Volcanic Hazard Mitigation

Mount Sinabung, North Sumatra

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Problem Overview:

Mt. Sinabung is a volcano located in North Sumatra, Indonesia. It reawakened to the surprise of the local population in August, 2010. Within a few days of the initial phreatic eruption the surrounding towns were relocated and local alert was raised to the highest level (Awas: Level 4). Since its first Holocene eruption there have been prolonged periods of the highest threat. Through analyzing topography, the range of previous pyroclastic density currents (PDCs), ash fall, and lahars, I will address the question: What is the range of potential damage to the nearby population?

1. **Data Collection:**

This hazard assessment required ASTER GDEM tiles of the North Sumatra and surrounding area, found through https://urs.earthdata.nasa.gov/.

Originally, I was able to download a vector file with the rivers of Asia from http://gaia.geosci.unc.edu/rivers/, but since the file was too large easily manipulate, digitizing was necessary. Though, please note, that only the rivers that were within range to be affected by previous pyroclastic flows and lahars were mapped. Populated places data downloaded from the defense mapping agency, geographic name server (http://geonames.nga.mil/gns/html/index.html) and, as explained below in step 3 and figure 2, was converted to a point file from an excel spreadsheet. File> add data >add XY data> pick spreadsheet from drop down.

- Retrieving GDEM tiles**:**

Search in top drop down: ASTER GDEM > zoom and drag to location of interest on map > select search by spatial rectangle > Highlight area > download zip files> extract files> load into ArcMap.

2. **Data preprocessing and ArcGIS processing**

First, all the imported datasets have a spatial reference of GCS_WGS_1984. ArcCatalog 10.2.2 was used to set the data frame. After uploading all 6 GDEMs into ArcMap, the create mosaic feature was used to combine them into a unified raster database as seen in Fig 1.

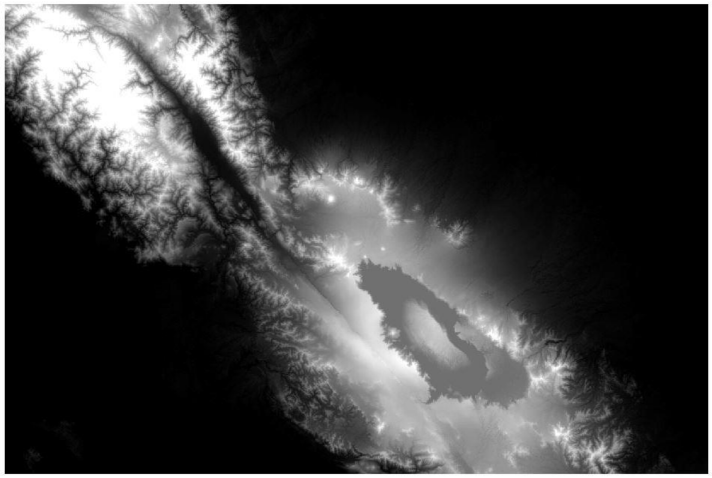

Fig. 1: GDEM Mosaic

Hillshade was generated from the mosaic to show 3D representation. A Z factor of .000009 was used to convert decimal degrees to meters for a correct elevation. Spatial Analyst Tools > Surface > Hillshade.

3. A **shapefile** was created from an excel spreadsheet to show population centers:

	A	B	C	D	E	F	G	H	I	J
1	NAME	F_CLASS	F_DESIG	LAT	LONG	ADM1	ADM2			
2	Berombar	P	PPL	2.5875	100.1277	Sumatera	Labuhan Batu			
3	Ulakmeda	P	PPL	2.7166	99.6333	Sumatera	Simalungun			
4	Ujungtanj	P	PPL	3.7333	98.6666	Sumatera	Deli Serdang			
5	Ujung Run	P	PPL	2.45	98.9333	Sumatera	Tapanuli Utara			
6	Ujungjilok	P	PPL	1.05	99.8666	Sumatera	Tapanuli Slt			
7	Ujungdaw	P	PPL	3.7	98.7	Sumatera	Deli Serdang			
8	Ujungdam	P	PPL	4.0166	98.4833	Sumatera	Langkat			
9	Ujungbatu	P	PPL	1.6333	100.0333	Sumatera	Tapanuli Slt			
10	Ujungbatu	P	PPL	1.0333	99.95	Sumatera	Tapanuli Slt			
11	Udjungtar	P	PPL	3.7333	98.6666	Sumatera	Deli Serdang			
12	Udjung Ru	P	PPL	2.45	98.9333	Sumatera	Tapanuli Utara			
13	Udjungdji	P	PPL	1.05	99.8666	Sumatera	Tapanuli Slt			
14	Udjungda	P	PPL	3.7	98.7	Sumatera	Deli Serdang			
15	Udjungda	P	PPL	4.0166	98.4833	Sumatera	Langkat			
16	Udjungba	P	PPL	1.6333	100.0333	Sumatera	Tapanuli Slt			
17	Udjungba	P	PPL	1.0333	99.95	Sumatera	Tapanuli Slt			
18	Tutupan	P	PPL	2.5333	99.2666	Sumatera	Tapanuli Utara			
19	Tungtungl	P	PPL	2.8166	98.1333	Sumatera	Karo			
20	Tungkangl	P	PPL	4.1333	98.1166	Sumatera	Langkat			
21	Tungkam	P	PPL	4.1333	98.1166	Sumatera	Langkat			
22	Tumuond	P	PPL	2.6666	99.1666	Sumatera	Deli Serdang			
23	Tumpakra	P	PPL	2.8333	98.3666	Sumatera	Karo			

Pop_places

Fig. 2: GRD file to spread sheet

- In ArcMap table of contents (TOC) added event theme created by add XY data tool was convert to a shapefile by: right click intended folder > New > Shapefile.

4. **Digitized area of interest** to zoom in on appropriate region (Fig. 3):

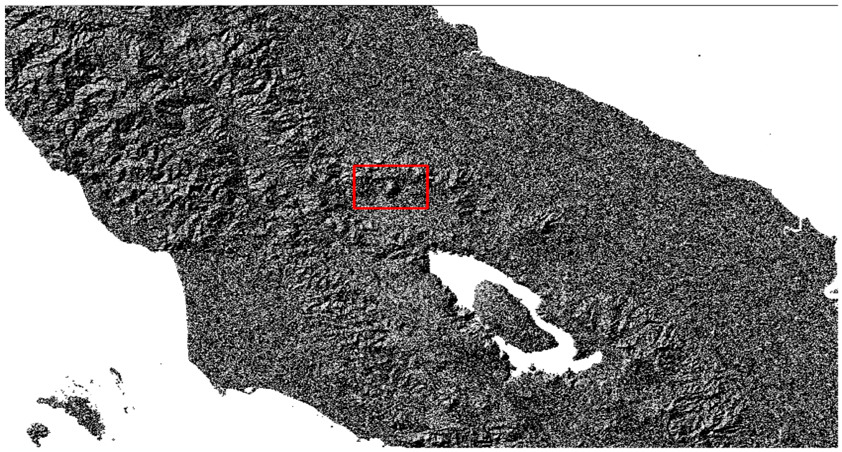

Fig. 3: Area of interest in red

Using the rectangle tool, a box was drawn by putting 3 points around the corners of the mosaic.

5. **Clipped mosaic**: Extract by mask tool to clip mosaic to the area of interest > Mosaic set to brown to blue green diverging, dark color map (fig. 4):

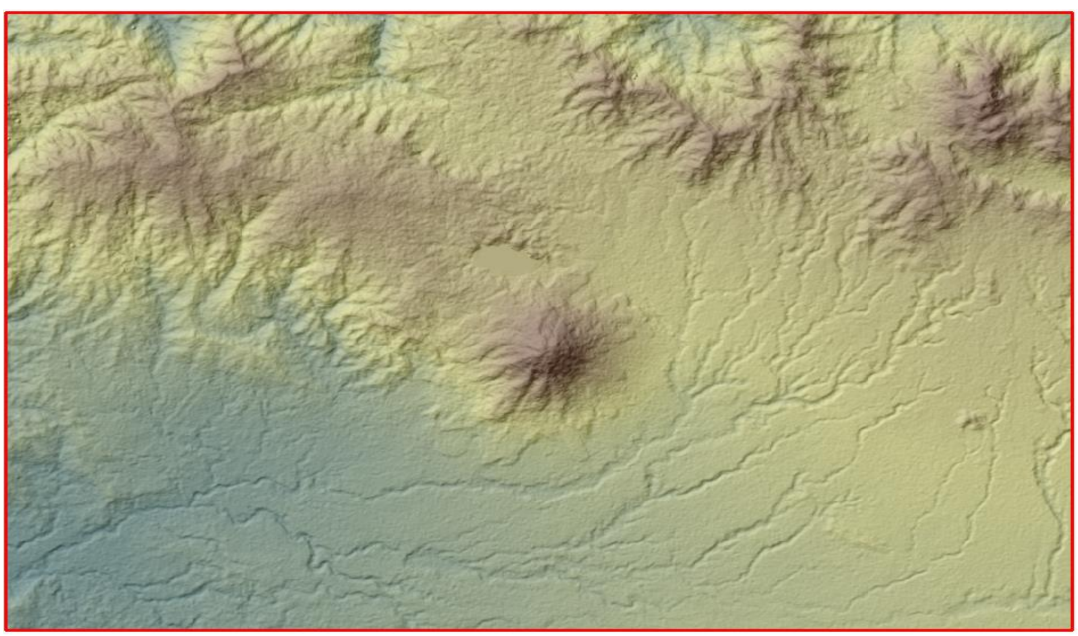

Fig. 4: Clipped mosaic

6. **Slope from Mosaic (**fig.5)**:** > z factor adjusted (.000009):

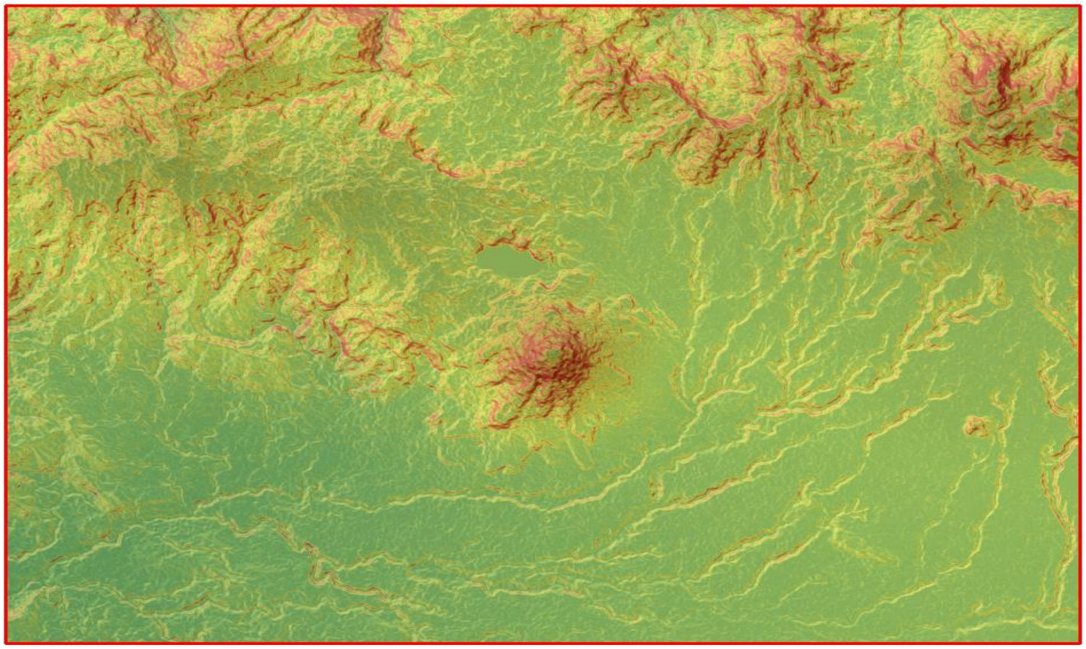

Fig. 5: slope map

7. **Digitized pyroclastic density currents**: (PDCs) based off slope and aerial photographs of prior PDCs (see fig.s 6 and 7):

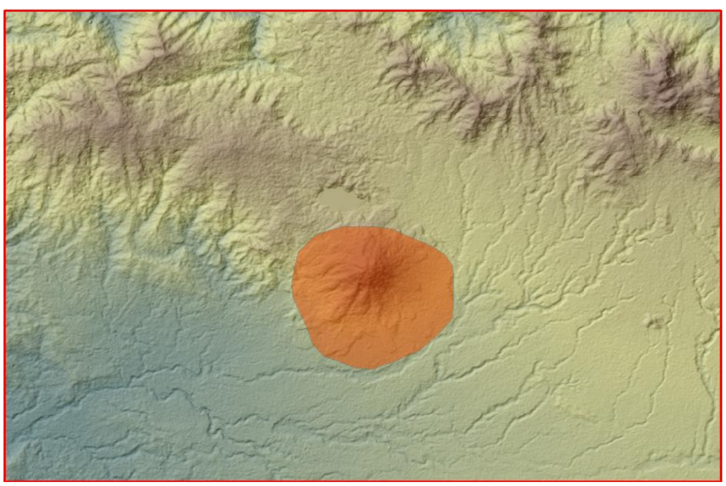

Fig. 6: Digitized PDCs

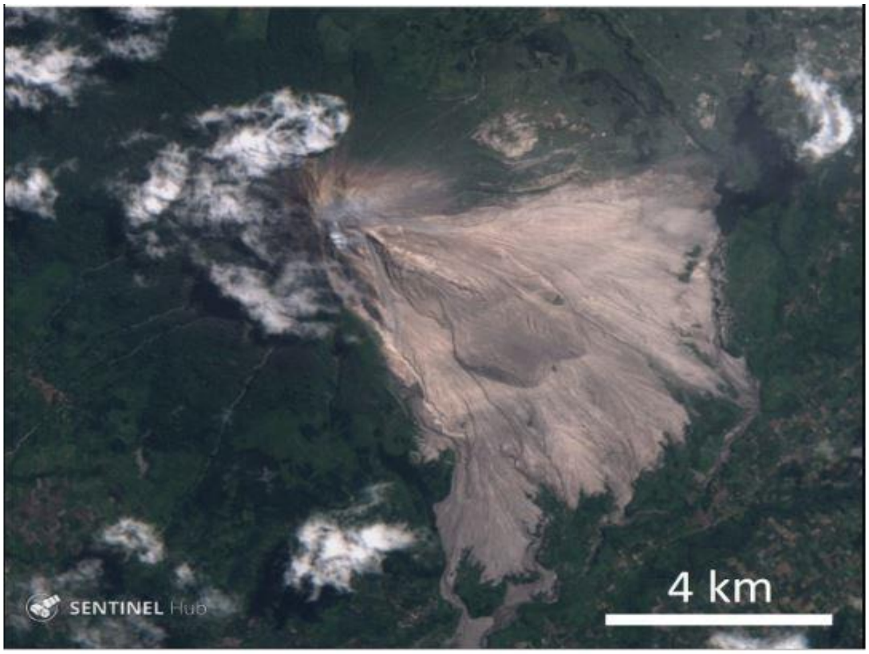

Fig. 7: Orthophoto showing the range of PDCs (light color debris).

Photo from the https://volcano.si.edu/volcano.cfm?vn=261080#bgvn_201702

In figures 6 and 7 the range of the PDCs were derived from the orthophoto to the river they run into.

8. **Digitized rivers:** Right click geodatabase within “My data” folder > new > feature class> Rivers. From TOC Rivers > edit features> start editing > continue feature tool> digitize rivers. (Fig. 8)

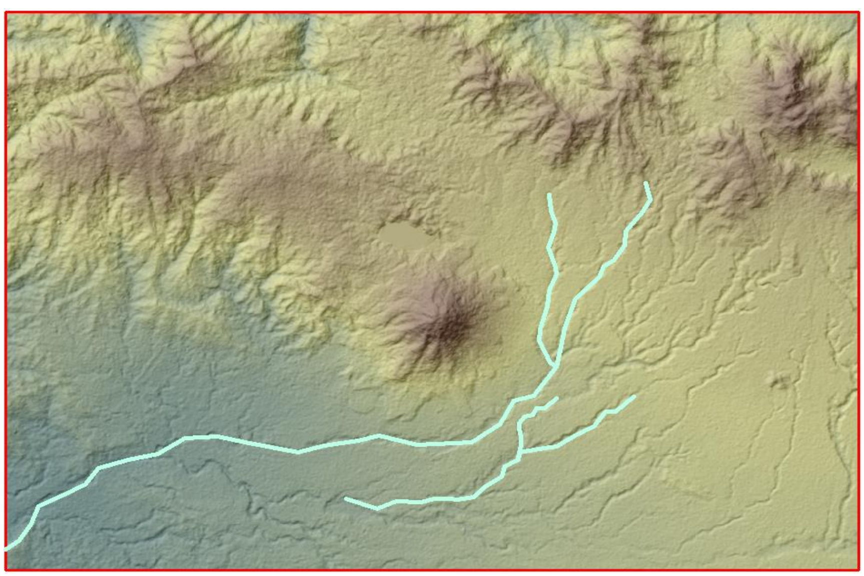

Fig. 8: Digitized rivers

9. **Clipped** population, rivers, lakes, and PDCs to Area of interest (Fig. 9):

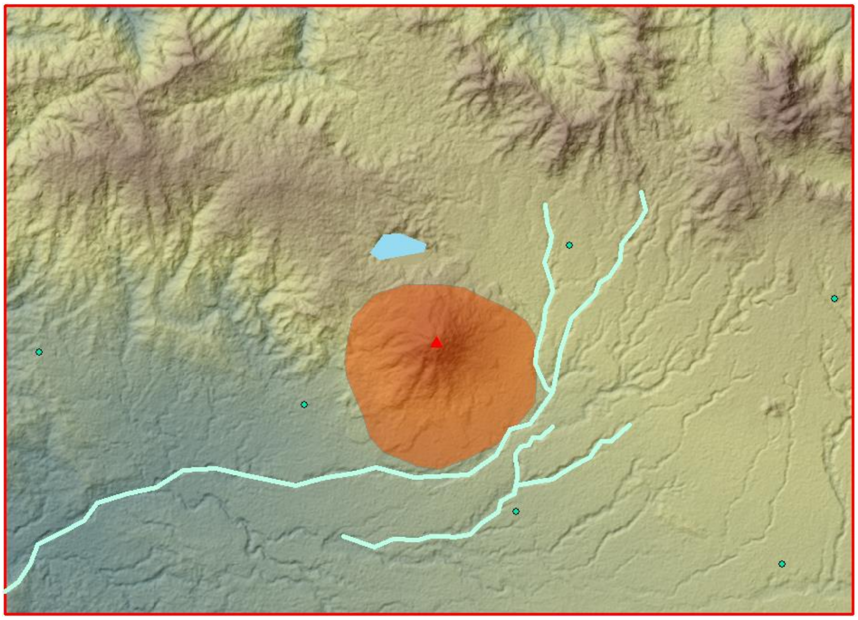

Fig. 9: Establishing a perimeter for PDCs and their relationship with the river.

10. **Buffered** the rivers to 250m, 500m, and 1km to represent lahar flows (Fig.10):

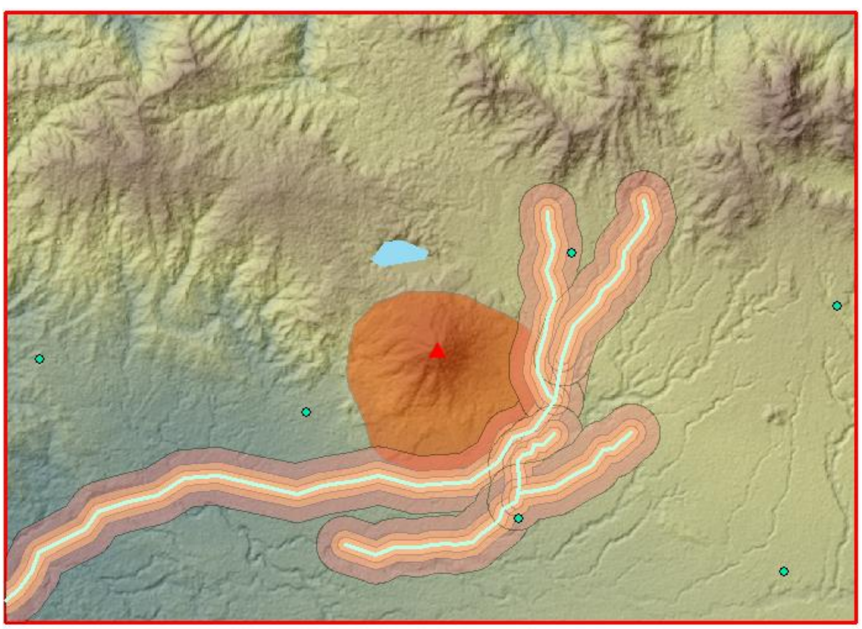

Fig. 10: Where pyroclastic deposits and regions prone to lahars over lap

North Sumatra is known for torrential rains during monsoon season. This with pyroclastic deposits can generate deadly lahar flows. The range of those are seen above in figure 10.

11. From reports of ash fall, buffer zones of fine ash, lapilli, and ballistics were generated radially from the summit of Mt Sinabung as seen below in figure 11.

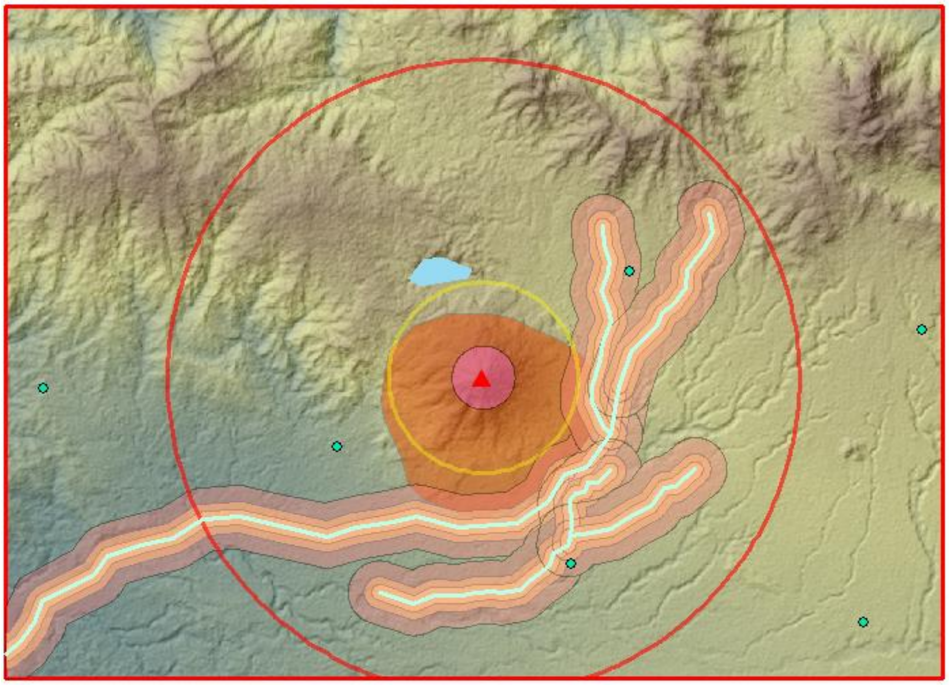

Fig. 11: Ranges for fine ash (6km), lapilli (2 km), and ballistics (1km)

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Mount Sinabung Hazard Profile

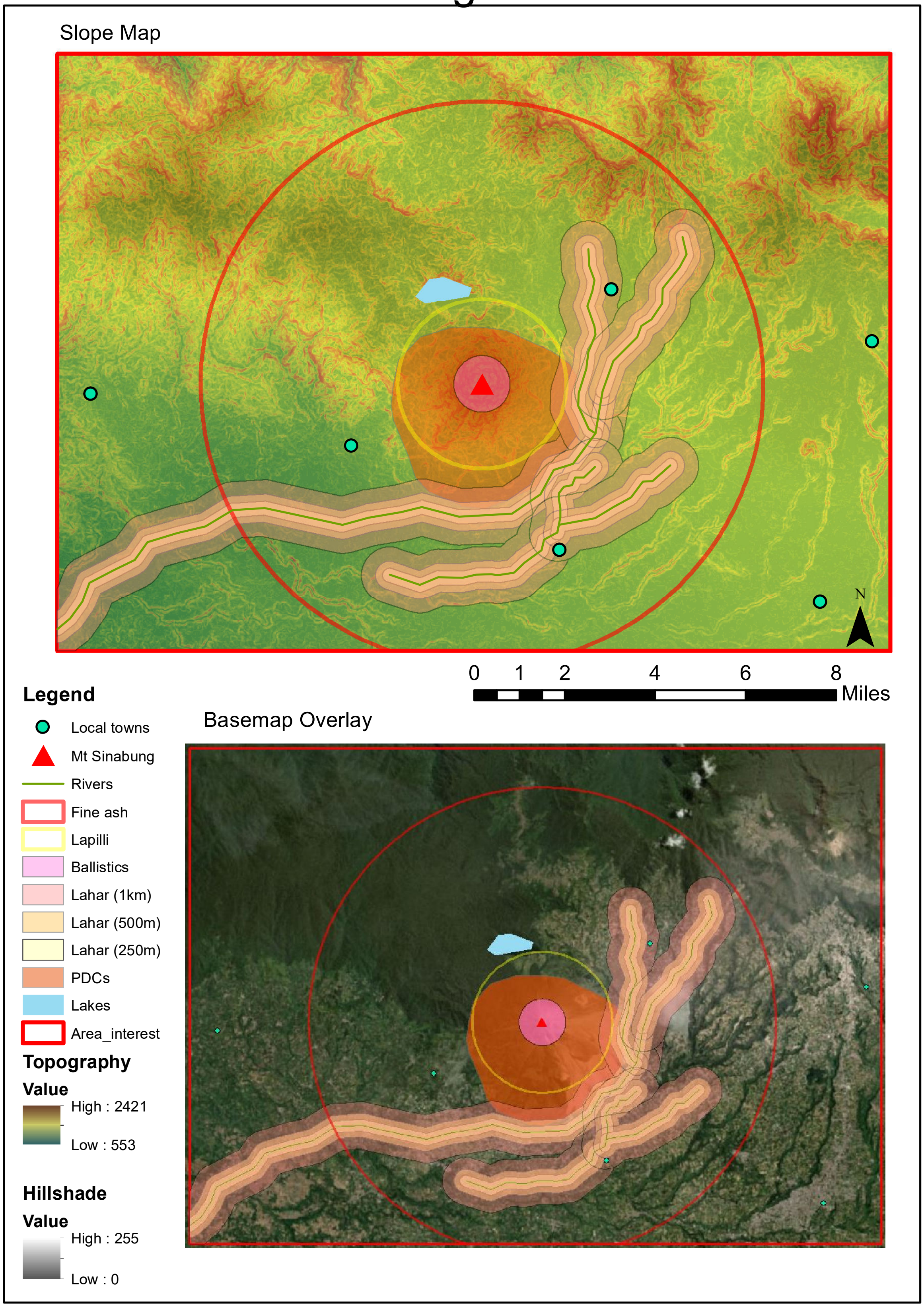

Plate 1: Final maps. The above map is a slope map overlay to show the affect slope has on the PDCs and lahars. The base map overlay shows the accuracy to the region.

Results and Conclusion:

The results show that areas surrounding the volcano and adjacent rivers as indicated in the final hazard map (Plate 1) should be evacuated immediately in the event of a lahar or PDC. Heavy rains have the potential to increase the range and probability of lahars. For this part of Indonesia, it is difficult to obtain precise population data. According to the references cited below, the towns and their populations located within the danger zone are Torajabernah: 13,543 and Tigapantjur: ~13,000. This does not include the vast region of farmlands that exist within the region southeast of the summit located between the two towns. These areas would also be inundated. With that knowledge and assuming that the total dispersed populations would be double that of the population in the two towns, then as many as 53,000 people could be displaced.

References:

Population data

- https://www.nationalgeographic.com/news/2016/08/indonesia-volcanoes-rinjani-sinabung-gamalama/#close
- http://www.fallingrain.com/world/ID/26/Torajabernah.html

Data and information on Mount Sinabung:

- https://volcano.si.edu/volcano.cfm?vn=261080#bgvn_201702