Risk Assessment of Lava Flows in the Island of Hawai'i

Gabriel Villaseñor

I. Background/Introduction:

Throughout history, the landscape and population of the Island of Hawai'i have been greatly affected by its five volcanoes: Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. Currently, Kohala, located in the northeastern most section of the island, is extinct and Mauna Kea, located adjacent to Kohala, is dormant while the other three are currently active. Lava flows from these volcanoes have affected the Island of Hawai'i's total population of 185,079 for which portions of the population live in direct paths of flows; along these paths are vegetation that are ultimately burned.

II. Purpose:

The goal of this case study is to examine and understand the risk that vegetation and the island's population face from lava flows from the volcanoes hosted by the Island of Hawai'i. Suitability analysis using ArcMap and a series of downloadable GIS shapefiles relating to the landscape, magnitude of lava flow hazards, areas vulnerable to wildfires, and census population blocks aided in finding the magnitude of risks in areas throughout the Island of Hawai'i.

III. Data Collection:

The shapefiles used were acquired from to sources that contained a variety of GIS shapefiles that are related to the interest of the case study. Below is the list of shapefiles with their associated source:

- The National Map (TNM) Download (https://viewer.nationalmap.gov/basic/):
    - Digital Elevation Models (DEM) of the Island of Hawaii – A series of five rasters 1/3 arc second 1x1 degree DEM footprints.
    - Island of Hawai'i State Boundary – A state boundary shapefile formulated by the United States Geological Survey (USGS) National Boundary Dataset in Hawaii.
- The State of Hawaii Office of Planning (http://planning.hawaii.gov/gis/download-gis-data/):
    - Lava Flow Hazards – Vector shapefile that shows the magnitude of risk of lava flows throughout the Island of Hawai'i. This shapefile was gathered in 2010.
    - Wildfire Risks – Vector shapefile that shows street blocks that are in high to low risk of wildfires. This shapefile was gathered in 2010.
    - Vegetation – Vector shapefile that illustrates the extent of three canopy types throughout the island. This shapefile was gathered in 2010.

- 2010 Census Blocks (Population) – Vector shapefile that shows general blocks throughout the Island of Hawai'i, and their associated population.
- Geographic Names – Point data of all civil and natural structures in the Island of Hawai'i. The use of this shapefile was to label volcanoes.

IV. Data Preprocessing:

Once downloaded, each of the mentioned files were compressed and zipped which were inaccessible unless they were extracted of all their content. To have access to the files, Windows File Explorer was used in order to "Extract All" the files within the zipped files (Figure 1).
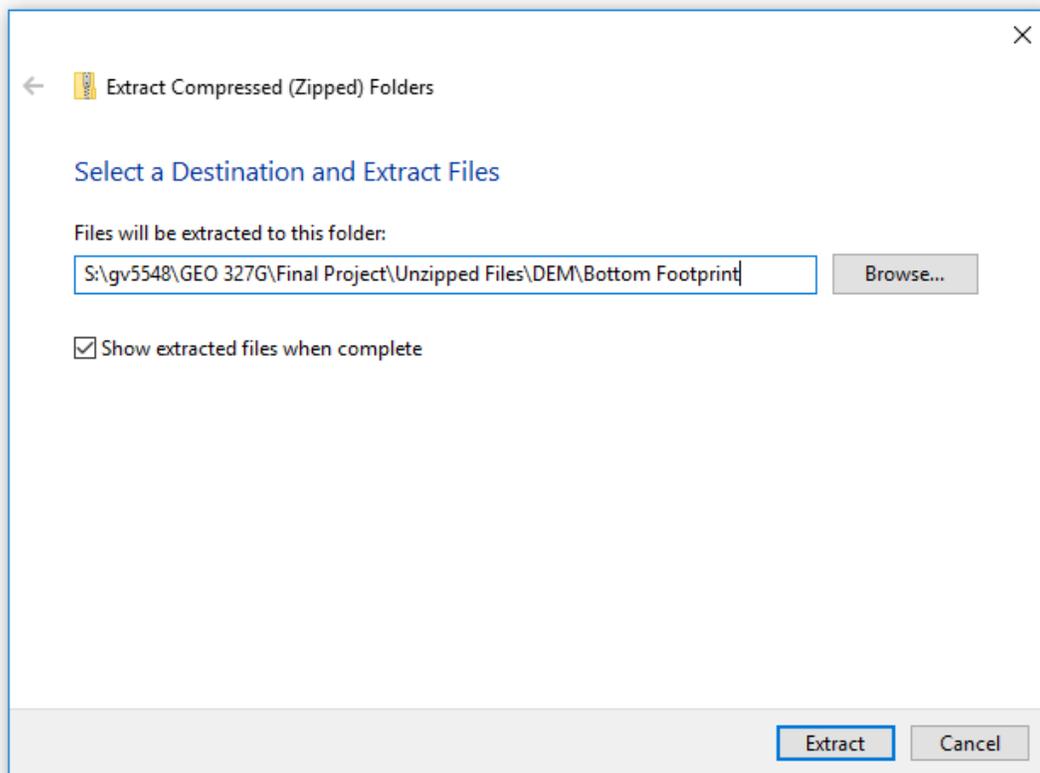
Figure 1: Extracting the zipped files to download shapefiles onto ArcMap.

Finally, the unzipped files were organized into a series of folders that allowed for efficiency (Figure 2).
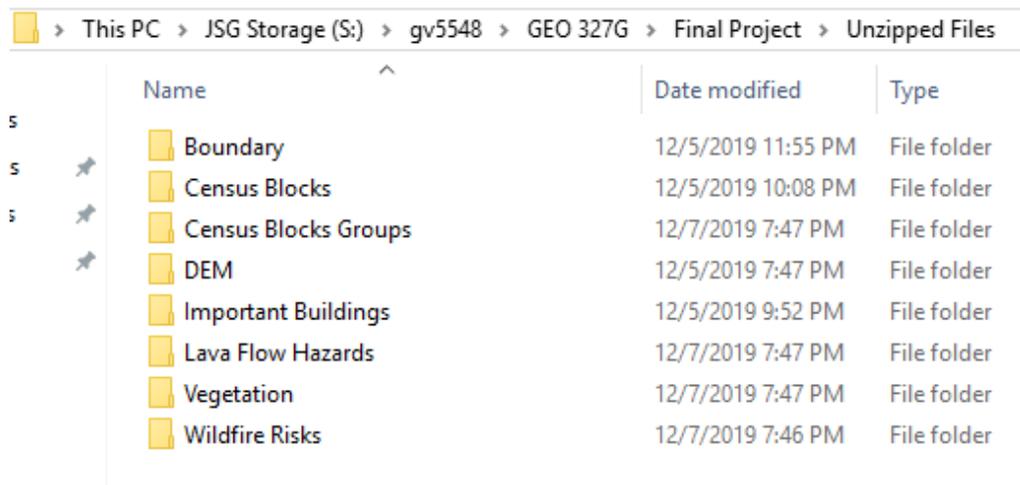
Figure 2: Unzipped Files within their correlated file

V. ArcGis Processing:

i. Downloading and Editing Data

Before adding files onto ArcMap, the projection of each file was defined in ArcCatalog; the shapefiles' projection was transformed from the North American 1983 High Accuracy Reference Network (HARN) geographic projection to the standard North American 1983 geographic projection. The first file to be downloaded was the Island of Hawai'i's state boundary for which contained the state boundary for all islands of Hawaii. The boundaries were joined as one attribute, so the "Explode" tool under "Advanced Editing" was used to separate the Island of Hawai'i from the its neighboring islands. The polygon has a blue fill to imitate the Pacific Ocean (Figure 3); however, figures throughout this report will show a hollow fill to highlight the data being projected. However, masking and clipping of other shapefiles were not to the state boundary because it is not the coastline of the island. To compensate this, the Lava Flow Hazards shapefile was uploaded due to it having a coastline boundary (Figure 4).
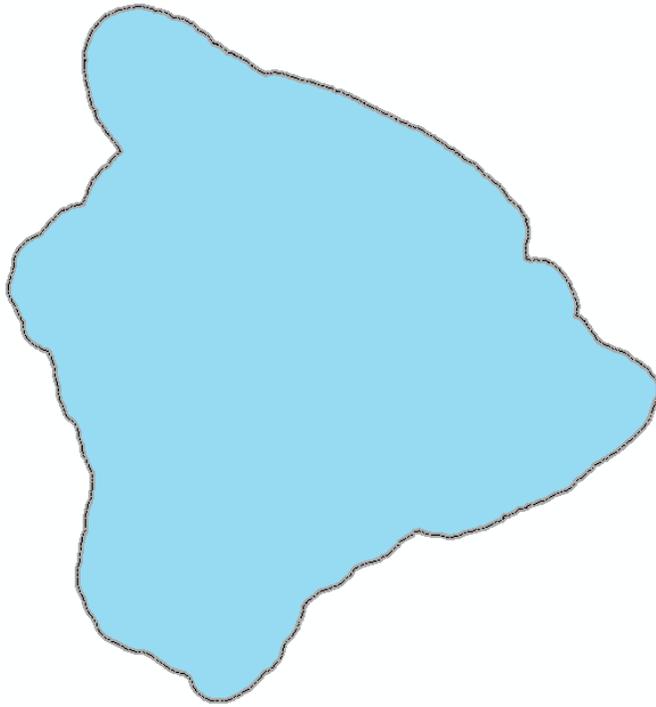
Figure 3: State boundary of the Island of Hawai'i coastline
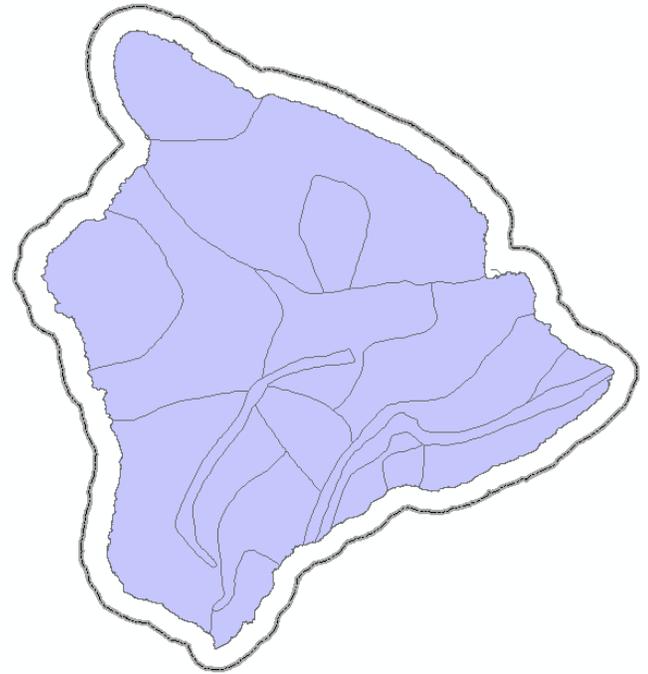
Figure 4: State boundary line versus

The overlying shapefile is the DEM of the island for which consisted of five footprints for which needed to be joined together in a mosaic. Each footprint contained approximately 390 megabytes of data, which led to approximately 1.2 gigabytes of data being used for creating a DEM. However, before being downloaded into ArcMap, pyramids needed to be built for each of the footprints; pyramids were created using the nearest neighbor resampling technique (Figure 5).
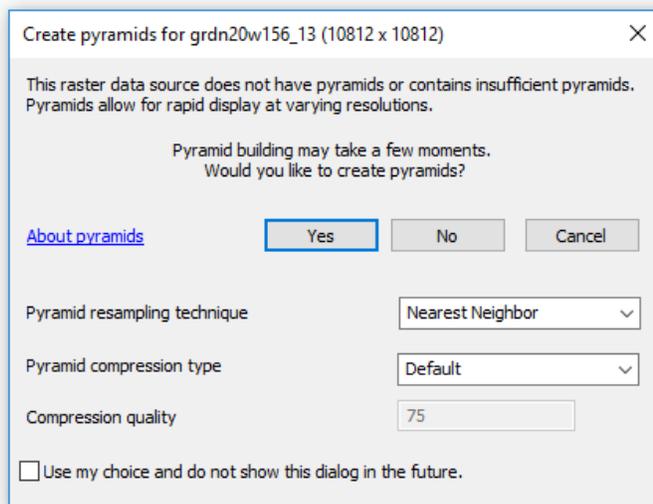
Figure 5: Creating pyramids for each footprint

Once pyramids were built for each footprint, the footprints needed to be joined together by building a mosaic. In order to build a mosaic, a geodatabase was created in order to create a mosaic dataset (Figure 6 & Figure 7).
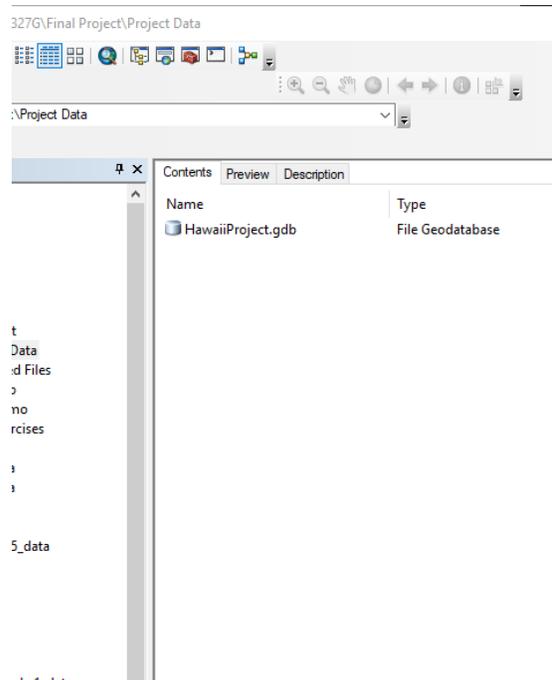
Figure 6: The file geodatabase, HawaiiProject.gdb
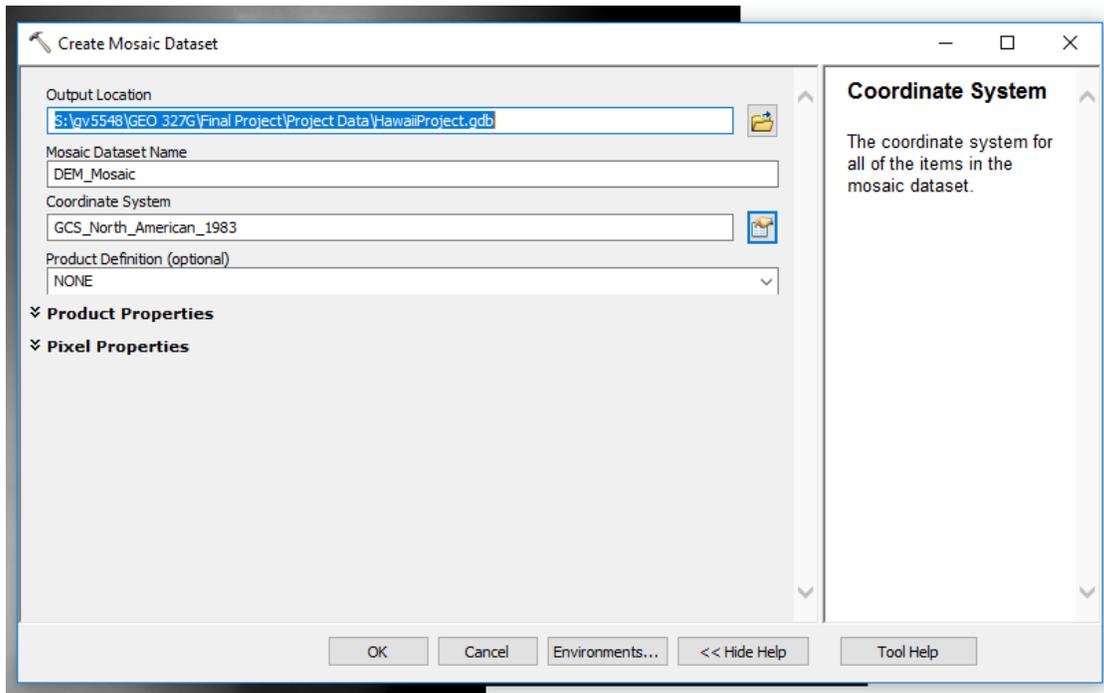
Figure 7: The "Create Mosaic Dataset" tool used to create the DEM mosaic

The mosaic dataset was named, "*DEM_Mosaic*", where the five footprints were added in order to build a mosaic (Figure 8).
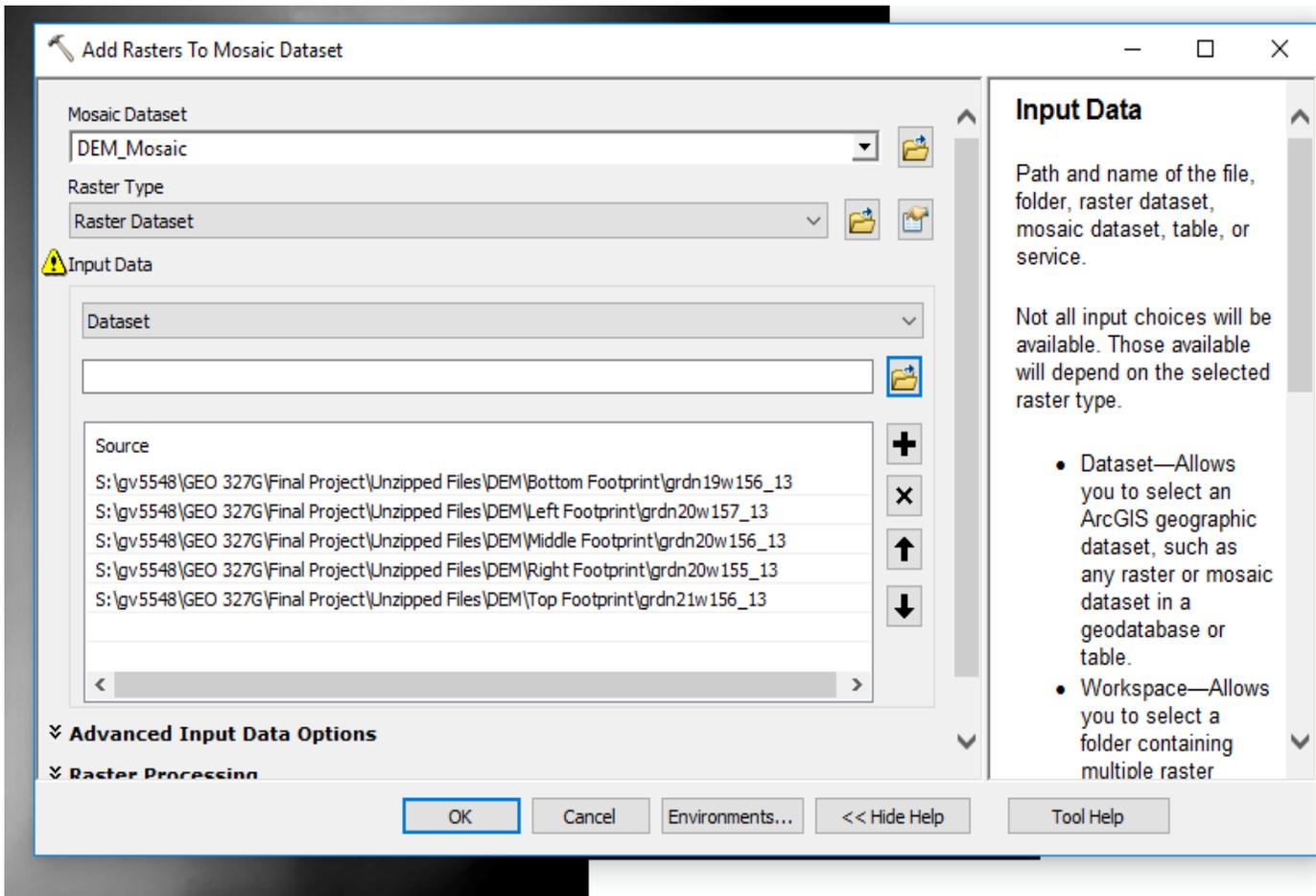
Figure 8: Adding the five raster footprints of the DEM to the Mosaic Dataset, DEM_Mosaic

The final product of this process created one file, *"DEM_Mosaic"*, for which it contained a mosaic of all five footprints. In order to set the maximum and minimum values of the DEM, the stretch type was set to "Standard Deviations" and the "n" value was set to 2.5 (Figure 9).
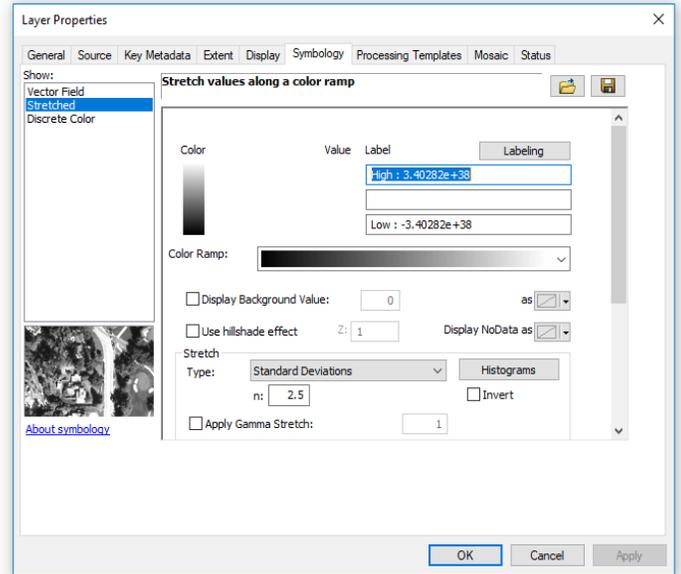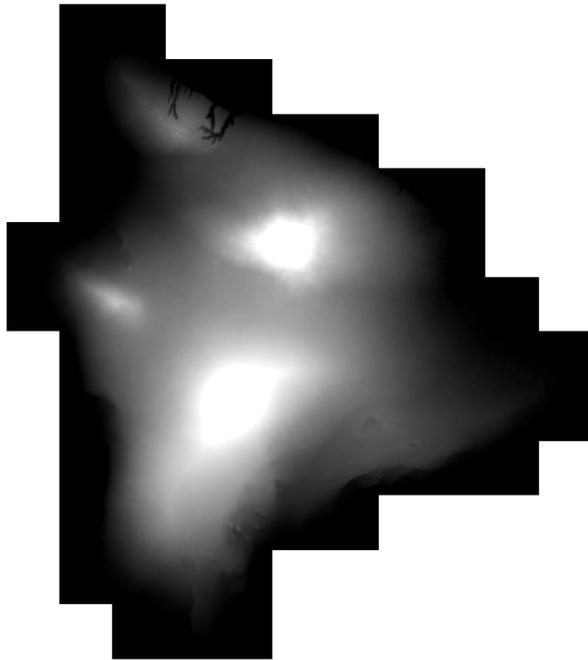
Figure 9: Mosaic of DEM along with changing the stretch type to "Standard Deviations

Then, *DEM_Mosaic,* was extracted by mask to the Lava Flow Hazards layer (Figure 10), where a hill shade was created in order to show differences in slope produced by the volcanoes extending throughout the Island of Hawai'i (Figure 11).
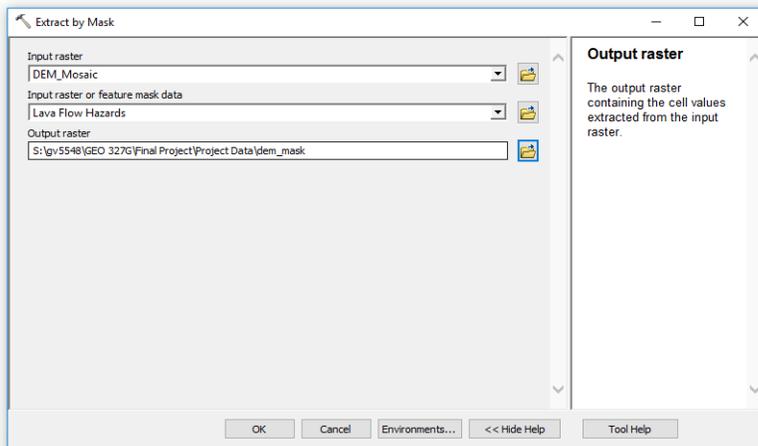
Figure 10: Extracting the DEM to the Lava Flow Hazards shapefile
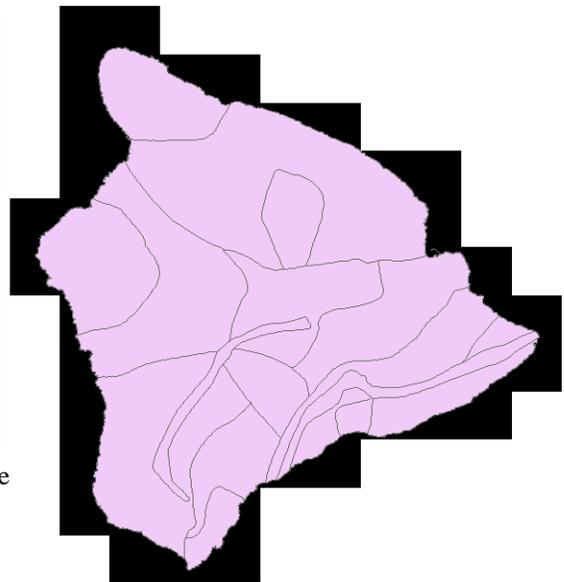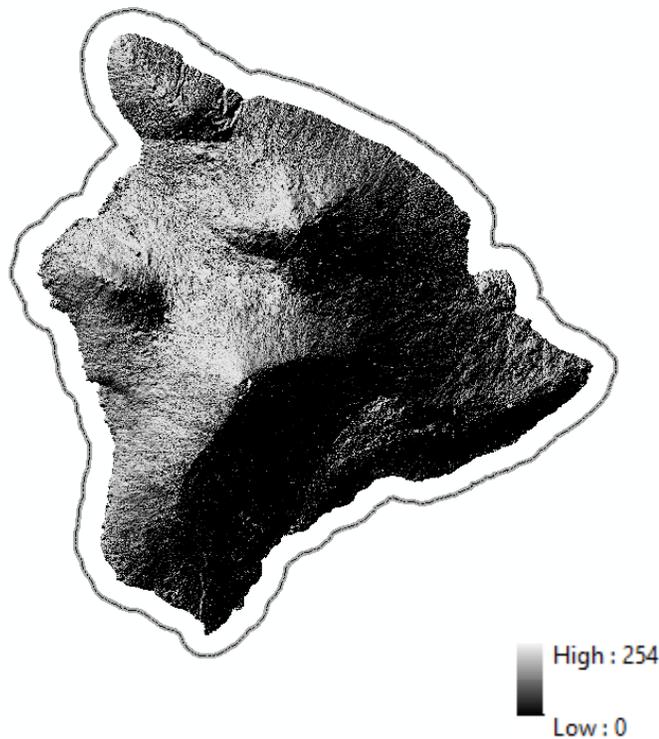
Figure 11: Hill shade of the Island of Hawai'i within its state boundary

The next file that was downloaded and used to accomplish the goal of this case study was the "Lava Flow Hazards" shapefile. In order to illustrate all the lava flow hazard zones throughout the island, the value field within symbology was changed to "hzone" (Figure 12).
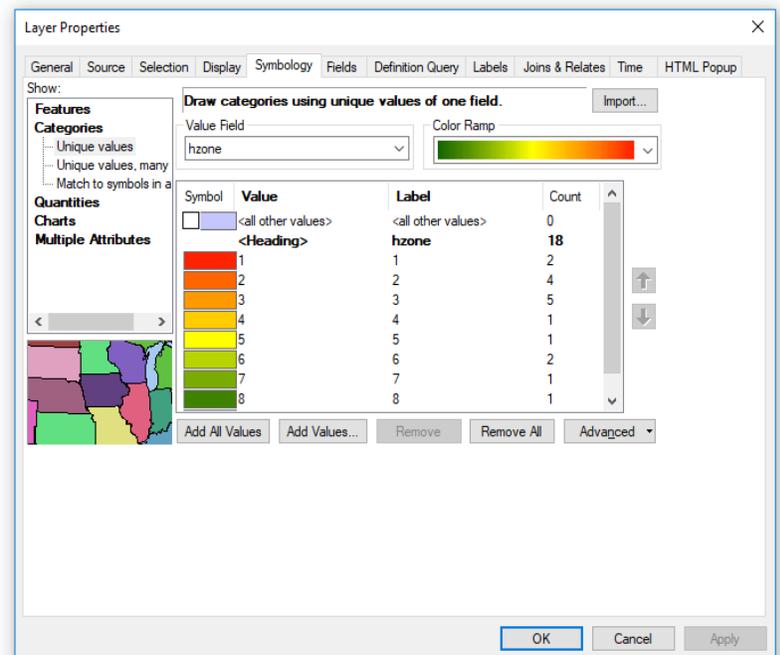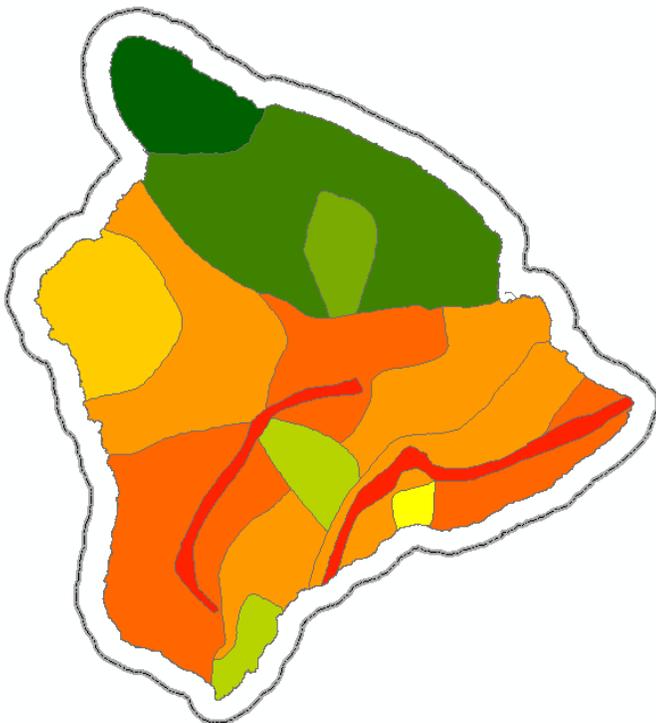
Figure 12: Lava flow hazard zones throughout the Island of Hawai'i. Areas that are red are highly susceptible to lava flows while green areas are least prone to experience lava flows.

The same process was done for both shapefiles that contain vegetation and areas that contain risks for wildfire; the value field for Vegetation was changed to "canopy_typ", while the value field Wildfire Risks was changed to "Risk_Ratin" (Figure 13 & 14).

Figure 13: The Wildfire Risks risk rating throughout the Island of Hawai'i. As shown, the red colors show the highest risk of wildfires, while the orange show the lowest risk of wildfires.
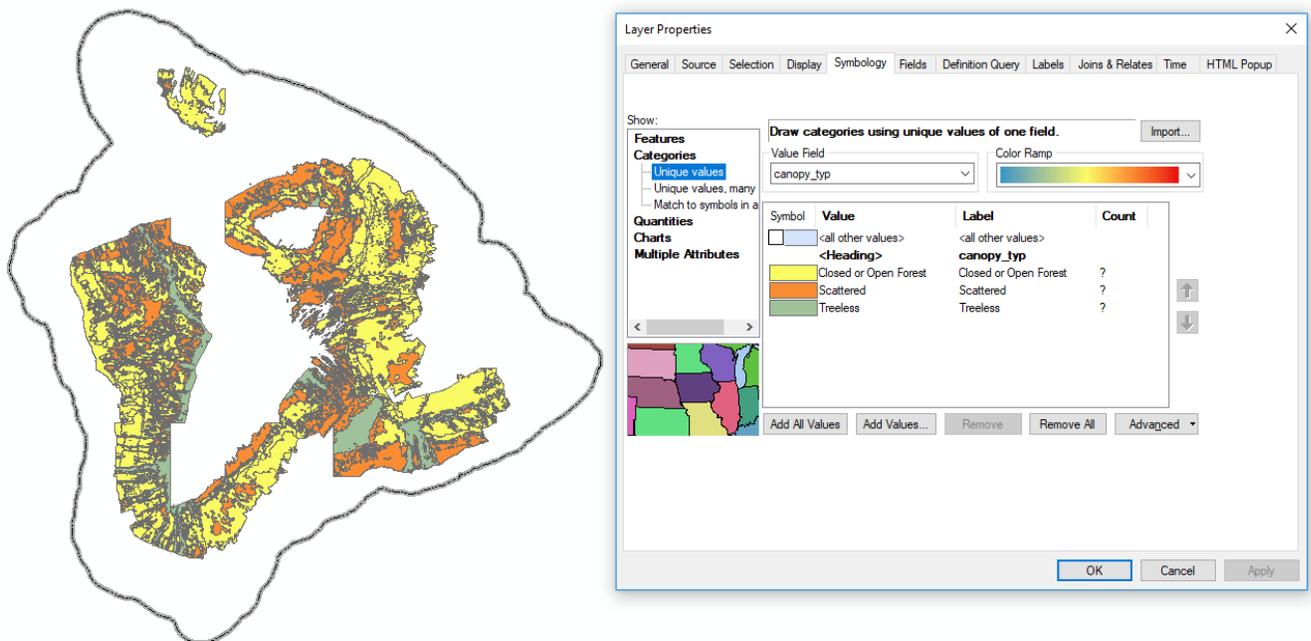
Figure 14: The three type of vegetation canopies throughout the Island of Hawai'i. Areas in yellow show closed and/or open forest, orange show scattered vegetation, and green show treeless and unvegetated areas. Areas in white are unknown.

Overlying these three altered layers was the Census Block shapefile. A chaotic, yet helpful preliminary product (Figure 15) aided in making a prediction where the highest and lowest risks for lava flows were going to be. Ranking of the Lava Flow Hazards, Vegetation, and Wildfire Risks shapefiles followed once predictions were made.
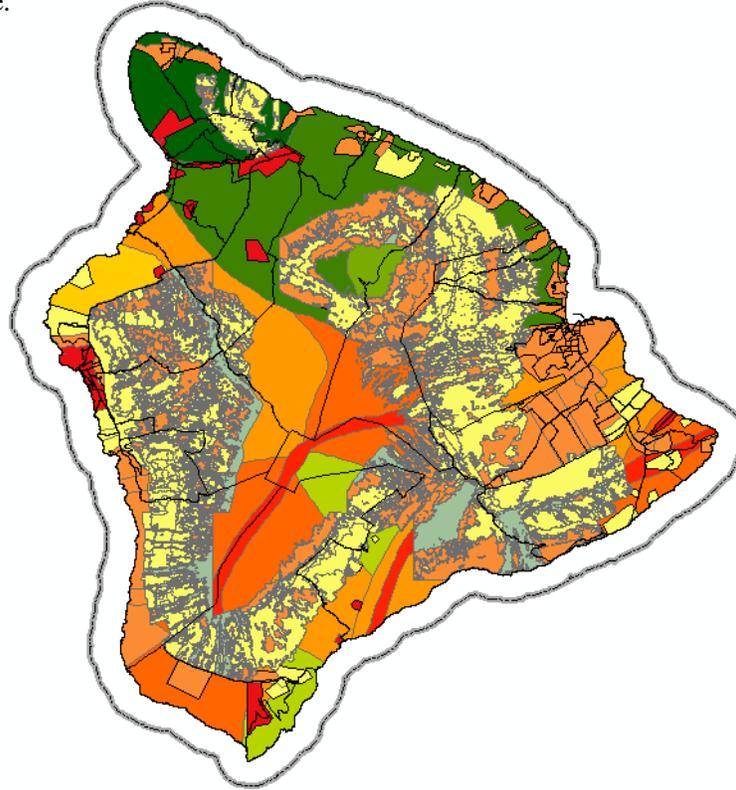
Figure 15: Map showing all shapefiles to make a prediction of the final product

ii. Ranking & Rasterizing

The four mentioned shapefiles were ranked with a range from 0 to 5 (Table 1). Each shapefile was reclassified within their attribute tables with a "*Risk_Rank*" column (Figure 16). The table below, areas within the attribute tables that show no data are correlated to a 0, while the lowest and highest magnitudes of risk are attributed to a 1 and 5, respectively.

Risk Rank	Wildfire Risk	Lava Flow Hazards	Vegetation	Population
0	NoData	NoData	NoData	NoData
1	Low	8,9	Treeless	339 - 833
2		6,7		868 - 1,658
3	Medium	4,5	Scattered	1,680 - 2,453
4		3		2,555 - 2,916
5	High	1,2	Closed/Open	2,954 - 4,234

Table 1: Ranking scheme for the four shapefiles.

canopy_typ	overstory	understory	modifier	degree_of_	shape_Leng	shape_Area	Risk_Rank
Closed or Open Forest	Me,nt	ns-xg-xs		NX	64408.627111	12283511.3095	5
Closed or Open Forest	Me,nt	ns/mf		NN	9166.396986	1039605.6791	5
Closed or Open Forest	xt,nt	ns-xg-xs		XX	3262.245685	263983.195118	5
Closed or Open Forest	Me,nt	ns-xg/xs		NX	28703.339442	21209805.27	5
Closed or Open Forest	xt,nt	ns-xg-xs		XX	2232.021597	104078.887121	5
Closed or Open Forest	Me,nt	ns/mf		NN	8629.690431	776374.478567	5
Closed or Open Forest	xt,nt	ns-xg-xs		XX	12392.33951	690550.858057	5
Closed or Open Forest	xt,nt	ns-xg-xs		XX	2141.567411	106479.327587	5

Figure 16: Example of "*Risk_Rank*" column within the Vegetation attribute table.

The next step of this process was to rasterize each of altered shapefiles using the "*Risk_Rank*" field to obtain rasterized layers that would show the ranking scheme of the attributes of each shapefile. The tool "Feature to Raster" (Figure 17) was used to rasterize the Wildfire Risks, Lava Flow Hazards, Vegetation, and Population layers (Figures 18 – 21).
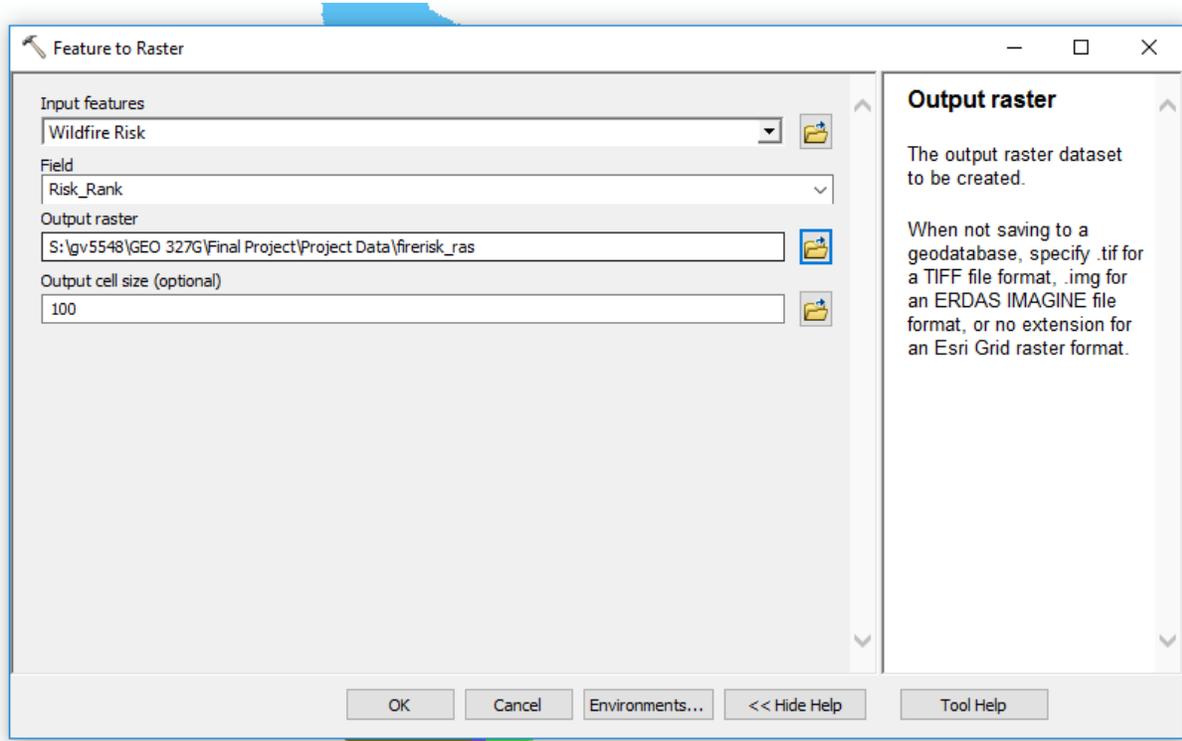
Figure 17: An example of "Feature to Raster" tool used to convert Wildfire Risk vector shapefile to rasters.
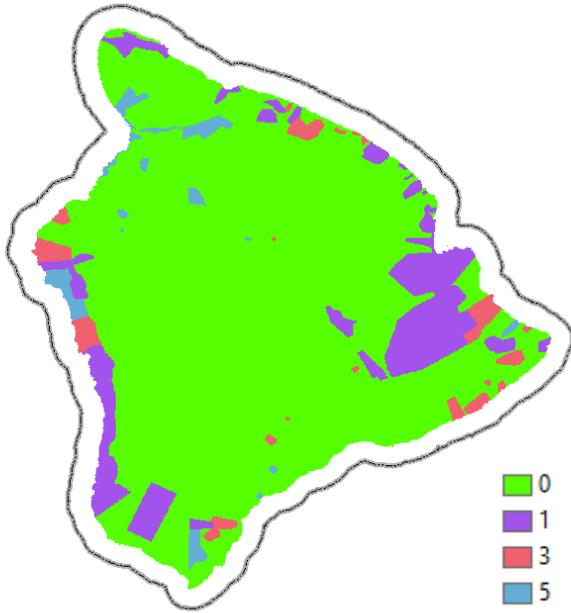
Figure 18: Rasterized Wildfire Risks
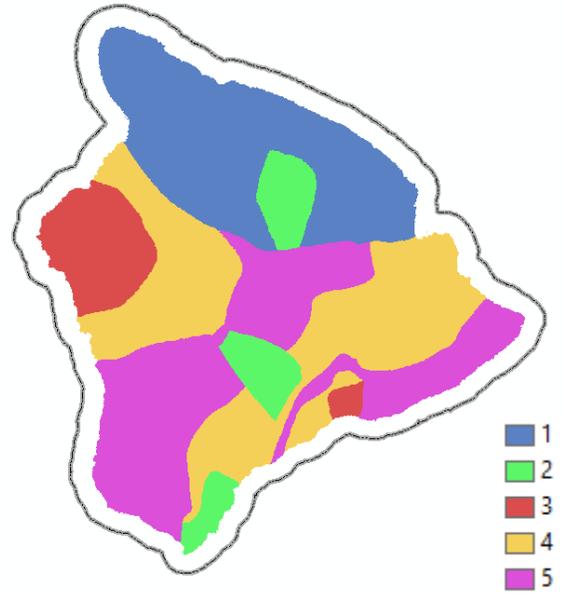
Figure 19: Rasterized Lava Flow Hazards
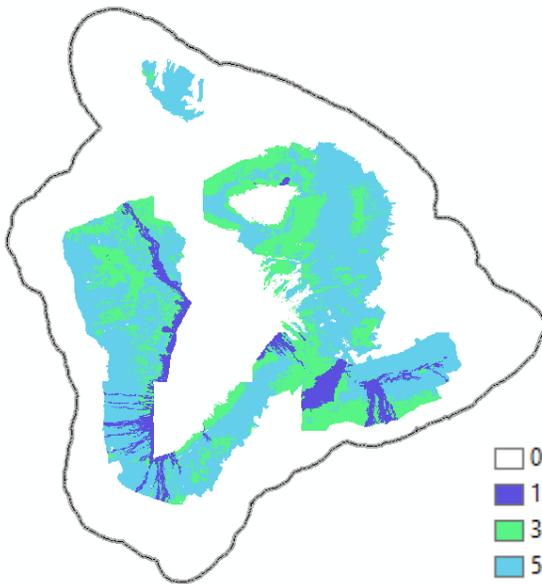
Figure 20: Rasterized Vegetation
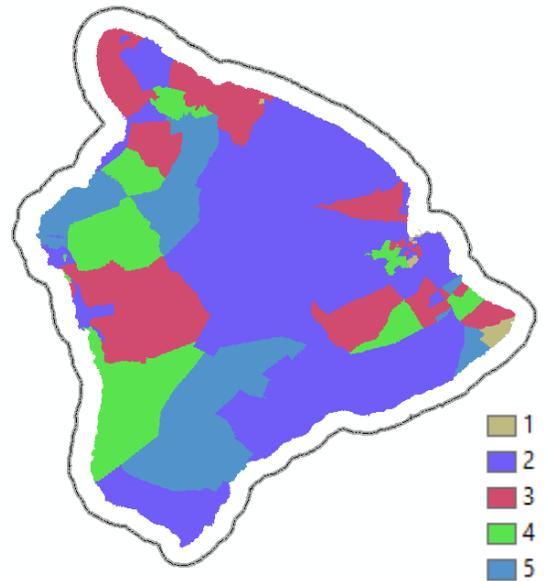
Figure 21: Rasterized 2010 Census Blocks

iii. Calculating Rasterized Layers

Once rasterized, the tool "Raster Calculator" (Figure 22) was used to produce a series of rasters that showed the magnitude of risk in areas throughout the Island of Hawai'i. There was a total of four final products calculated in order to provide suitability analysis of risk assessment of the different layers used.
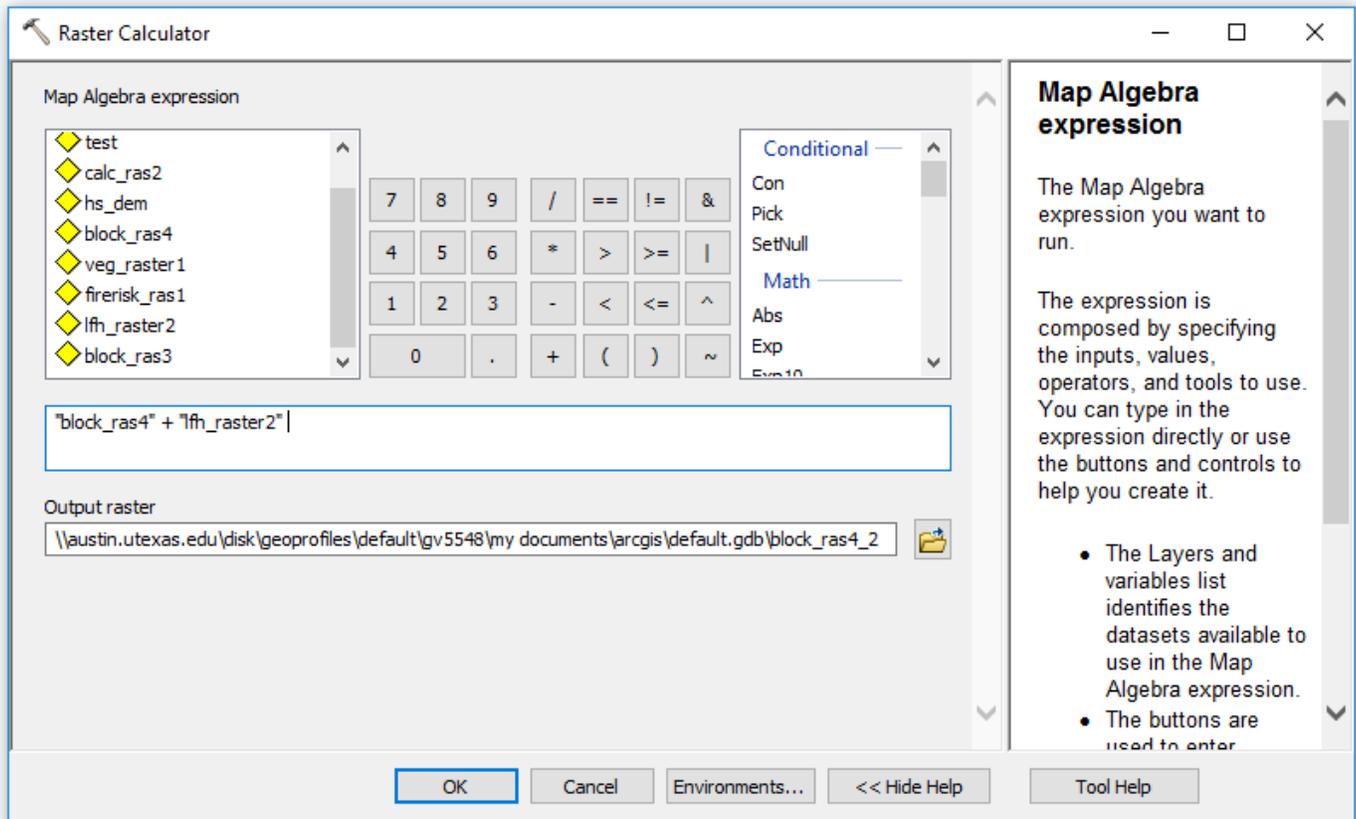
Figure 22: An example of the "Raster Calculator" using both Population and Lava Flow Hazards layers.

VI. Results

A total of two maps were created to understand where in the Island of Hawai'i that both vegetation (Map 1) and population (Map 2) of the Island of Hawai'i face.
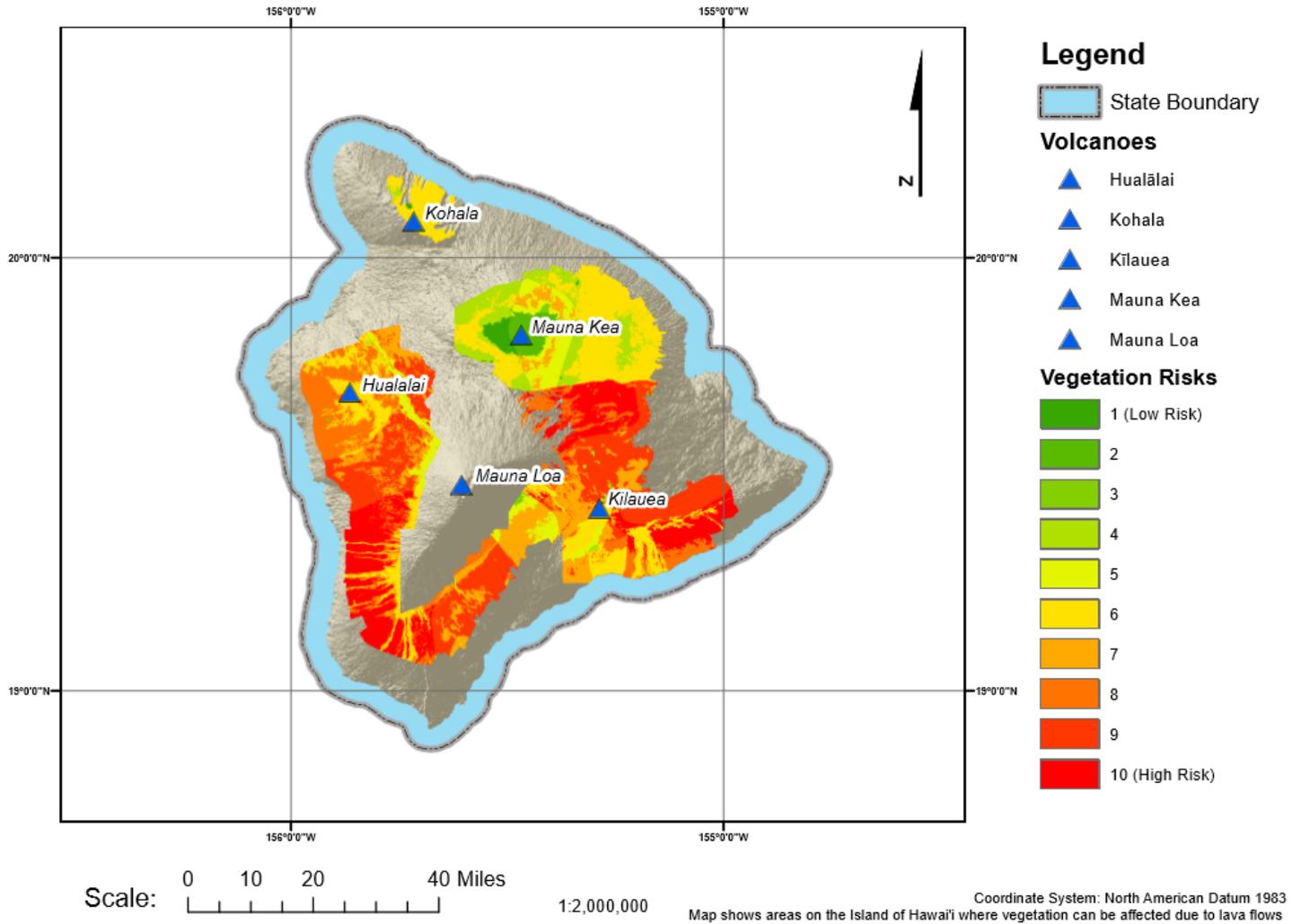
Map 1: Risks faced by vegetation within the Island of Hawai'i effected by lava flows.

Gabriel Villaseñor

Areas of Risk in Populated Blocks by Lava Flows in the Island of Hawai'i

Legend

- State Boundary
- Census Blocks

Volcanoes

- ▲ Hualālai
- ▲ Kohala
- ▲ Kīlauea
- ▲ Mauna Kea
- ▲ Mauna Loa

Risk Zones

- 1 (Low Risk)
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13 (High Risk)

Scale: 0 10 20 40 Miles

1:2,000,000

Coordinate System: North American Datum 1983
Map shows areas on the Island of Hawai'i where vegetation can be affected due to lava flows
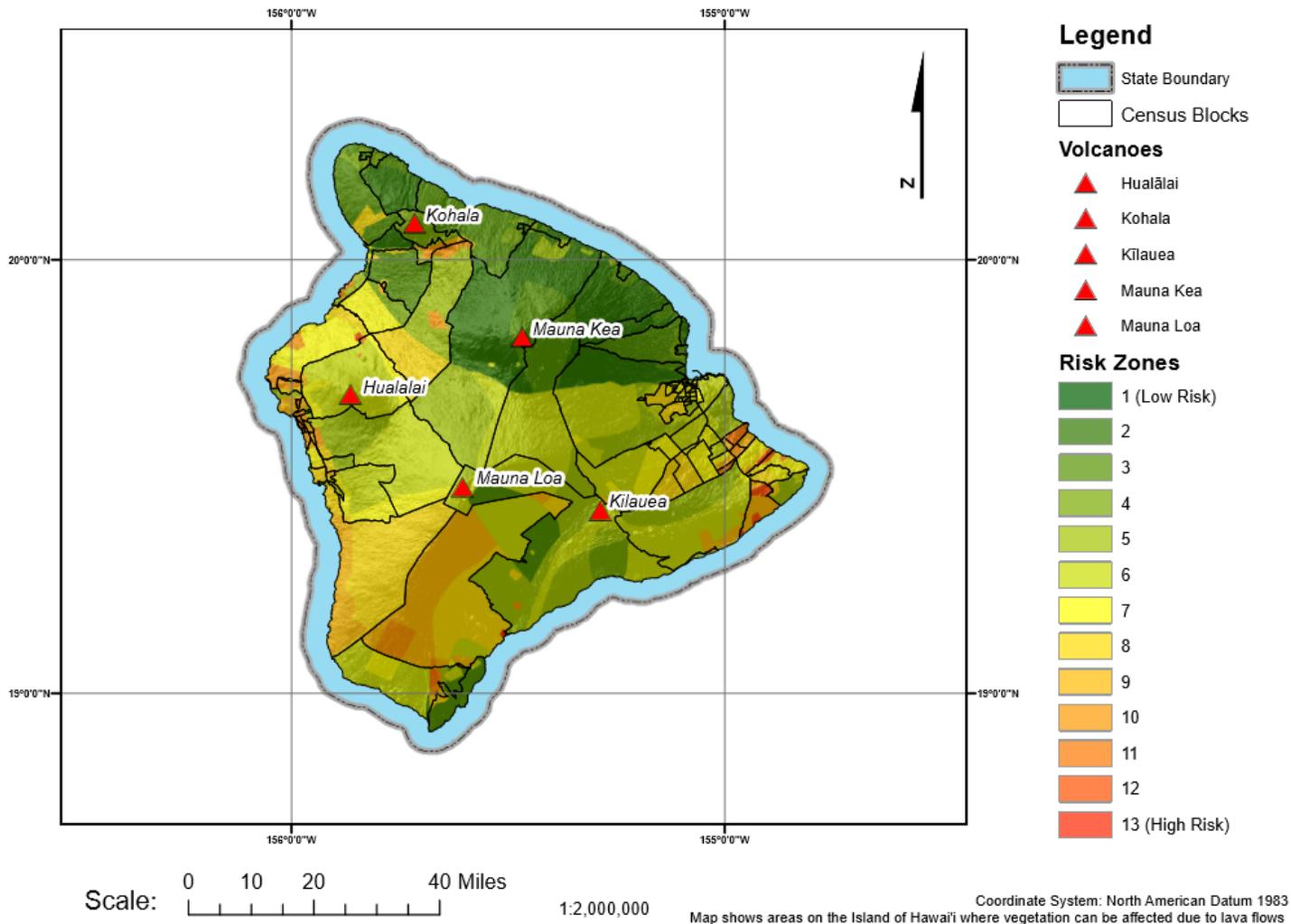
Map 2: Magnitude of risks in areas within populated blocks of the Island of Hawai'i.