Vegetation Analysis & Change Detection

Before & After Volcanic Eruption

Devon Elam

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Dr. Huidae Cho

Abstract:

Guatemala is home to more than 34 active volcanoes, but as the June 3rd tragedy shows, lack of appropriate warning systems and emergency protocols leave the country's population vulnerable to lava flows, landslides, and other hazards equal to these situations. On June 3rd of last year, a horrific volcanic eruption occurred in Guatemala that led to 197 fatalities and 246 people still missing. There are some reports that the death tally isn't even accurate. Furthermore, Volcan de Fuego is the name of the volcano and its name means Volcano of Fire. Fuego is one of the three most active volcanoes in Central America. According to a 2016 report by the United Nations University Institute, Guatemala is the fourth least prepared country to respond to their own potential climate disasters. Furthermore, the people who had to endure the tragedy wondered why the officials took so long to warn the people and not give them enough time to evacuate from their communities. Besides the fact that many people become lost or separated from their families after an eruption, it also plays a part in the environment as well. It can leave long lasting effects on all organisms and the climate because of the gases releases after the eruption and ignites a chain of negativity. Now here I have provided visual representations of the volcano's before and after effects of the eruption with a change detection map and also a Normalized Difference Vegetation Index. The Change Detection maps are an accurate depiction of how the volcano and the surrounding area looks after the damage has been endured. Its purpose is to show a measurement of how the attributes of a particular area have changed over either a brief or a lengthy time period. Change detection often involves comparing two different types of photographs, one from aerial imagery and another from satellite imagery and then take the best observation of the difference. NDVI map will show the elevation levels of the ground and if there is any remains of life in the vegetation. Normally, the healthy vegetation reflects more near-infrared and green light than basically all of the other wavelength. Green, yellow, and red colors will differentiate the elevation levels with green being the most damage and red being the least.

1) Introduction

Objective:

My study site will be the same site for both of my maps. I will focus on the site of the Volcan de Fuego and surrounding areas. Using Landsat data, I will create two maps detailing the change detection of the land that surrounds the mouth of the volcano, and also the Normalized Difference Vegetation Index of the same area. I will also do a land use analysis for the study site, which could help gauge the kind of economic impacts a similar site would face. I will look at population data from the Guatemalan census in conjunction with USGS elevation data to identify populations most vulnerable to rapid lava flows and landslides. The two images captured by NASA's Landsat 8 satellite were used for this analysis. Imagery was acquired through the USGS Earth Explorer portal. The first image was captured on March 3, 2018 (pre-event) and the second on June 25, 2018 (post event).

"The impact of satellite sensor viewing geometry on time-series analysis of volcanic emissions"

Volcanoes are mostly known to be located in remote areas surrounded by nothing but land, but the effects of the eruptions can cause critical damage to the ecosystem that often goes unknown. They can cause massive changes in the climate, and disrupt peoples breathing ability for days depending on impact. For instance, sulfur dioxide emitted during an eruption is one of the leading factors in the causes of air pollution (Froger, J. L., Famin, V., Cayol, V., Augier, A., Michon, L., & Lénat, J. F. (2015). Satellite imagery became important instruments that were at first used just to measure vegetation and sea level temperatures and surfaces. In this article, it talks about thermal anomalies and how using the Moderate

Resolution Imaging Spectroradiometer and Ozone Monitoring Instrument to determine sulfate levels is one of the best spatial resolution outcomes of all of the equipment (Rix, M., Valks, P., Hao, N., Van Geffen, J., Clerbaux, C., Clarisse, L., ... Emmadi, S. (2009).. In addition the spatial resolution and the specific type of data that you choose and what type of restrictions come along with this data are all variables that if one change can cause problems for all the data (Global Volcanism Program (2008). Report on Kelut (Indonesia). In R. Wunderman (Ed.), Bulletin of the Global Volcanism Network, 33:3. Smithsonian Institution. H). This study is relevant to my project because one of the maps that are going to be created is one the land cover change map and the analysis of the volcano along with the subpixel volcanic fumes. To be able to see the extent of the ash is great to identify how far the lava has reached the surrounding areas and to be able to identify which populations were affected the most and the least (G. Asrar, Theory and Applications of Optical Remote Sensing. New York: Wiley, 1989, ch. 4, pp. 125–125.).

<center>"VIIRS Nightfire Remote Sensing Volcanoes "</center>

Remote sensing is a term that has been relevant since the 1960s and volcanic observations using remote sensing methods, analysis and tools started in 1965. In the article "VIIRS Nightfire Remote Sensing Volcanoes" it focused on a new specific algorithm known as Nightfire that has immersed in the current generation of sensors. Before, they had a program known as MODVOLC data in which the MODIS satellites were able to locate the Satellite Zenith Angles in Nadir (Wooster, M.J., Roberts, G., Perry, G.L.W., Kaufman, Y.J., 2005). This Landsat program is used to identify the subpixel sources and estimate the characteristics of them using nighttime data (Elvidge, C.D., Zhizhin, M.N., Hsu, F.C., Baugh, K.E., 2013.). Originally, Nightfire data used multiple infrared bands to detect gas levels, but it has evolved now to where it can predict the location and size of hotspots along with temperature of it and radiant heat. The Short Wave Infrared Range, SWIR, band M10 is identified as possessing the best ability to reveal hotspots, while the Mid Wave Infrared Range is an advanced identifier of all of the cool surfaces using its M12 and M13 bands (Elvidge, C.D., Zhizhin, M.N., Hsu, F.C., Baugh, K.E., 2013., J.A., D., 1981). This article is relevant to my study because you are able to tell the effects of before and after of eruption just by using thermal anomalies and clustering them spatially so that it distinguishes a certain color to depict warmer and colder temperatures. Furthermore, there have been problems with recording data since its gets darker faster during the summer which initiates the problem of organisms making too much noise (Girina, O.A., Manevich, A.G., Melnikov, D.V., Nuzhdaev, A.A., Demyanchuk, Y.V., 2017. NOAA, a. Viirs nightfire data.). In addition, city officials will be able to have a reasonable procedure to alert the citizens of the area known to evacuate the area whenever an unusual error is spotted for future references.

"Eruption mass estimation using infrasound waveform inversion and ash and gas measurements: Evaluation at Sakurajima Volcano, Japan"

This article is great for my project because it covers the extent of lava flow during an eruption and show how you're able to estimate the damage based on gas and ash data. The two main ideas stated in this research were the infrasound and ground-based techniques used to detect eruption mass Kazahaya, R., Mori, T., Yamamoto, K., 2013. Separate quantification of volcanic gas fluxes from Showa and Minamidake craters at Sakurajima Volcano, Japan. Bull. Volcanol. Soc. Jpn. 58, 183–189.). In order to get that data you must know the density of the flow of the lava. There are certain equipment that are needed to identify other components such as volume, mass flux of explosions in combination with ash multispectral imagery. The methods necessary include numerous mathematical equations to properly set each variable to its accustomed attribute. One of the more important functions needed is the Green's function in coherence with a high resolution DEM and 3-D Finite Difference Time Domain modeling to be able to observe and collect data about the eruption mass (Johnson, J.B., Ripepe, M., 2011. Volcano infrasound: a review. J. Volcanol. Geotherm. Res. 206, 61–69.). The equation is d=GM, where the D is

the vector data, G is the matrix for Green's function, and m is the monopole representation to prevent change of momentum (Williams-Jones, G., 2008. The COSPEC Cookbook: Making SO2 Measurements at Active Volcanoes. IAVCEI). Although technology is constantly advancing, accurately determining these quantities is very much challenging. First off you don't know how many explosive events will take place at the specific landform, and also the gas estimates have different results each run so data may be unpredictable times (Sparks, R., Wilson, L., 1982. Explosive volcanic eruptions—V. Observations of plume dynamics during the 1979 Soufrière eruption, St Vincent. Geophys. J. Int. 69, 551–570).

"Ndvi: Vegetation Change Detection Using Remote Sensing and Gis – A Case Study of Vellore District"

The following article consists of one of the processes that I did for my map. I used NDVI and Dem data when constructing how I was going to portray the damage done to the volcano. The difference is that this article talks more of performing " Multi-Spectral Remote Sensing data technique to find Vegetation Index, land cover classification, vegetation, water bodies, open area, scrub area, hilly areas, agricultural area, thick forest, thin forest with few band combinations of the remote sensed data (Karaburun A. A. K. Bhandari, "Estimationof   C factor for soil erosion modelling using NDVI in Buyukcekmece watershed",   Ozean Journal of applied sciences 3, 77-85., 2010). It also talks about how the "digital image processing of satellite data provides tools" in order for you to be able to analyze a picture through all of its characteristics (Johnson, J.B., Ripepe, M., 2011. Volcano infrasound: a review. J. Volcanol. Geotherm. Res. 206, 61–69). There are various ways to highlight vegetation and mostly it comes from the lights being reflected off of the image itself. Most importantly, a good length of my time was used to composite the "bands named near infrared band, red band and green band" in which my attempt was to extract them, so that I could reuse them (Global Volcanism Program (2008). Report on Kelut (Indonesia).

"Initial constraints on triggering mechanisms of the eruption of Fuego volcano (Guatemala) from 3 June 2018 using IASI satellite data"

The reason that I picked this article is because it's specifically talking about the event that I am doing my project over. The only difference is that this article specifically talks about the sulfur emitted from the volcano and how it affected hundreds of fatalities. It talks a little about how "satellite remote sensing is a very valuable technique as it provides regular monitoring data from a safe distance" (Webley et al., 2008; Lyons et al., 2010). This is great because we have a lot of pictures of what the representation supposedly looks like from space but there's no way to assure that the pictures quality will be efficient or if the data is efficient enough in and of itself. I grabbed my data using Landsat imagery off of Earth explorer website but in the article they used "satellite observations acquired by IAS" (
Hughes et al., 2012; Heng et al., 2016). IAS stands for image assessment system and its purpose is to take ellipsoids of the earth and allow you to utilize them and the imagery to perform whatever geospatial process that you'd like to obtain the information necessary.
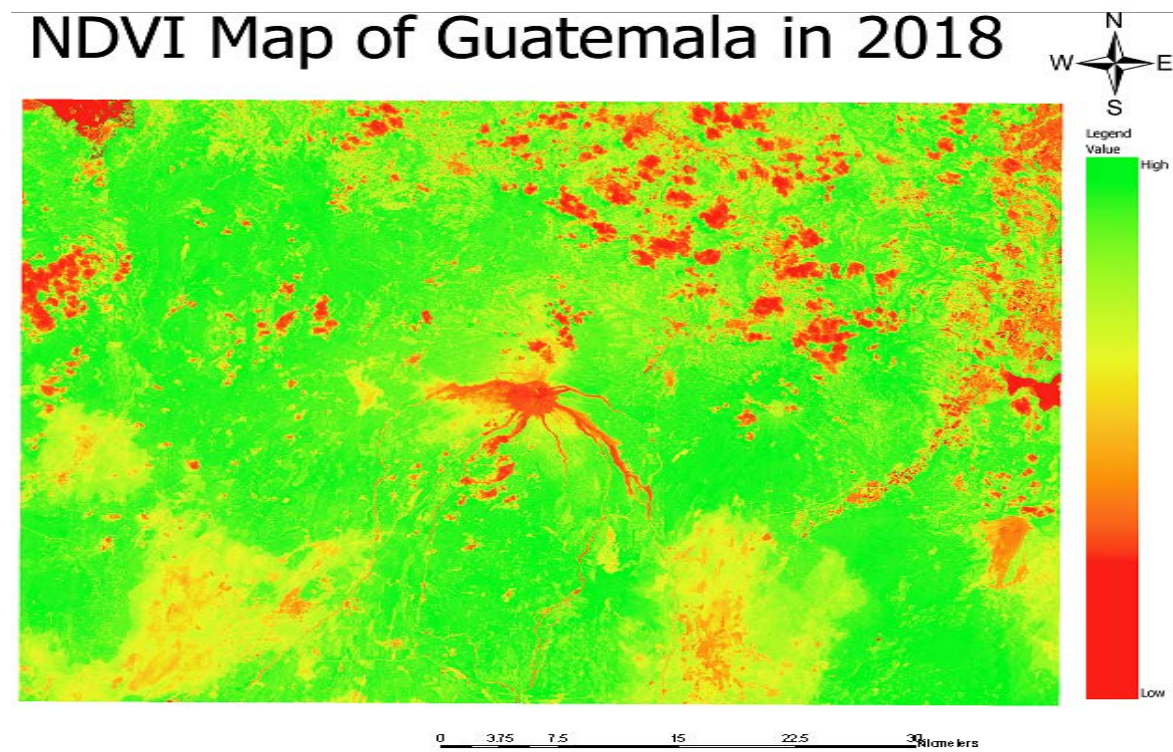
2) Materials and Methods

All of my materials and methods came from some type of sorcery of the web. I made an account on the website Earth Explorer and downloaded Landsat 8 imagery of the volcano in Guatemala. All of the other materials that I used came from both the Geoprocessing tools in ArcPRO, the raster calculator, and also the raster functions tools. My first chronological steps will be on how I constructed my Normalized Difference Vegetation Index of before and after the eruption and the changes of the elevation level. First locate Landsat 8 data of clear imagery of the before and after effects of the volcanic eruption on USGS

Earth Explore.Once data is chosen, send them to your item basket and submit order request and await the confirmation for downloadable access.Then you must add/load the raw data imagery bands on to ArcPRO and make sure each one is visibly clear.Next, group all the bands together by stacking them numerically from band one to band seven using the composite function in the Geoprocessing tools.

   After that you must change the symbology of the Composite function to Natural/Vegetation band color combination.Create a feature class by dropping a rectangle over my study area, and clipped it out. Then locate the NDVI tool in the Raster Functions toolbox.Use the composite layer as the raster input and put the number 4 for the Visible Band ID and 5 for Infrared Band ID.After that locate the Raster Calculator, also in the Geoprocessing tools, and subtract the Before and After NDVI image layer to form an Output image of the differences between the NDVI images Created Normalized Difference Vegetation Index using Landsat 8 bands 4 and 5 from March 3, 2018 and the raster calculator using the following formula: NDVI= (Band NIR-Band red)/ (Band NIR + Band red). In addition, to construct the NDVI difference of my maps, I use the raster calculator once again and just subtracted the after picture to the before picture.
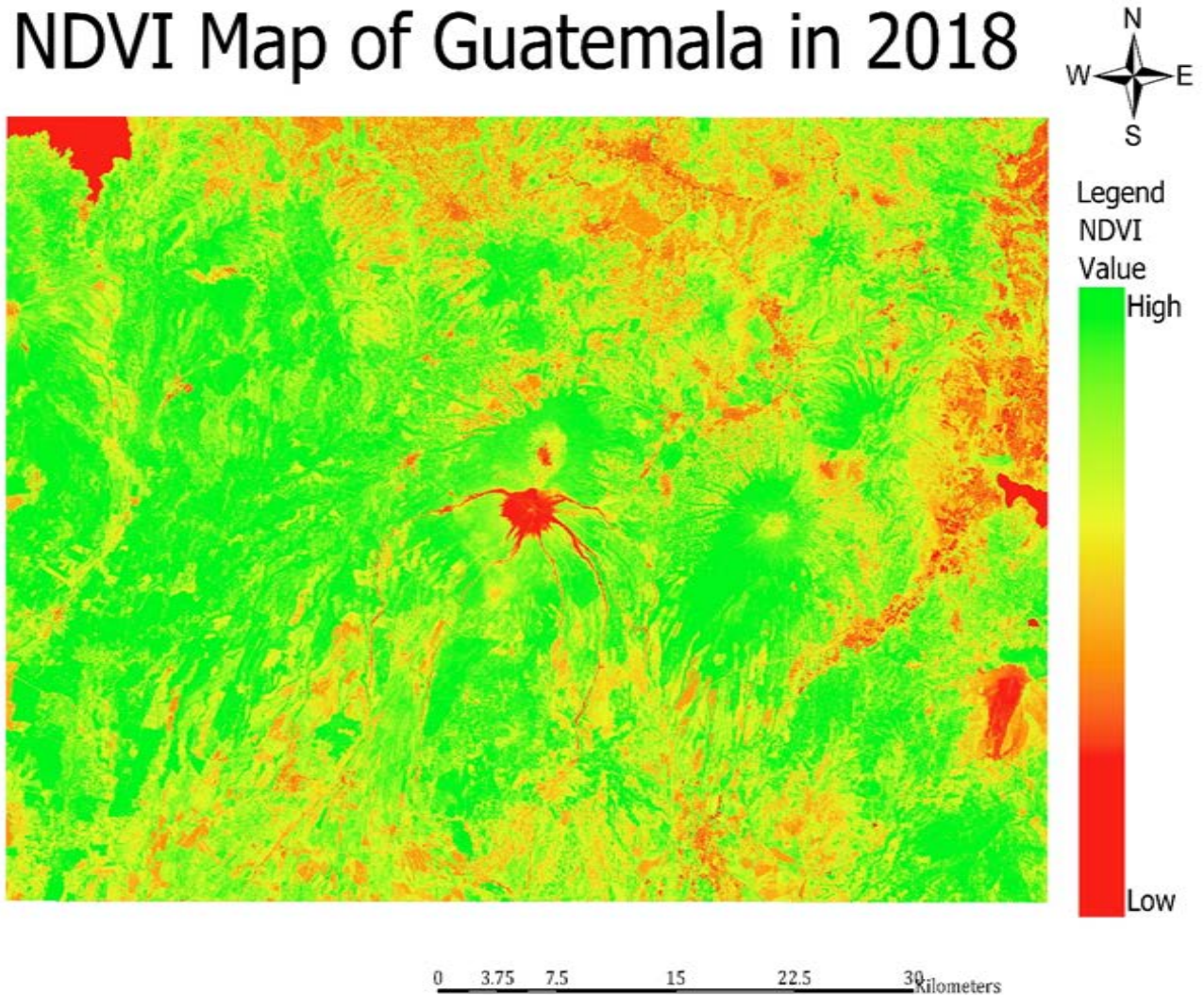
   The next procedure that stated will be the one to create the change detection map. First and foremost I ran the ISO Cluster Classification tool to process each raster (10 classes). I then reclassified both ISO Cluster output raster's to group similar classes together and reduce number of classes to 6. Next the new classes were given values from 1 to 6 in the first raster, and the corresponding classes in the second raster were given values 10 to 60. Then using the plus tool on the new reclassified raster's, a new raster detailing the type of change, if any, for each pixel in the raster was produced. Each type of change for each pixel could be determined by the new values of the pixel, for example, a pixel with value 1 in the first raster and value 10 in the second raster would have a value of 11 in the output raster and thus could be determined to have undergone no change, as both 1 and 10 values corresponded to the same class.

3) Results and Discussion
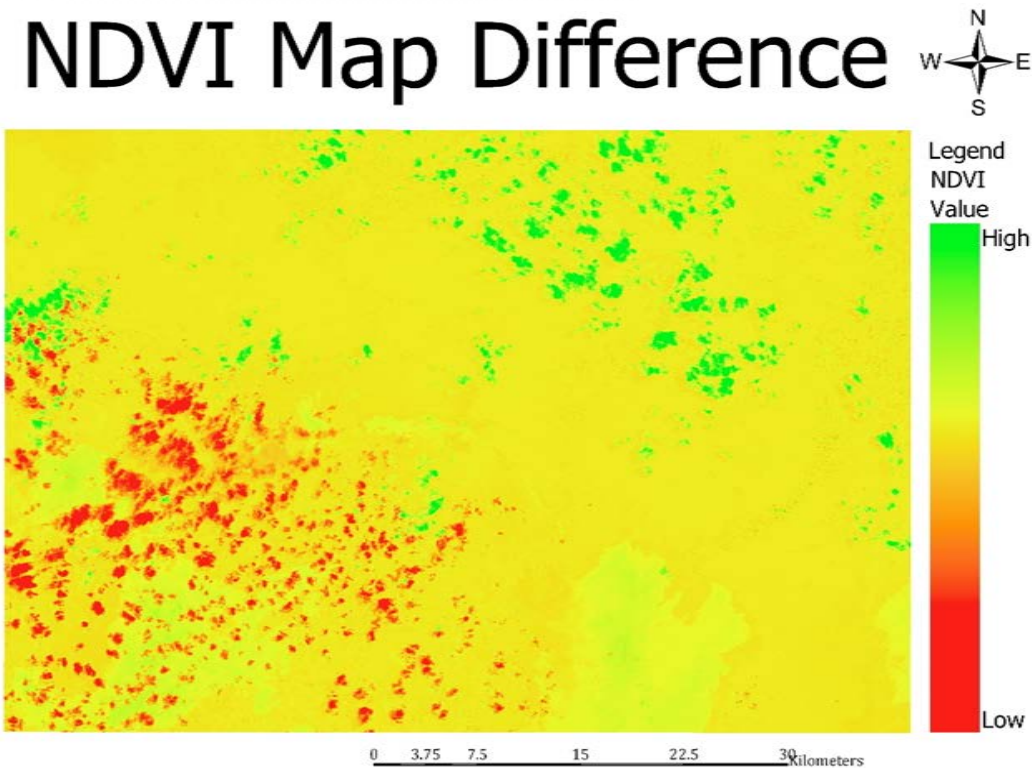

NDVI Map of Guatemala in 2018

The following image is the NDVI image of before the eruption which is dated back to March 3, 2018, so exactly 3 months to be exact. The image under this one is after the eruption on the 25th days of June and you can see majority of the map is green which shows the vegetation is dead which is to be expected. The following equation is the formula used to calculate the NDVI. Next, you have the Bands identifier for Landsat 8 imagery which helped determine which bands to run the composite functions with because they alter for different Landsat data. Furthermore, you have the actual visual representation of the volcano after being erupted and can see the huge body of smoke that still in the very middle and how it looks to be spread the clouds out more. Lastly, the change detection analysis produced focuses on the change in land use/ land cover. Changes in land use/land cover may have great social or economic implications. This change detection map helps give an overall summary of the impact of the June 3rd eruption.
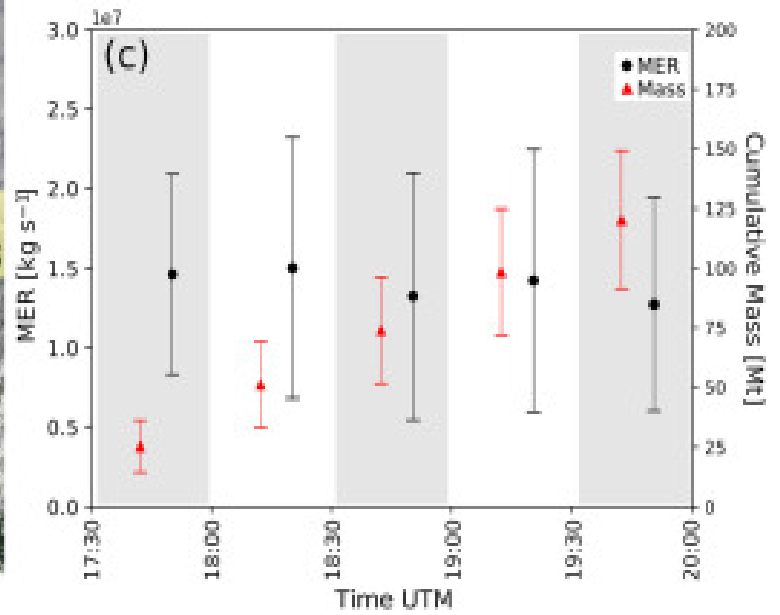
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NDVI Map Difference

Band	Name of the band	Wavelength (μm)	Characteristics and usage
1	Visible blue	0.45 - 0.52	Maximum Water Penetration
2	Visible Green	0.52 - 0.60	Good for measuring plant vigor
3	Visible Red	0.63 - 0.69	Vegetation Discrimination
4.	Near InfraRed	0.76 - 0.90	Biomass and shoreline mapping
5.	Middle InfraRed	1.55 - 1.756	Moisture Content of Soil
6.	Thermal Infrared	10.4 – 12.5	Soil moisture and Thermal Mapping
7.	Middle InfraRed	2.08-2.35	Mineral mapping

Fuego volcano
19h UTM 3 June 2018

(c)

March 3, 2018

June 25, 2018

Change Detection Analysis
Volcan de Fuego

Land Cover
- lava flow
- ash cover
- developed
- agriculture
- forest
- cloud obstruction

Guatemala is home to 30+ volcanoes, including the Volcan de Fuego, one of the most active volcanoes in the world. On June 3, 2018, Volcan de Fuego had a major eruption event that devastated the country. The death toll for this catastrophic event is at least 190, with hundreds of others still missing. The purpose of this analysis is to see the impact of the eruption on the surrounding area. Analysis was completed using Landsat 8 imagery taken on March 5th and June 25th of 2018. Figures at the top show the land cover for the area on each date. The legend above corresponds to both figures. Land cover was determined using unsupervised ISO cluster classification. The figure at the bottom shows how the land cover changed between March 5, 2018 and June 25, 2018. The figure below shows the study area for this analysis.

Change Type
- agriculture-ash cover
- agriculture-developed
- agriculture-forest
- agriculture-lava flow
- ash cover-agriculture
- ash cover-developed
- ash cover-forest
- ash cover-lava flow
- cloud obstruction
- developed-agriculture
- developed-ash cover
- developed-forest
- developed-lava flow
- forest-ash cover
- forest-developed
- forest-lava flow
- lava flow-agriculture
- lava flow-ash cover
- lava flow-developed
- lava-agriculture
- lava-forest
- no change

Data acquired through USGS Earth Explorer portal & processed using ArcPro

Devon Blam
Spring 2019
University of North Georgia

Conclusion:

Volcanoes are different from other natural disasters because they are positioned in isolated and fixed areas, which is an advantage in remote sensing applications. Unfortunately, many countries and regions across the globe do not collect high quality remotely sensed data. This could be due to a multitude of reasons such as a lack of funding or a lack of awareness to the possible applications of remotely sensed data. I hope to demonstrate the usefulness of digital image processing, remote sensing, and cartography through this project, especially in respect to this particular area of high tectonic activity, which could greatly benefit from close monitoring. My biggest points of concern with the volcano site is the limited imagery of the Fuego Volcano after effect. Limited on available and clear data options (only could use Landsat). Inability to use NLCD Data because of Geographic location because most developing countries won't have the same technology as the United States to which they could have visual data of a specific area. NDVI Values wouldn't stay between -1 and 1, and a lot of data had a lot of cloud imagery which blocks the view of the volcano. I performed the cloud detection experiment as a backup project just in case no data was readily available to use but I was able to prevail with what I was provided with. Overall the project was great, I learned a lot of new features in ArcPro and also learned that there are numerous features to perform some of the same operations as well.

References:

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