Estimating and mapping wildfire risk and its impacts on residents

in the San Francisco Bay Area region

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Introduction

Among several natural disasters, wildfire is a major concern as it diminishes the air quality, living environment, and ecosystem. This project aims to develop the wildfire risk index (WRI) with different attribute factors associated best within research area. This includes drought level, land cover, land surface temperature, slope, distance to urban areas, elevation, and aspect. Specifically, the impact of these factors can be shown in the algorithm results and visualization in choropleth map. After reclassifying, the Weighted Overlay tool will be used for the wildfire risk model.

The project also spatially visualizes the demographic status against the wildfire risk. This includes the total population, the percentage of non-white (Hispanic, American Indian and Alaska Native, Asian, African American, Native Hawaiian and other Pacific Islanders) in 2020, and the median household income in 2021. This has shown the potential impact of wildfire on these groups, playing a key role in the wildfire risk status in the Bay Area at a granular level.

Method

This project uses the WGS_1984_UTM_Zone_10N Coordinate System, and all the layers will be converted to raster format.

| Layer	File Format	Data Source	Time Frame
Bay Area Counties	Vector	DataSF	Sep 7th, 2019
Drought Level	Vector	National Drought Mitigation Center	August 06th, 2021
Urban lands	Vector	Stanford Libraries	2008
Land Cover	Raster	MRLC	2019
MODIS	Raster	USGS	August 06th, 2021
DEM	Raster	USGS	2020
Fire	Vector	CAL Fire	2020
Population, Income, Races	Vector	Esri's demographic databases	2020, 2021

Table 1: Data source.
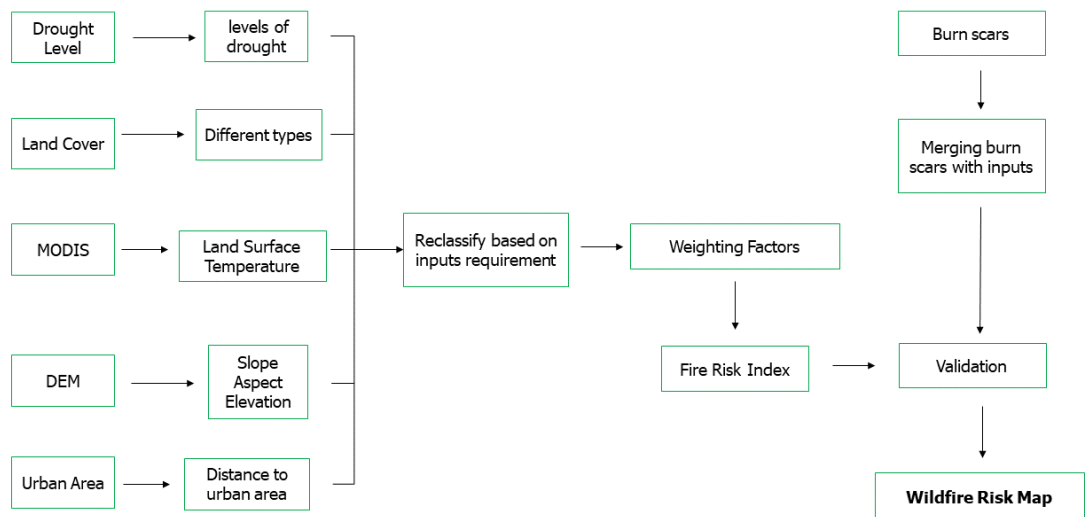
Figure 1: Workflow

The data analysis process follows upon the data collection completion, and it has two main steps. The first step is to create a wildfire risk model. The input factors include drought level (Heyer et al., 2018; Dennison et al., 2014), land cover (Heyer et al., 2018; Parajuli et al.2020; Littell et al., 2009; Dennison et al., 2014), land surface temperature (Parajuli et al., 2020; Dennison et al., 2014), aspect (Parajuli et al., 2020; Barros et al. 2013), slope, distance to urban areas, and elevation (Parajuli et al., 2020).

After reclassifying all these input factors, they have been weighted based on the equation below:

$$\textbf{WRI} = 25\%\textbf{D} + 25\%\textbf{LC} + 20\%\textbf{LST} + 10\%\textbf{S} + 10\%\textbf{DS} + 5\%\textbf{A} + 5\%\textbf{E} \textbf{ (1)}$$

(D: drought level; LC: land cover; LST: land surface temperature; S: slope; DS: distance to the urban areas; A: aspect; E: elevation)

With natural breaks (Jenks), the risk model is expected to have 5 levels: 1 - very low, 2 - low, 3 - moderate, 4 - high, and 5 - very high. The Jenks method provides the logical breakpoints in the data set by similar grouping values that "minimize differences between data values in the same class and maximize the differences between classes" (Slocum, 2009). The second step is to validate the model by overlaying the fire locations that happened in 2020 on the WRI map.

Drought level

The map below shows the drought level in the Bay Area before reclassifying the value into five levels.
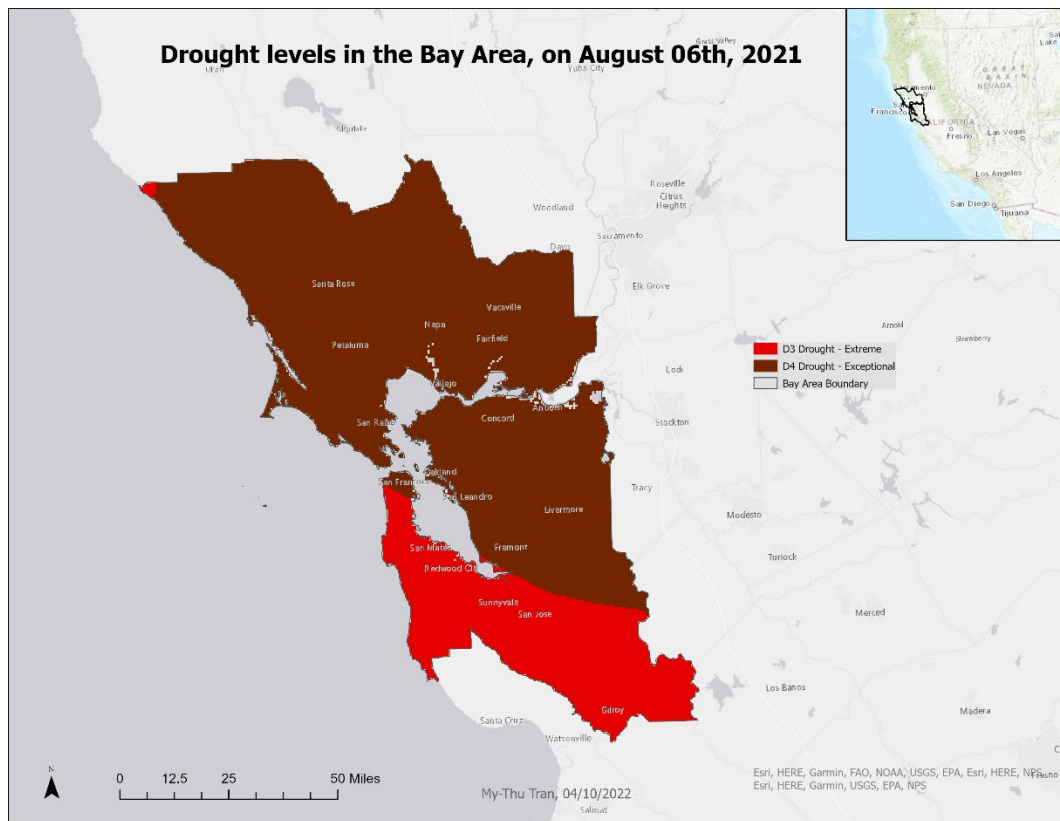

Figure 2: Drought levels in the Bay Area.

Distance to the urban areas

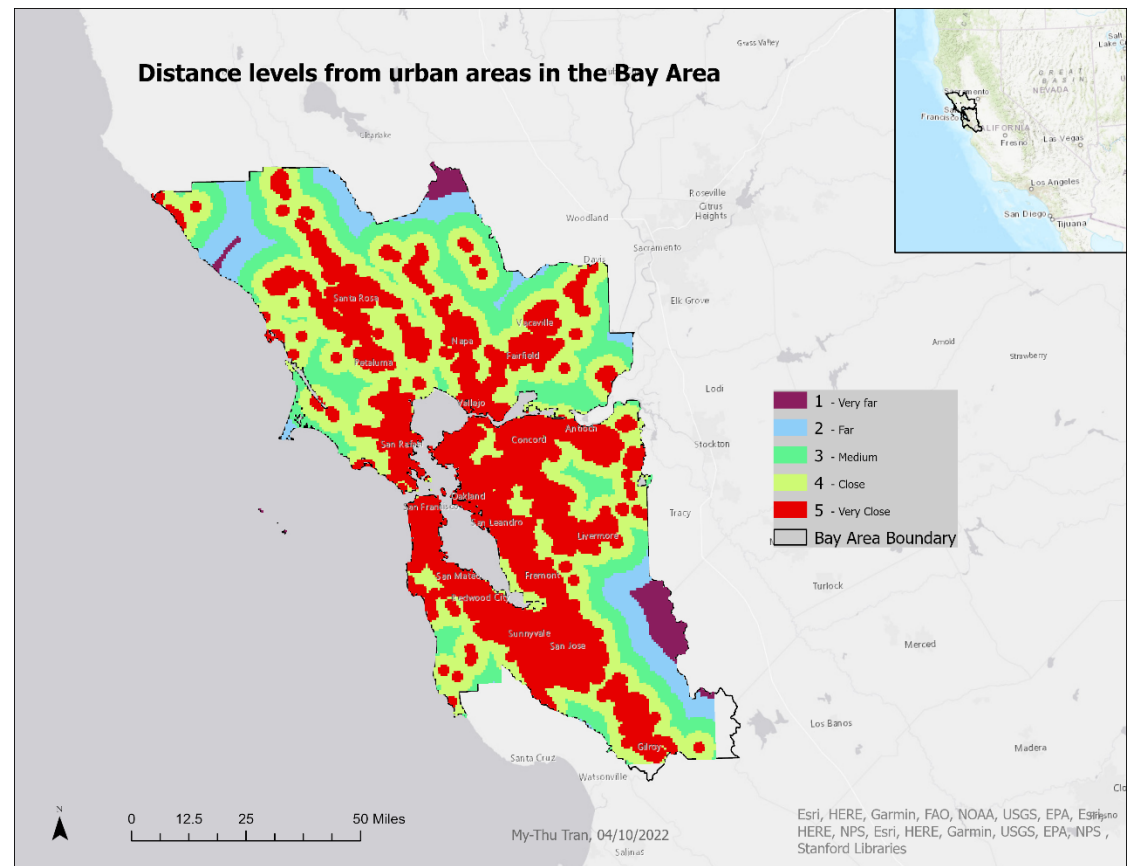The Euclidean Distance tool has been used to conduct the distance from the urban area to the research area boundary.

Figure 3: Distance levels from the urban areas.

Land cover

The study area has 15 classes and needs to be reclassified to the five new levels.

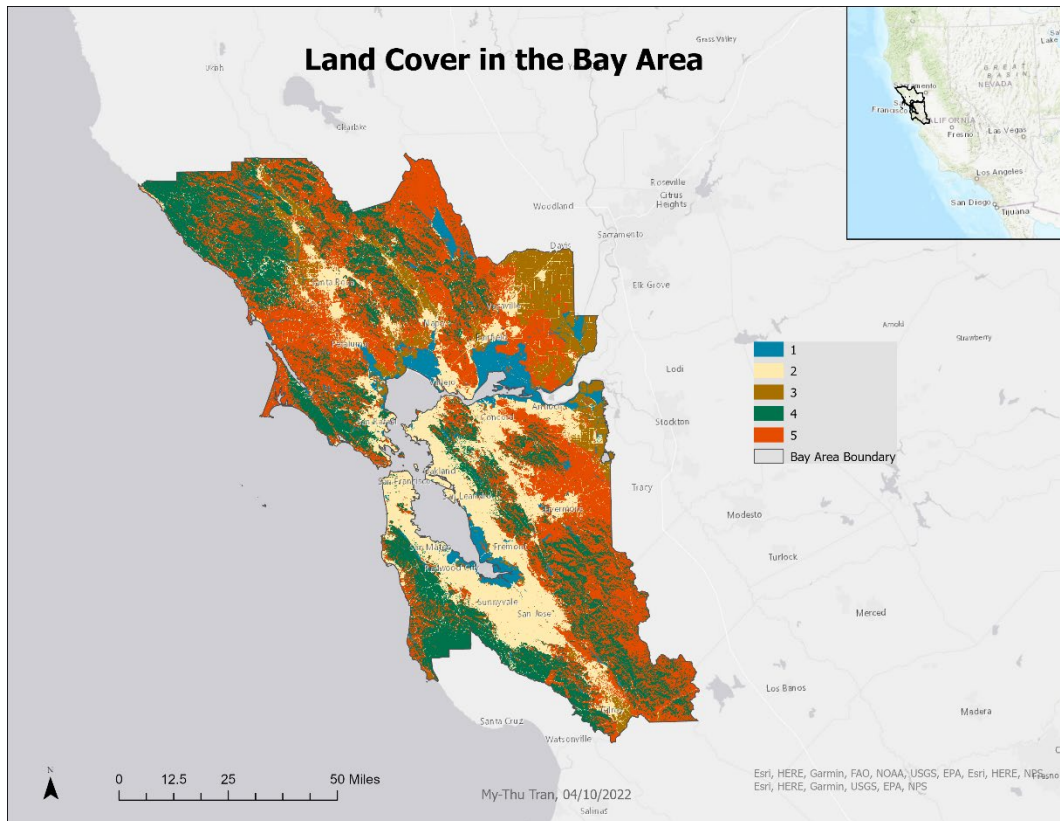| Land cover classes	Reclassify levels
Open water, Woody wetlands, Emergent Herbaceous Wetlands	1
Developed, Open Space; Developed, Low Intensity; Developed, Medium Intensity; Developed, High Intensity	2
Baren land, Cultivated Crops	3
Deciduous Forest, Evergreen Forest, Mixed Forest	4
Shrub/Scrub, Herbaceous, Hay/Pasture	5

Table 2: Reclassified Land cover.

Figure 4: Land cover classification of the Bay Area.

Land surface temperature

To convert the digital values from MOD11A1 data to the degree Celsius, it has been multiplied 0.02 and then subtracted 273.15 by using the Raster Calculator tool.
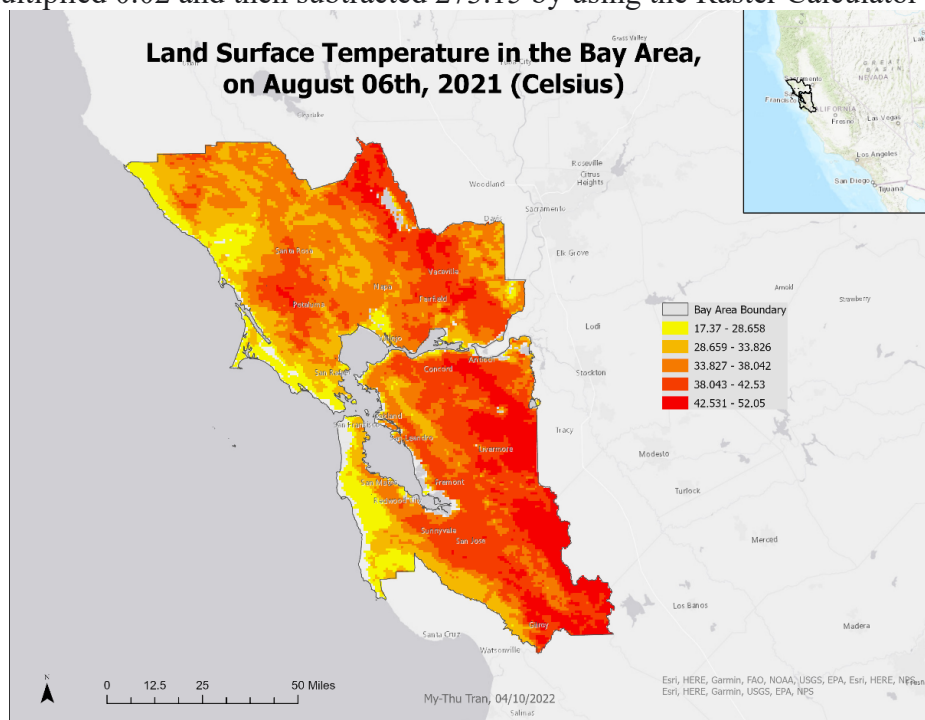

Figure 5: Land Surface Temperature in the Bay Area.

Elevation

The DEM value is reclassified into 5 new levels. The higher elevation relates to the higher risk level of wildfire.
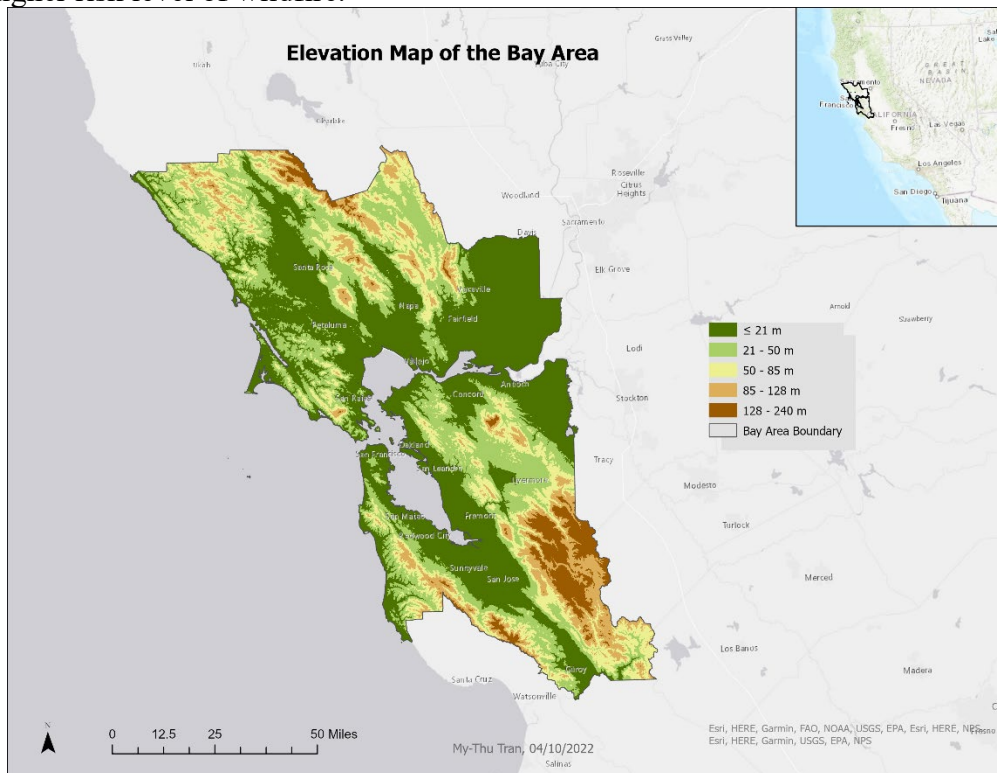

Figure 6: The elevation map of the Bay Area.

Slope

From the DEM data, a slope tool has been used to conduct the slope. The higher slope relates to a higher risk level of wildfire.
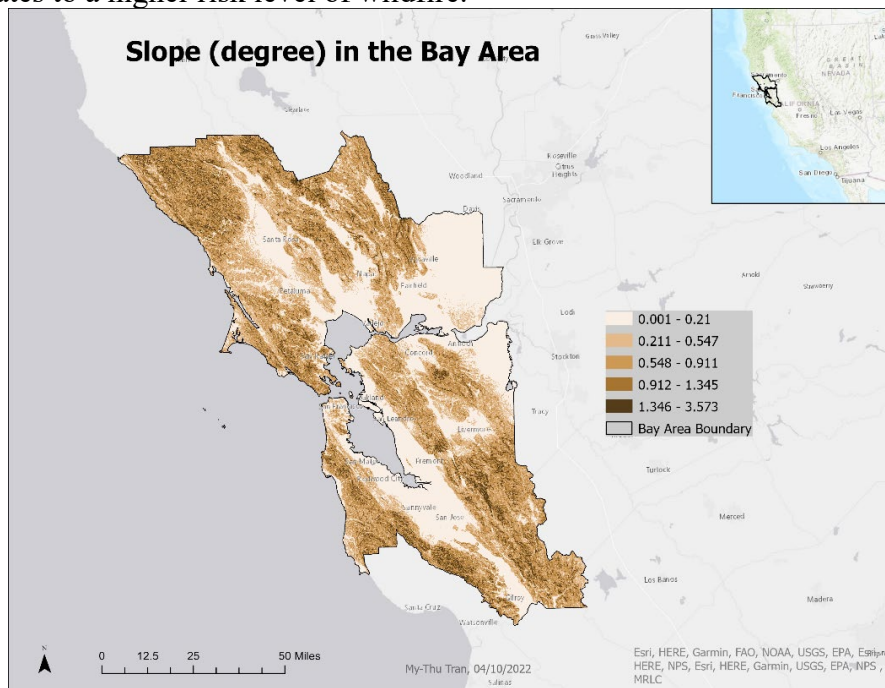

Figure 7: Slope map of the Bay Area (degree).

Aspect

From the DEM file, an aspect tool has been used to show the aspect analysis result of the study area, then it has been reclassified into 5 new levels.
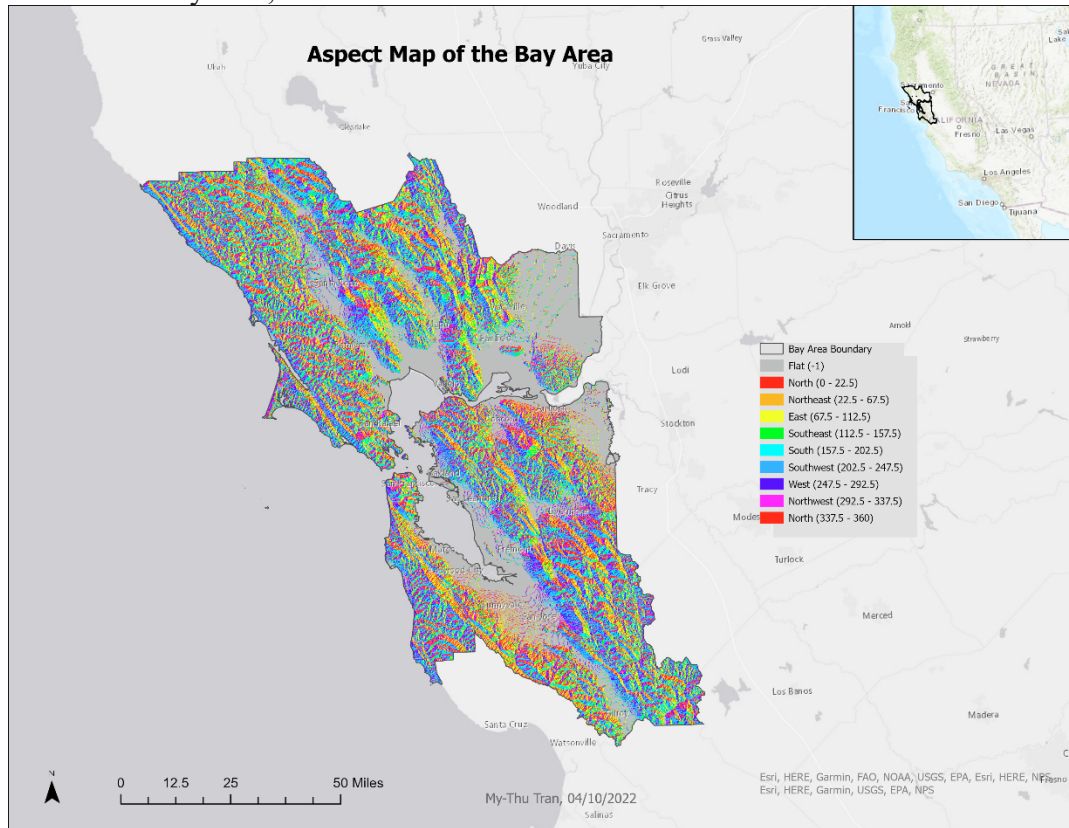

Figure 8: Aspect Map of the Bay Area.

Results

The map below shows five levels of WRI separated by the boundaries of the nine counties. Most of the North Bay is at high risk, whereas South Bay has the largest high-risk and low-risk wildfire areas.
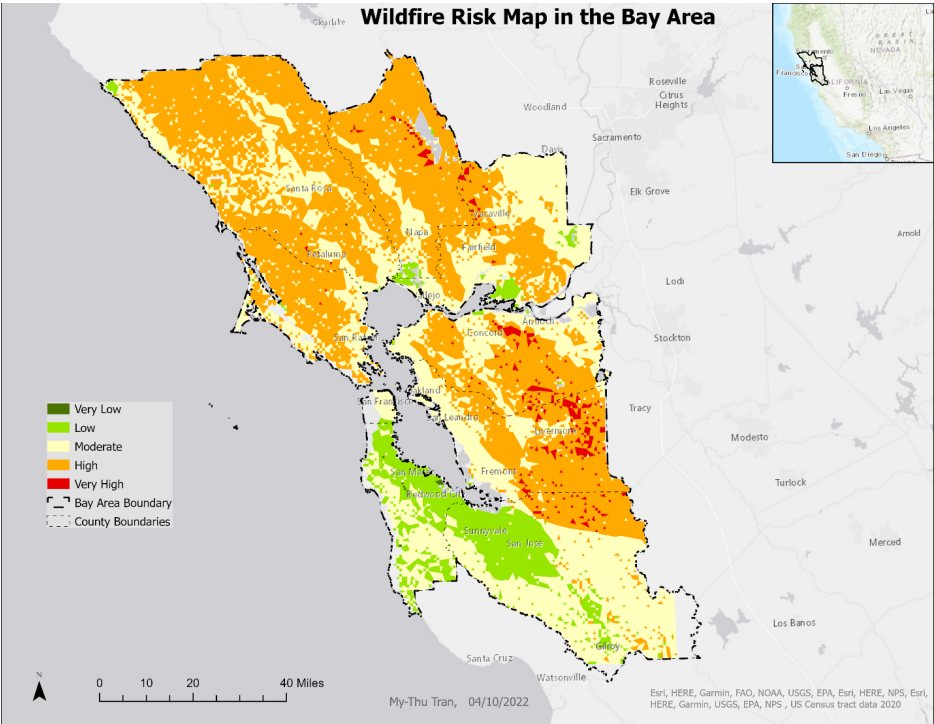

Figure 9: Wildfire Risk Map (WRM).

The WRM has been overlaid with the fire locations that happened in 2020 to validate the result.
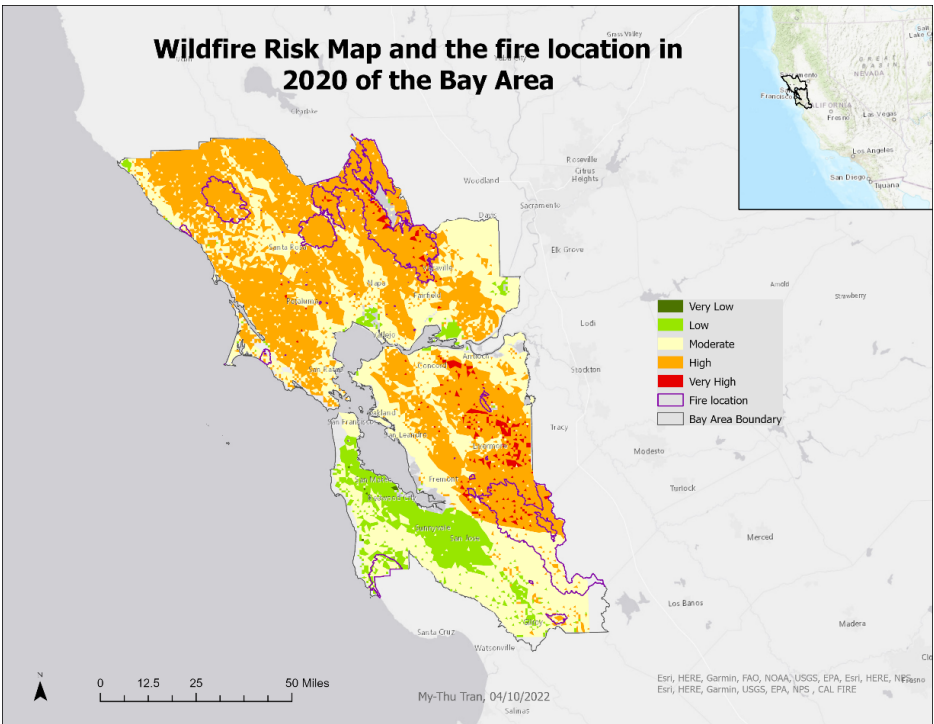

Figure 10: WRM with the fire location in 2020.

In the North Bay, fire locations were at the same high and very high-risk levels. Although Southern Santa Clara County experienced a large fire, it was placed under moderate risk. In addition, the fire spread to North San Mateo, even though those areas have been in the map's very low and low-risk index. Further research needs to be conducted to solve these concerns.
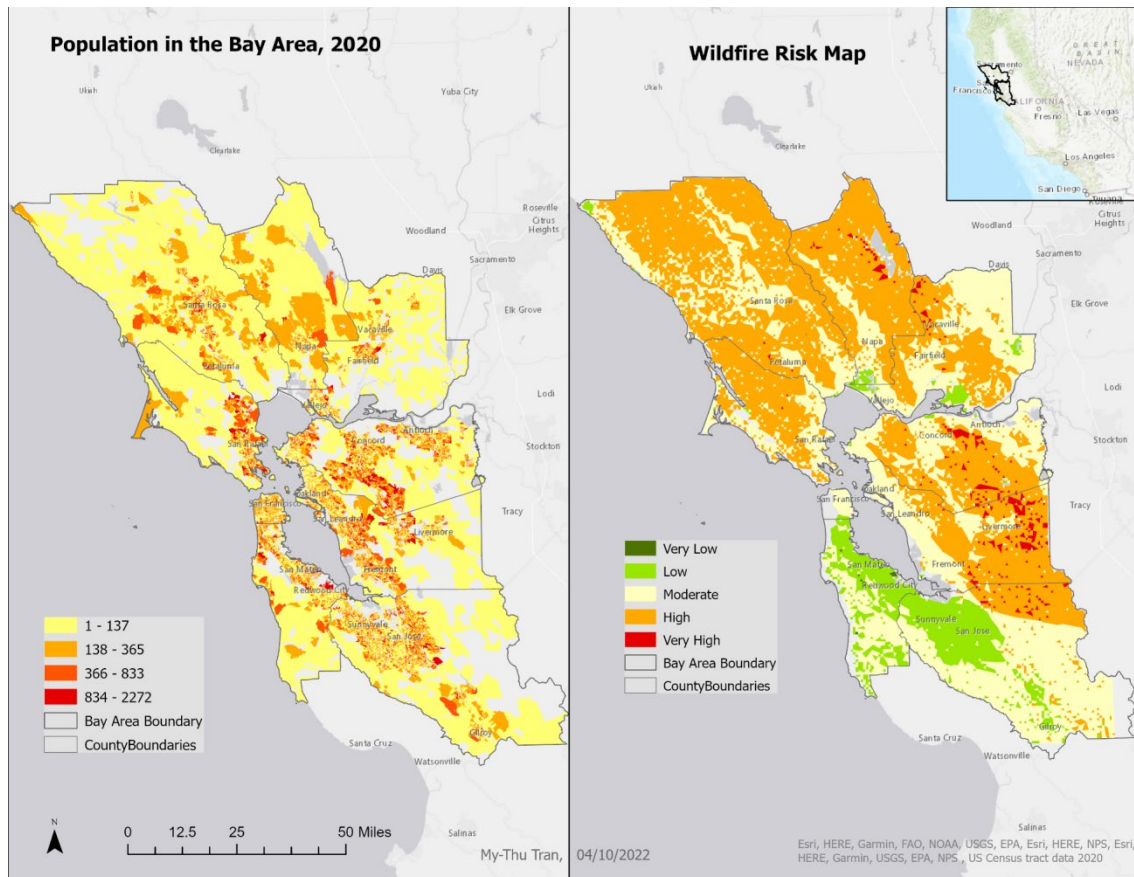

Figure 11: WRM with the population.

The high populations based on the census tract level are located on the very low, low and moderate WRM. Whereas in the high and very high level, it is located on small census tracts, the population is below 137 people.
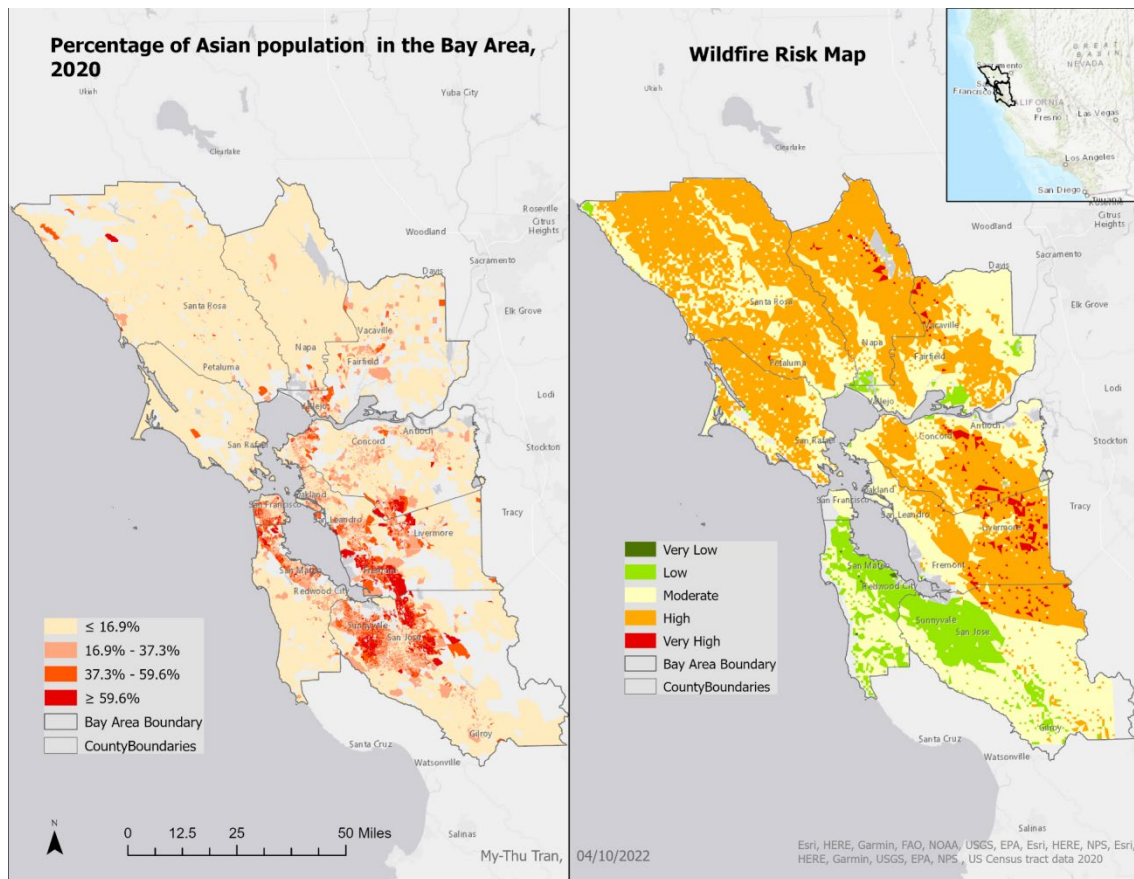
Figure 12: WRM with the percentage of Asian population.

A large group of the Asian population is shown above as very low, low, and moderate wildfire risk levels. It means that this community has a low impact from wildfire. However, a group of census tract - with a high percentage of an Asian population and between the border of Contra Costa and Alameda County - need to take action as they are under a high and very high-risk level.
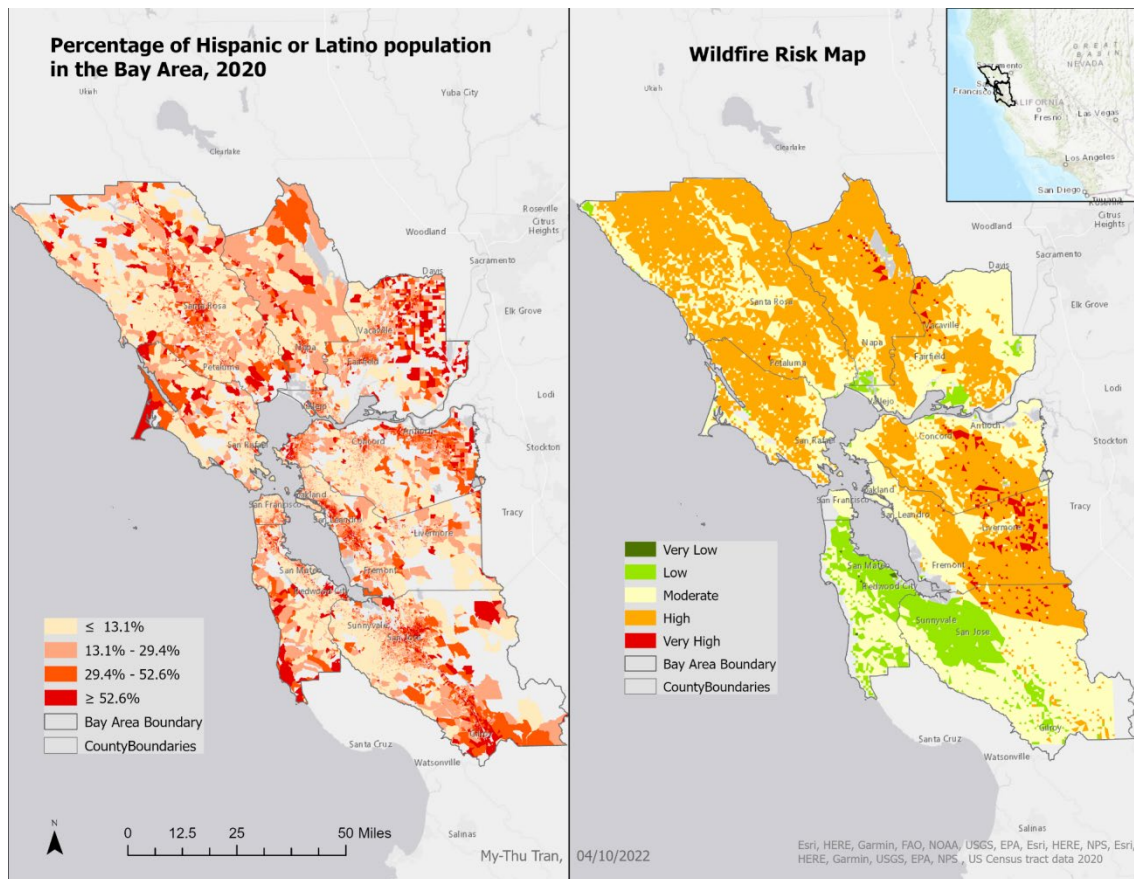
Figure 13: WRM with the percentage of Hispanic/Latino population.

The Hispanic population has shown their location all over the Bay Area. For the WRM, many areas that are under a high and very high-risk level also have a high percentage of this population. The areas of concern include the areas around Lake Berryessa and the Northeast of Contra Costa.
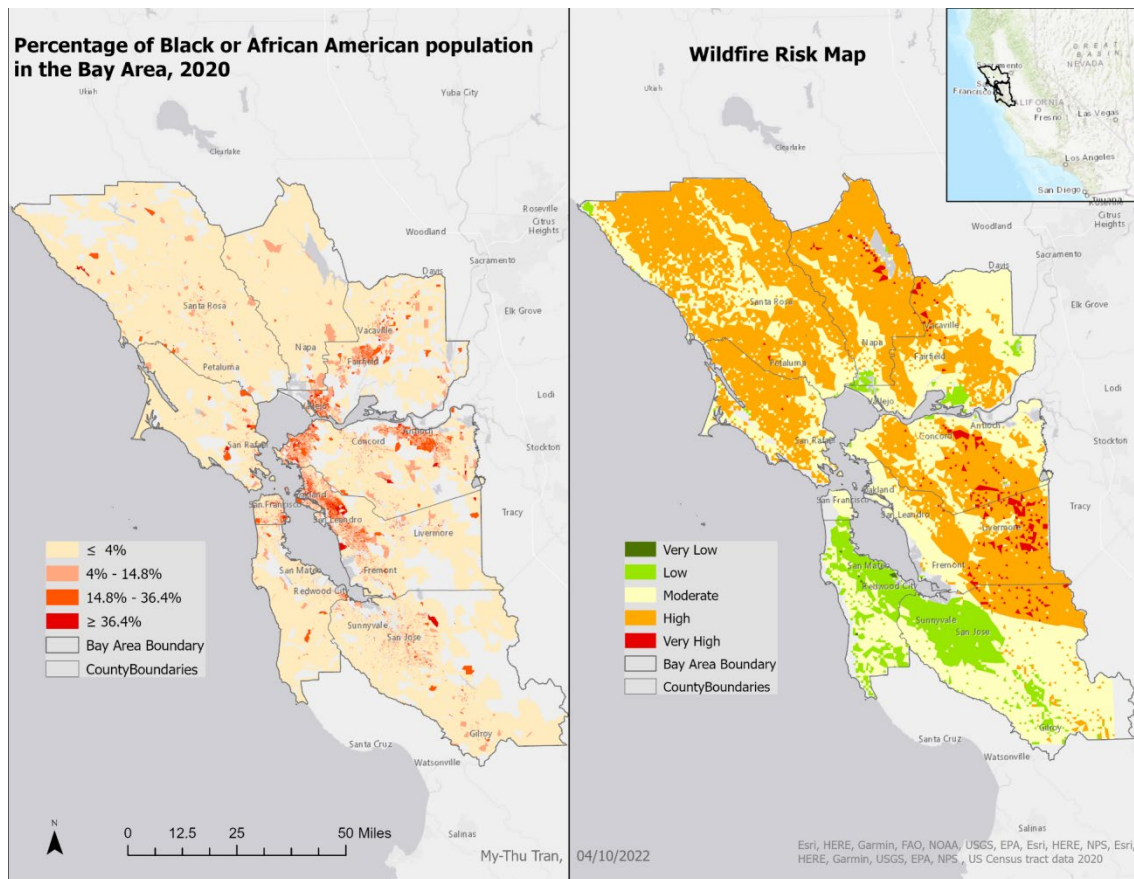
Figure 14: WRM with the percentage Black/African American population.

A high percentage of the African American population is also in moderate, very low, and low-risk levels. In Solano County, Vallejo, Fairfield, and Vacaville there is a high percentage of this group, and they are under a moderate risk level. In Contra Costa and Alameda County, the following urban areas near the coastline are at moderate risk.
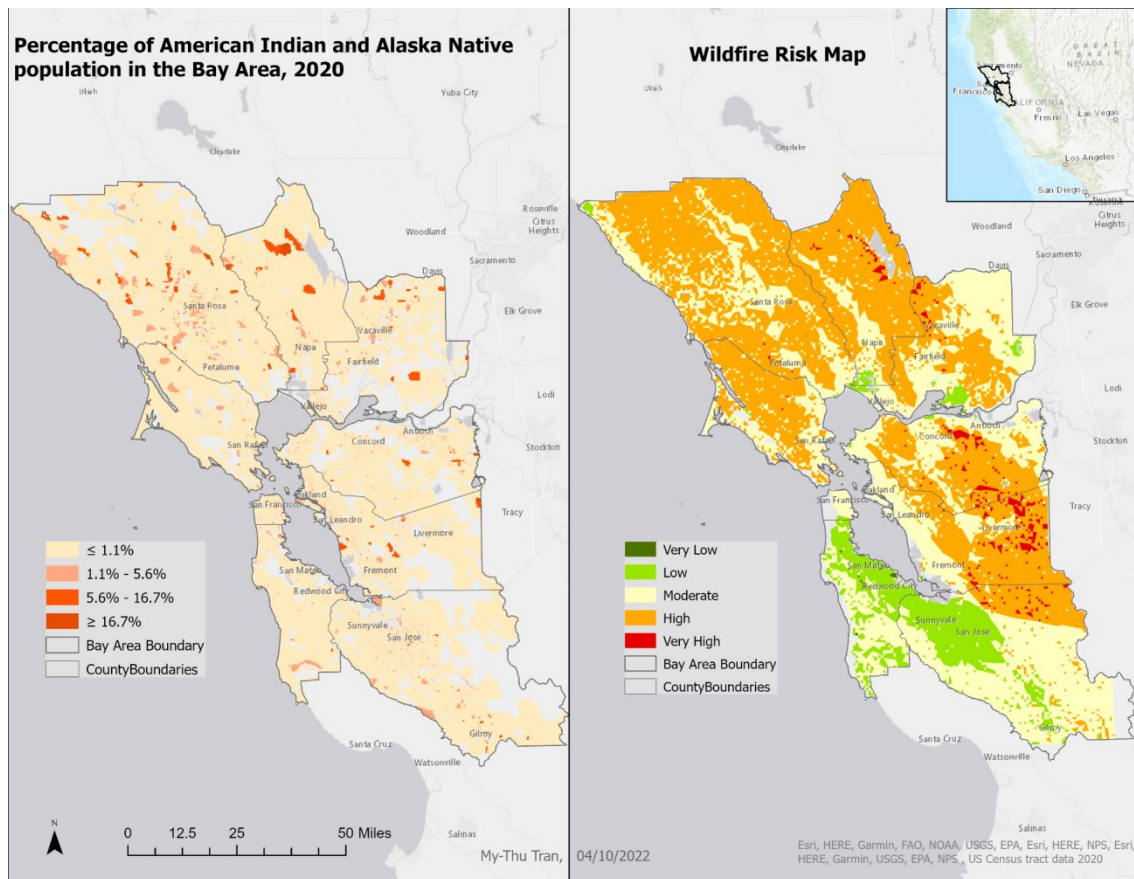
Figure 15: WRM with the percentage of American Indian and Alaska Native population.

For the American Indian, and Alaska Native population, the map has shown some census tracts - having over 5.6% of this group in the total population - need to pay more attention. In the central of Sonoma County, it shows the living area of this group under a moderate to high-risk level. Moreover, this population around Lake Berryessa, and in the Northwest of Solano County are also under a high and very high-risk level.
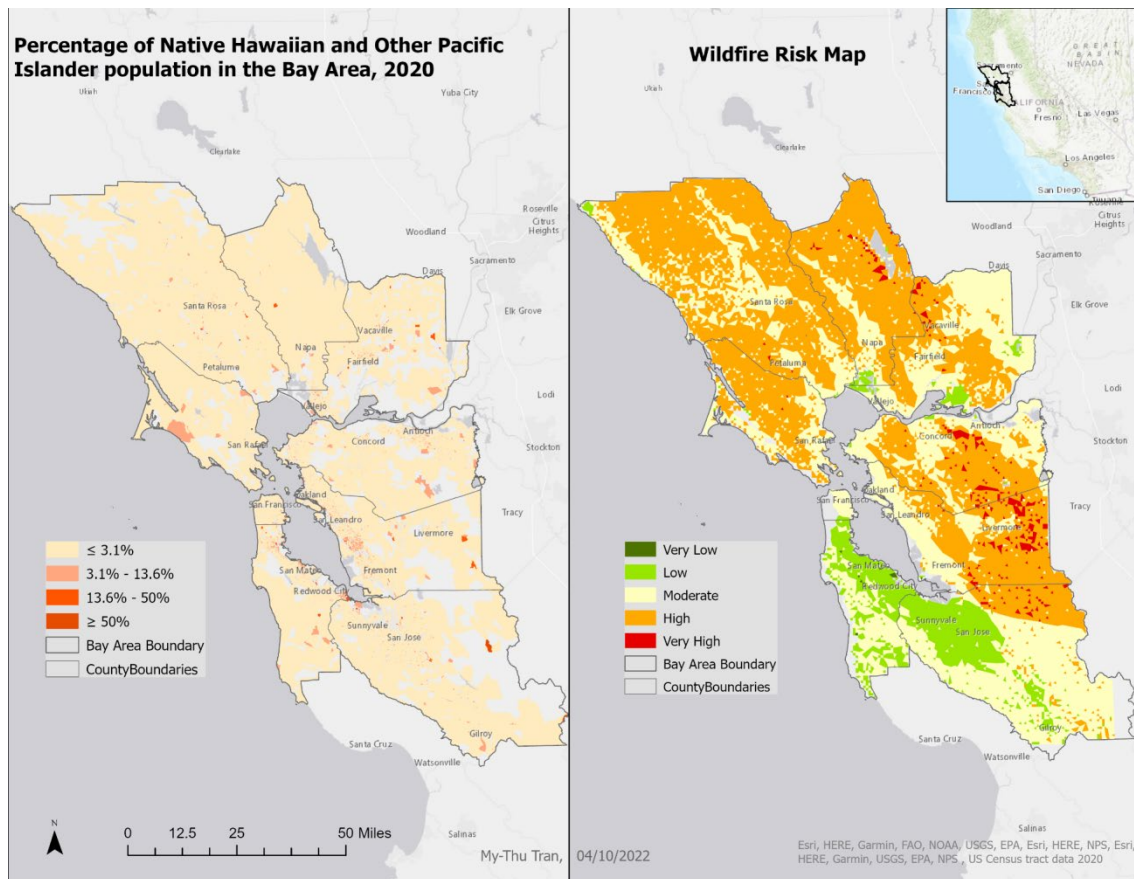
Figure 16: WRM with the percentage of Native Hawaiian and Other Pacific Islander population.

       Even though the Native Hawaiian and Other Pacific Islander population does not show a high percentage in the Bay Area, the safety of this population is a concern. Some of the census tracts are inside the high and very high-risk levels in the Eastside mountainous areas of Alameda and Santa Clara County.
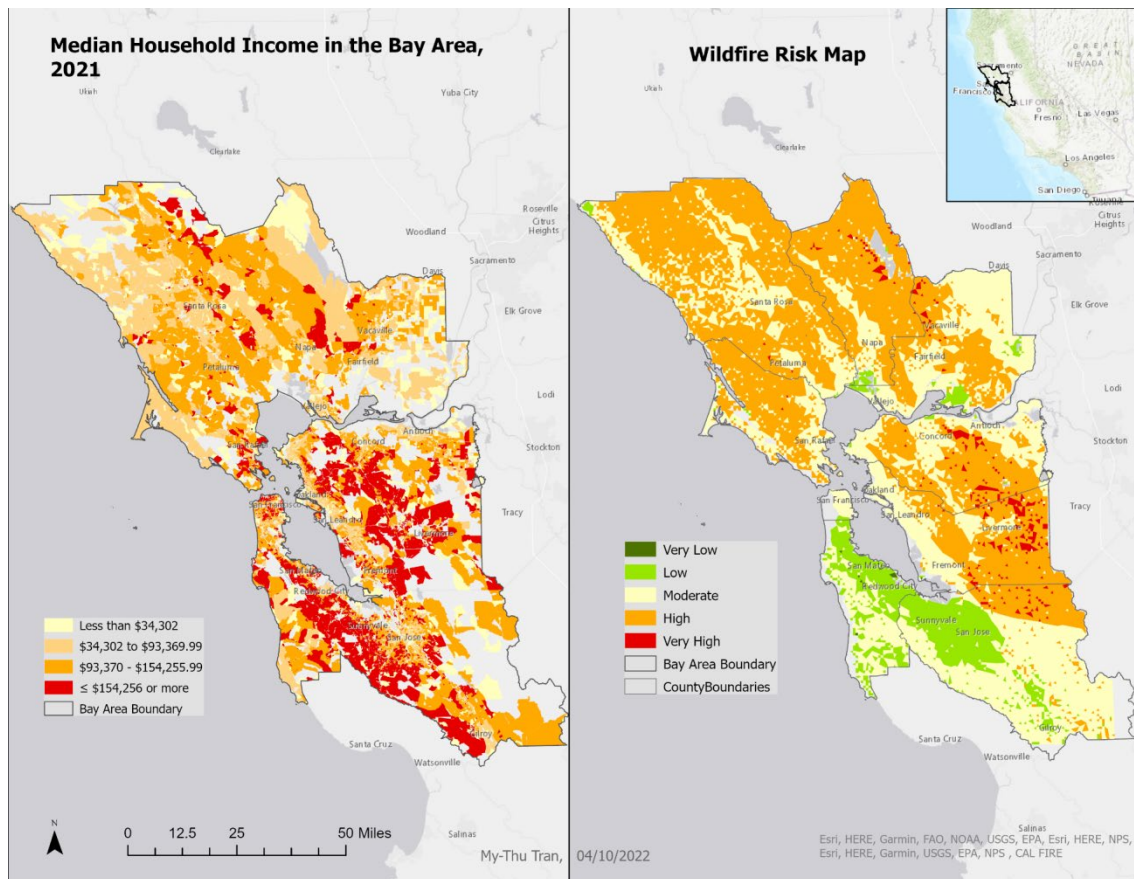
Figure 17: WRM with the Median Household Income.

In 2021, the census tracts have less than $93,369.99 in median household income - in the North of Sonoma, North of Napa County – are in high-risk wildfire level. In the Contra Costa and Alameda counties, these areas earn more than $154,256 and are at a high and very high-risk level. In contrast, high-income census tracts are found in San Francisco, San Mateo, and the Western part of Santa Clara County, which is under very low and low-risk levels.

Discussion and Conclusion

The main finding of this project is developing the WRM for the Bay Area by using seven factors. These factors have been reclassified based on their value in a trend where the higher the value gets, the higher the risk index shows. Besides showing the physical geographical relationship between the risk index and other factors, this project also shows the risk in the different communities.

The risk index from this project can be flexibly used for other research areas with suitable local factors and adjusted to the percentage of each factor to predict the local index. Due to the time limit, the relationship between each factor that is used to calculate the WRI has not been proven. In the future, these relationships can be shown by using regression or another statistical modelling.

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