2**. Overall Natural Hazard Risks in California*

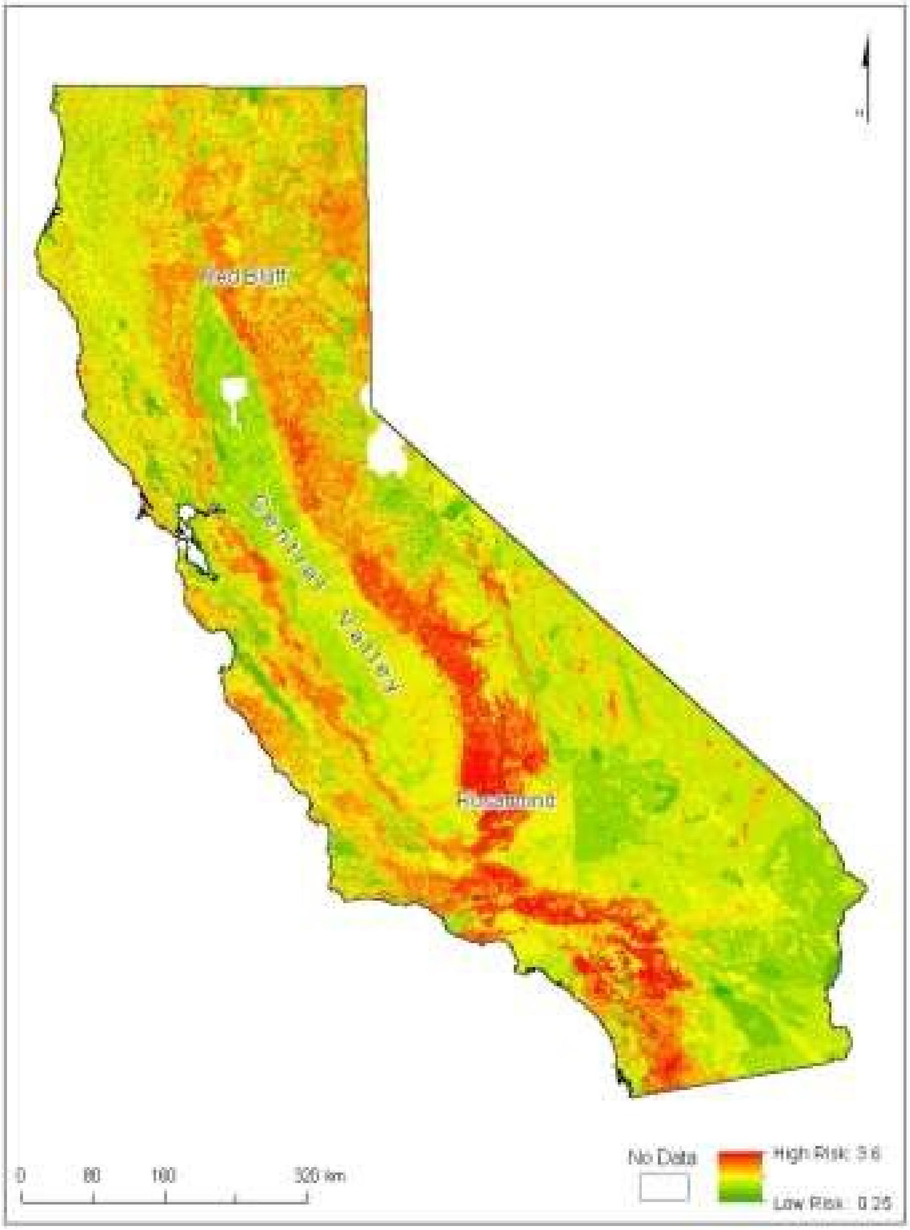


***Figure 3**. Overall High Environmental Hazard Risks Areas with Low Income in California*

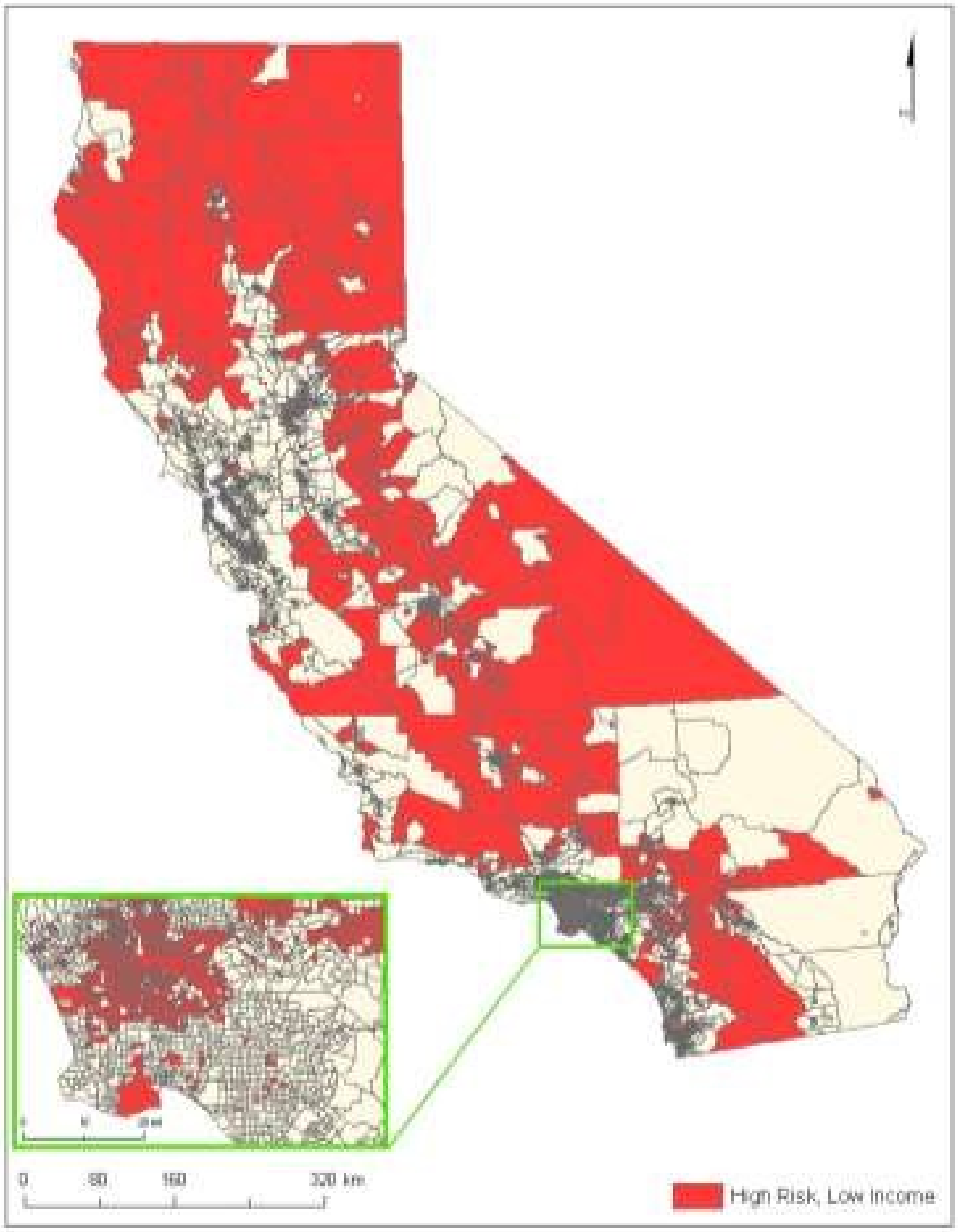


***Figure 4**. Scatterplots of Relationship Between Income and the Four Environmental Hazard Risks of Flood, Fire, Landslide, and Air Pollution.*

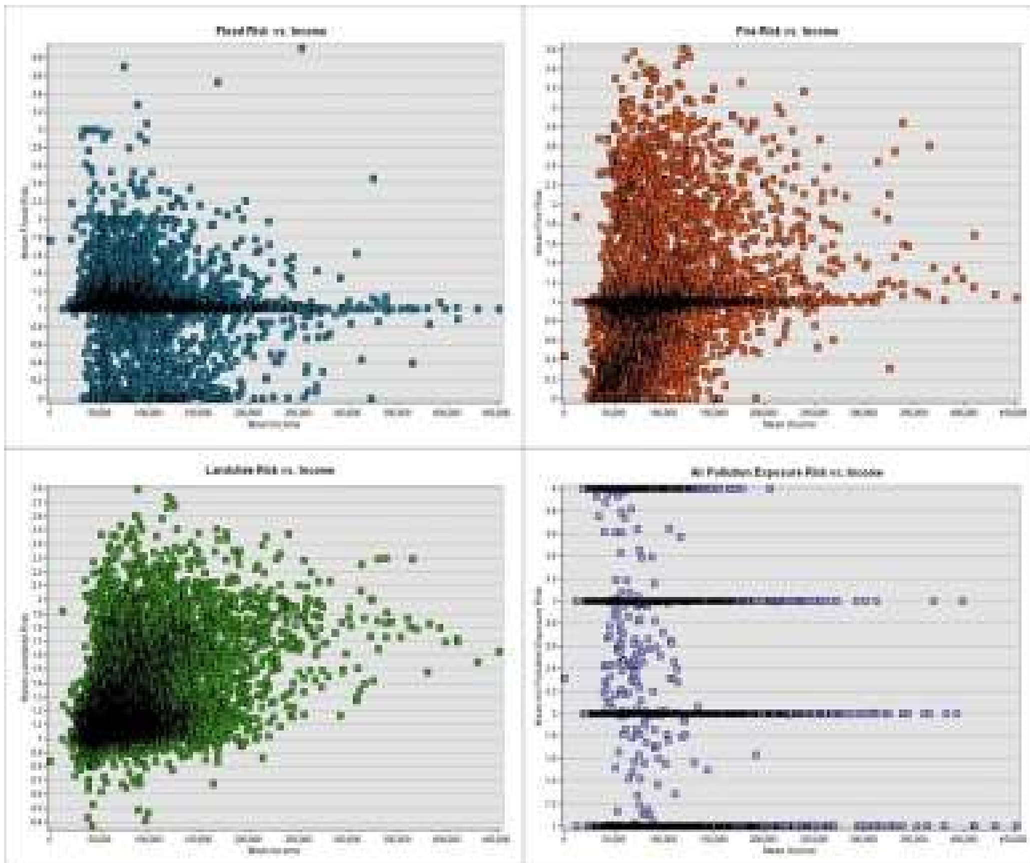
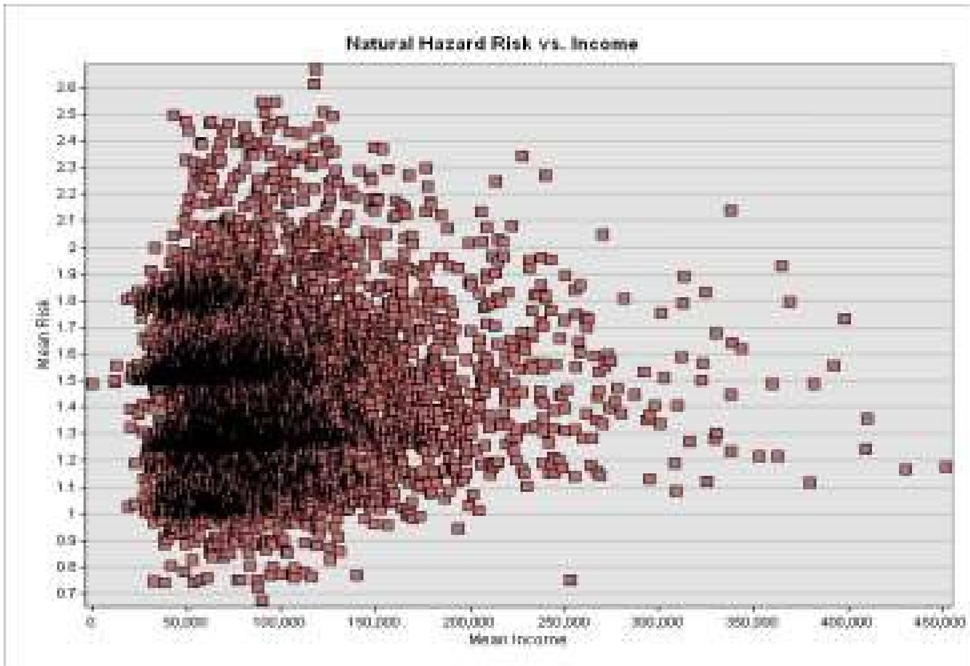


Figure 5. *Scatterplot of Relationship Between Income and Overall Natural Hazard Risk from Flooding, Fires, Landslides, and Air Pollution.*



References

Adams, Peter N., Barnard, Patrick L., Erikson, Li H., Eshelman, Jodi, Foxgrover, Amy C., Hapke, Cheryl, van Ormondt, Maarten, and Peter Ruggiero. 2014. "Development of the Coastal Storm Modeling System (CoSMoS) for Predicting the Impact of Storms on High-Energy, Active-Margin Coasts." *Natural Hazards* 74(2):1095-1125.

Allen, Jeannie. 2004. "Tango in the Atmosphere: Ozone and Climate Change." *NASA: Earth Observatory*. Accessed December 9, 2018. https://earthobservatory.nasa.gov/features/Tango.

Barnard, Patrick L., Erikson, Li H., Espejo, Antonio, Hegermiller, Christie A., Limber, Patrick W., Mendez, Fernando J., O'Neil, Andrea, Ruggiero, Peter, and Katherine A. Serafin. 2018. "Identification of Storm Events and Contiguous Coastal Sections for Deterministic Modeling of Extreme Coastal Flood Events in Response to Climate Change." *Environment Today* 140(1): 316-330.

Benmarhnia, Tarik. 2017. "Decomposition Analysis of Black-White Disparities in Birth Outcomes: The Relative Contribution of Air Pollution and Social Factors in California." *Environmental Health Perspectives* 125(10): 1-7.

Bolin, Bob, Boone, Christopher, and Sara Grineski. 2015. "Criteria

Air Pollution and Marginalized Populations: Environmental Inequity in Metropolitan Phoenix, Arizona." *Social Science Quarterly* 2:130-157.

Brulle, Robert J. and David Naguib Pellow. "Environmental Justice: Human Health and Environmental Inequalities." *Annual Review of Public Health* 27(1): 103-124.

California Department of Forestry and Fire Protection. 2015. "California Metadata." Accessed November 29, 2018. https://frap.fire.ca.gov/data/statewide/FGDC_metadata/fthrt05_1_metadata.xml.

Carver, Steve, Tricker, James, and Peter Landres. 2013. "Keeping It Wild: Mapping Wilderness Character in the United States." *Journal of Environmental Management* 131:239-255.

Clark, Lara P., Millet, Dylan B., and Julian D. Marshall. 2014. "National Patterns in Environmental Injustice and Inequality: Outdoor NO_2 Air Pollution in the United States." *PLoS ONE* 9(4): 1-8.

Environmental Protection Agency. 2018. "Ozone Generators that are Sold as Air Cleaners." Accessed November 28, 2018. https://www.epa.gov/indoor-air-quality-iaq/ozone-generators-are-sold-air-cleaners.

ESRI and Natasha Geiling. 2015. "These Maps Help Explain the Numerous, Complicated Factors Behind Income Inequality." *Smithsonian Magazine*. Accessed October 25, 2018.

https://www.smithsonianmag.com/innovation/these-maps-help-explain-numerous-complicated-factors-behind-income-inequality-180955941/.

Geology.com. 2018. "California Physical Map: Elevation Data." Accessed December 1, 2018. https://geology.com/topographic-physical-map/california.shtml.

Hanson, Chad T. 2018. "Landscape Heterogeneity Following High-Severity Fire in California's Forests." *Wildlife Society Bulletin* 42(2): 264-271.

Harris, Ruth A. 2017. "Overview of the HayWired Scenario Earthquake-Hazards Volume." *California Geological Survey* 1(1): 20-34.

Irceline. 2018. "What is PM10 and PM2.5?" Accessed December 2, 2018. http://www.irceline.be/en/documentation/faq/what-is-pm10-and-pm2.5.

Lowe, Sarah R., Sampson, Laura, Gruebner, Oliver, and Sandro Galea. 2015. "Psychological Resilience After Hurricane Sandy: The Influence of Individual- and Community-Level Factors on Mental Health after a Large-Scale Natural Disaster." *PLoS ONE* 10(5):1-15.

Marshall, Julian D. 2008. "Environmental Inequality: Air Pollution Exposures in California's South Coast Air Basin." *Atmospheric Environment* 42(21): 5499-5503.

Montgomery, David R. 2018. "Deadly California Mudslides Show the Need for Maps and Zoning that Better Reflect Landslide Risk." *The Conversation*. Accessed October 25, 2018. http://theconversation.com/deadly-california-mudslides-show-the-need-for-maps-and-zoning-that-better-reflect-landslide-risk-90087.

Second Look Flood. N.d. "Flood Zone Definitions." Accessed November 12, 2018. https://www.secondlookflood.com/floodzonedefinitions/.