Vegetation and crater analysis of Mt. St. Helens Volcano related to eruptive cycles and seasonal conditions

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Abstract

Mt. St. Helens is a volcano that has had a continuous eruptive history along the Cascade Range, USA. The purpose of this research is to determine the vegetation and crater size changes related to the eruptive cycles and seasonal conditions of said volcano. Landsat images of MSS, TM, ETM+ and OLI sensors where used and processed using the Exelis Visual Information Solutions (ENVI) software. Supervised classifications and Normalized Difference Vegetation Index (NDVI) were performed to ascertain visual samples of landscape changes and vegetation growth, respectively. The craters diameter did not exhibit any change in diameter. Vegetation shows a pattern of regrowth after the volcano's eruption during 1980.

Keywords: Mt. St. Helens, volcano, subset, vegetation, classification, NDVI

1. Introduction

1.1 Background

Mount Saint Helens (**Figure 1**) is an active stratovolcano located in Skamania County, Washington, USA (**Figure 2**). It is found in the Cascade Range and it is part of the Cascade Volcanic Arch and the Pacific Ring of Fire, which includes over 160 active volcanoes. Located 96 miles south of Seattle, Washington and 50 miles northeast of Portland, Oregon. A volcano can be described as an opening in the surface of the Earth from where molten rock, hot gases and rocks are ejected.

Figure 1: Photograph of Mt. St. Helens Volcano, WA, USA (from: http://volcanoes.usgs.gov/vsc/ images/ image_mngr/500-599/img569.jpg)

Figure 2: Photograph of the location of Mt. St. Helens in Washington, USA (from: Google Earth)

A stratovolcano or composite volcano (**Figure 3**) is a volcano that has a conical shape, a steep profile and periodic explosive and effusive eruptions. Some stratovolcanoes have collapsed craters called calderas. Stratovolcanoes are common in subduction zones (convergent-boundary).

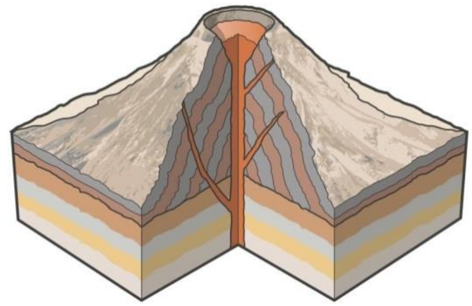

Figure 3: Photograph of a typical stratovolcano (from: http://res.cloudinary.com/dk-find-out/image /upload/q_70,c_pad,w_1200,h_630/AW _Strato_Volcano_wzuwi3.jpg)

Mt. St. Helens is the youngest and most active volcano in the Cascade Range; it is one of the many volcanoes in the U.S and the only one to have a continuous eruptive history.

1.2 May 18, 1980 Eruption

Mt. St. Helens is known for its catastrophic eruption on May 18, 1980 at 8:30 a.m. PDT (**Figure 4**). This eruption was the deadliest and most economically destructive volcanic event in the history of the United States of America. Fifty-seven people were killed, 185 miles of road and 200 homes were damaged or destroyed, and ashfall was seen nearly 22,000 square miles away from the eruption.

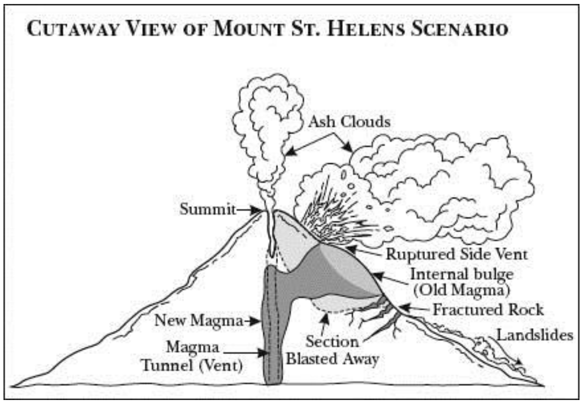

Figure 4: Schematic illustration of the Mt. St. Helens eruption on May 18, 1980 (from: Notable Natural Disasters)

Even though volcanic activity increased during the days prior to the eruption, scientist and government officials were unable to anticipate its magnitude. During the first seconds of the eruption, a magnitude 5.1 earthquake, on the Richter scale, was caused by the pressure from a magma intrusion. This earthquake triggered a collapse of one side of the mountain that lowered its overall height from 9,677 feet to 8,364 feet. The collapse caused an enormous debris avalanche of large rocks and smaller particles, moving at speed from 70 to 150 miles per hour.

1.3 Modern Activity

The United States Geological Society (USGS) has created a hazard map (**Figure 5**) for the Mt. St. Helens volcano in case of future eruptions. The last known volcanic activity occurred in October, 2004, which included explosive episodes spewing ashes that reached up to 3 km above the crater. Very few earthquakes were recorded and those that were only reached 2.0 on the Richter scale. This continued until the events subsided from late January to early February, 2008. As of late, in February, 2011, an earthquake north of the crater registered a magnitude of 4.3, followed by aftershocks with a magnitude of 2.8. No further activity has been registered.

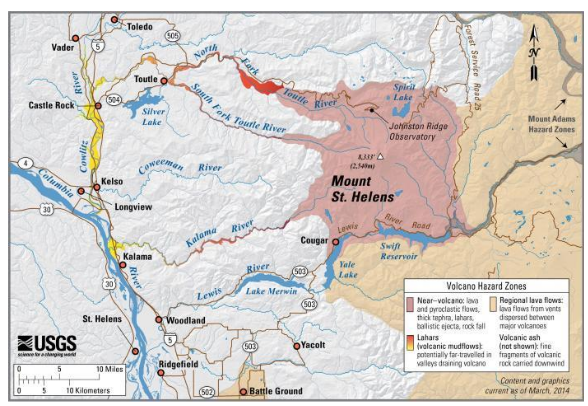

Figure 5: Hazard map for Mt. St. Helens (from: https://volcanoes.usgs.gov/volcanoes/st_helens/st_helens_hazard_75.html)

2. Objectives

Using satellite images provided by the Earth Explorer webpage to determine the vegetation index and seasonal change. Determining the rate of change for the crater area of the volcano related to its eruptive cycle.

3. Methodology

Satellite images of the Mt. St. Helens Volcano were obtained from the Earth Explorer Website from the Landsat satellites (or previously known as the Earth Resources Technology Satellite). The Landsat satellite was developed in the 70's and was first launched in July 1972 by the National Aeronautics and Space Administration (NASA).

3.1 Image acquisition

The images were acquired from the following Landsat sensors: Multispectral Sensor (MSS) and Thematic Mapper (TM) Enhanced Thematic Mapper Plus (ETM+), Operational Land Imager (OLI). The dates chosen were: August 28, 1986 (MSS), September 07, 1999 (ETM+), January 29, 2001 (ETM+), February 28, 2008 (TM), January 01, 2016 (OLI).

	MSS	TM	ETM+	OLI
Bands	G, R, 2 NIR	B, G, R, NIR, 2 MIR, FIR	B, G, R, NIR, 2 MIR, FIR, PAN	2B, G, R, NIR, 3 MIR, PAN
Sensor Type	Opto-mechanical	Whiskbroom	Whiskbroom	Pushbroom
Spatial Resolution	80 m	30 m (120m thermal)	30 m (120m thermal, 15m pan)	30 m (100m thermal, 15m pan)
Temporal Resolution	18 or 16 days	16 days	16 days	16 days
Image Size	185 km x 185 km	185 km x 172 km	184 km x 185.2 km	185 km x 185 km
Radiometric Resolution	6 bits	8 bits	8 bits	12 bits
Programmable	No	Yes	Yes	Yes

Table 1: Description of the Multispectral, Thematic Mapper, Enhanced Thematic Mapper Plus and Operational Land Imager Landsat sensors

3.2 Image Processing

Each image was processed using the ENVI. After opening the MLT files of each image a subset was created, with a size of 3000 x

3000. Using the same subset a Dark Subtraction was applied to enhance the image. A supervised classification was chosen, in this case Maximum Likelihood Classification. For each subset a specific Region of Interest (ROI) was designed, using the following criteria: Clouds, Ice, Vegetation and Water. Finally a NDVI calculation was made for the subsets to determine the change of vegetation throughout the given area. In addition another ROI was created to estimate the change in area of the crater.

4. Results

4.1 Subset

From **Figures 6 – 10** maps were created using ENVI Classic QuickMap tool from the subsets made in ENVI. These subsets were made to help determine the primary focus of this research which is the Mt. St. Helens volcano. With ENVI Classic the maps were formatted to represent the coordinates of the given area.

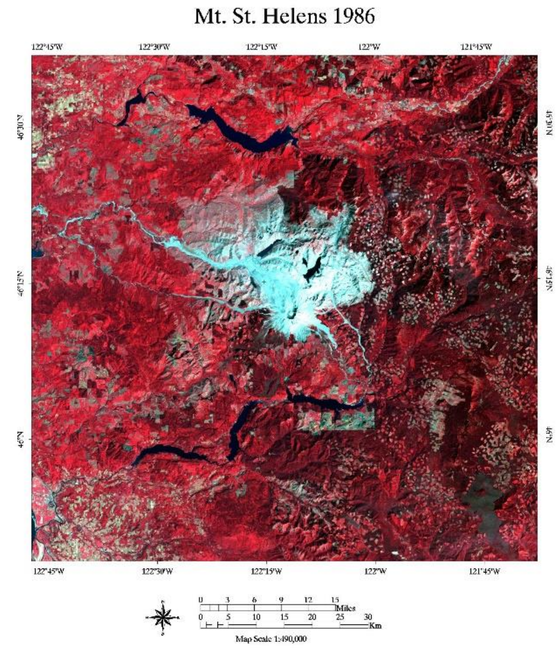

Figure 6: Subset for August 26, 1986

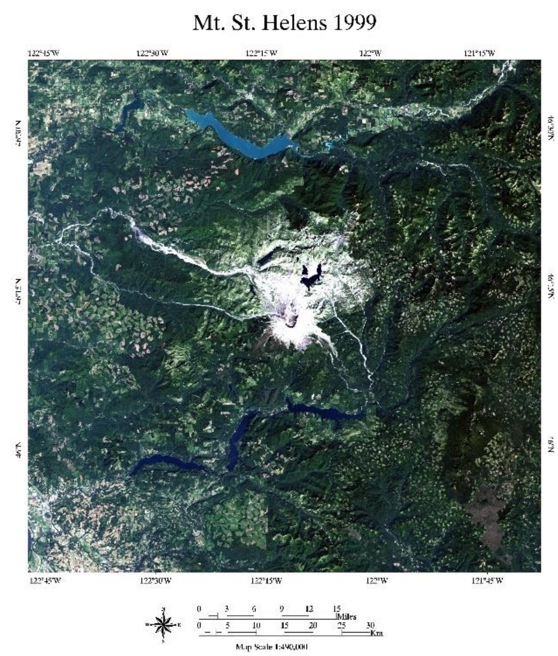

Figure 7: Subset for September 7, 1999

Figure 8: Subset for January 29, 2001

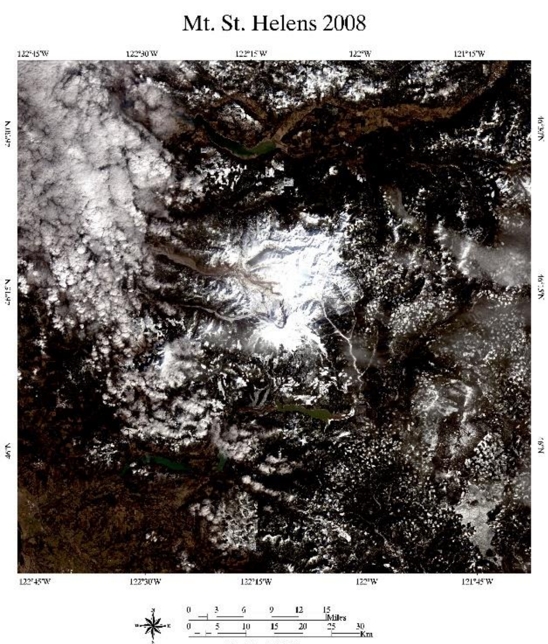

Figure 9: Subset for February 28, 2008

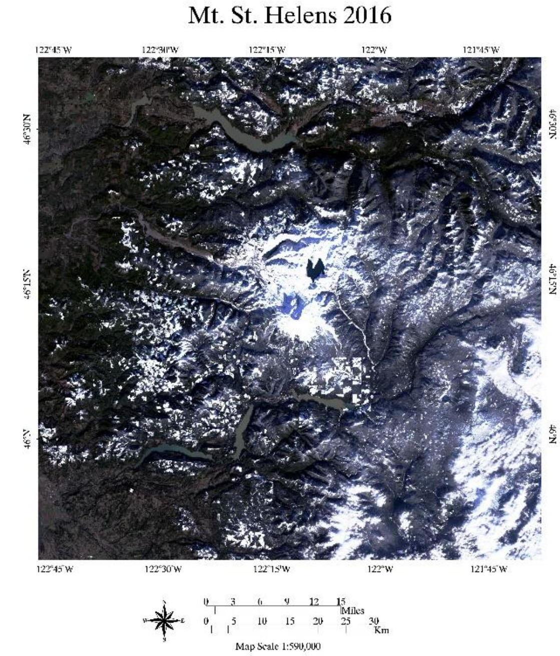

Figure 10: Subset for January 1, 2016

4.2 Maximum Likelihood Classification

Figures 11 – 15 are supervised classifications made using the ENVI tool of Maximum Likelihood Classification. There were a total of four criteria (not including unclassified) which are: snow (light blue), vegetation (red), water (blue) and clouds (purple). These correlate with the subsets previously mentioned (**Figures 6 – 10**). In **Figure 11** there are no visible clouds or snow present in the area (image), in which case the unclassified region would represent the soil.

This image shows a regrowth of vegetation six years after the 1980 eruption.

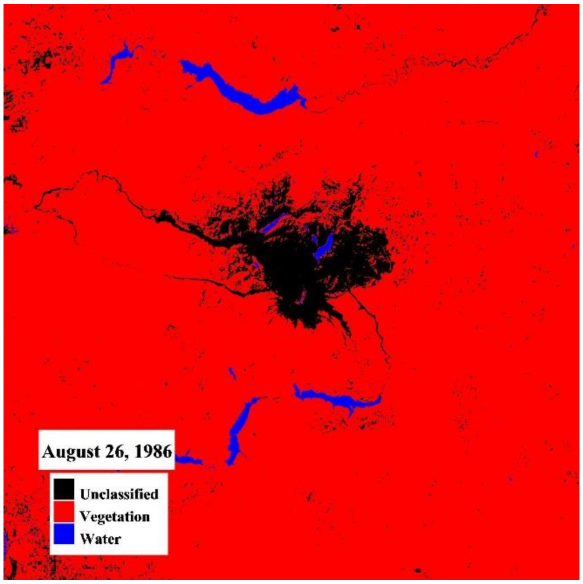

Figure 11: Maximum Likelihood Classification for August 26, 1986

In **Figure 12** there is a difference pertaining to the unclassified region which is now mostly cover in snow. According to the classification it shows less vegetation and more snow in comparison with **Figure 11**.

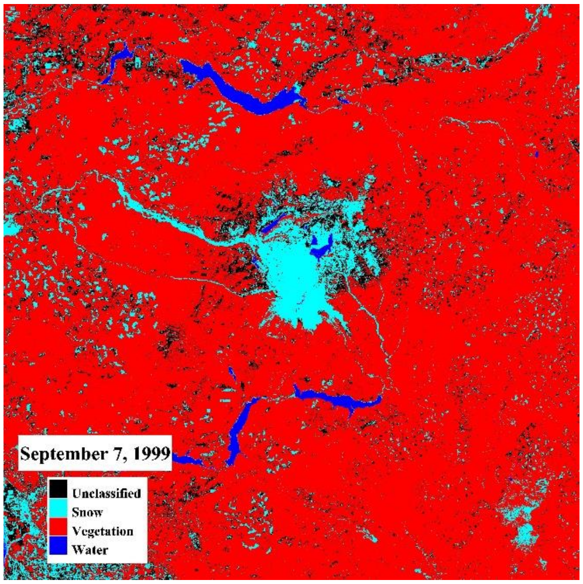

Figure 12: Maximum Likelihood Classification for September 7, 1999

Clouds are now visible in **Figure 13**. Snow has accumulated in the region closest to the volcano; meanwhile vegetation is inversely proportional to the amount of snow in the area. Water also seems to be increasing in the vicinity of Mt. St. Helens.

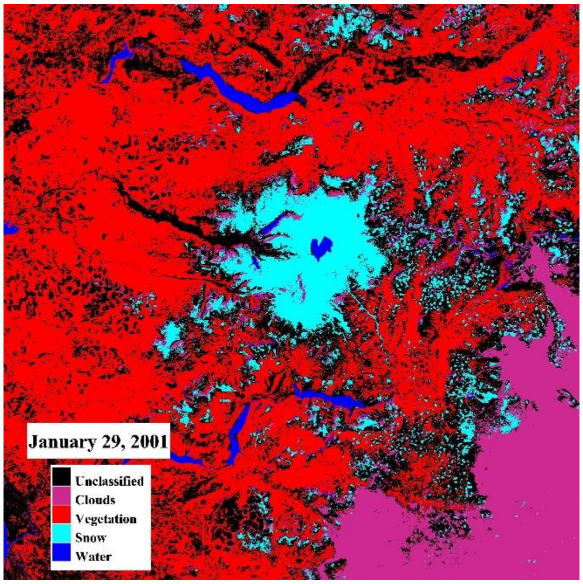

Figure 13: Maximum Likelihood Classification for January 29, 2001

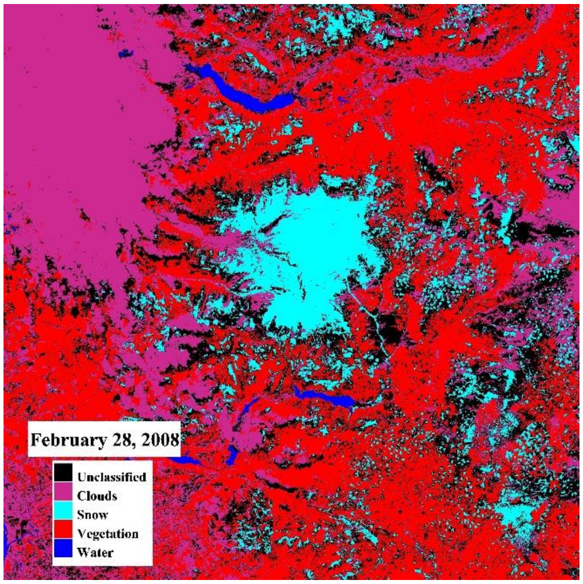

Figure 14: Maximum Likelihood Classification for February 28, 2008

A larger set of clouds is visible in **Figure 14**. The water nearest to the crater has frozen over and it has helped expand the coverage of snow. The presence of clouds makes the visual of vegetation difficult to determine.

Figure 15 shows little to none unclassified region, since it consistently registered the other four classifications. Clouds are sparsely seen, meanwhile snow covers a larger are of the subset, leaving less vegetation to be recognized. The large amount of snow that covers the area could pose a problem if an eruption is going to take place, since lahars or mudslides can form once the snow melts from the high temperatures emitted.

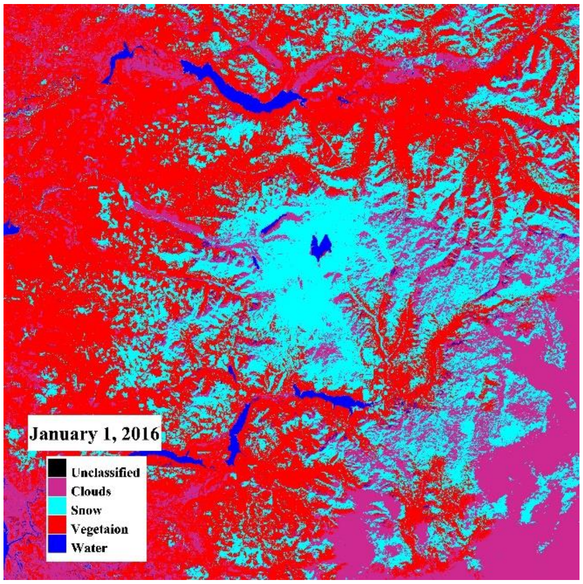

Figure 15: Maximum Likelihood Classification for January 1, 2016

4.3 NDVI

ENVI Classic was used to create a **Figures 16 – 20**, adding the color ramp scale as vegetation measurement tool. Darker colors on the color ramp mean more vegetation and lighter colors represent less vegetation. A mask was not applied to the images meaning that the white areas are not considered relevant for this calculation. **Figure 16** shows greater vegetation away from the volcano and little to none closest to it.

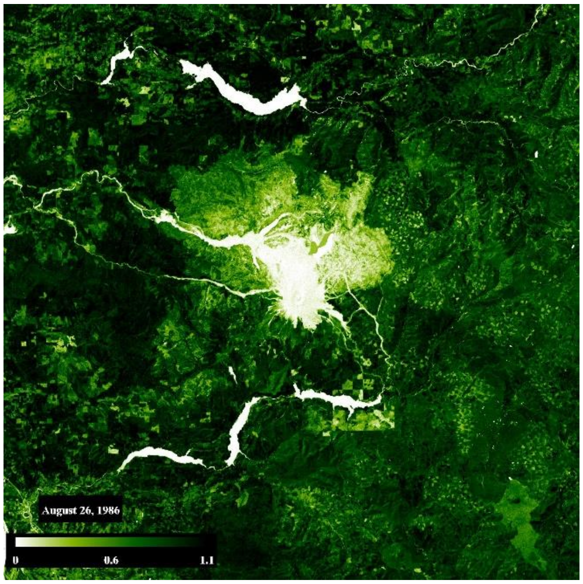

Figure 16: NDVI calculation for August 26, 1986

In **Figure 17** a vegetation regrowth is seen visible contrary to **Figure 16** which showed less vegetation near the volcano.

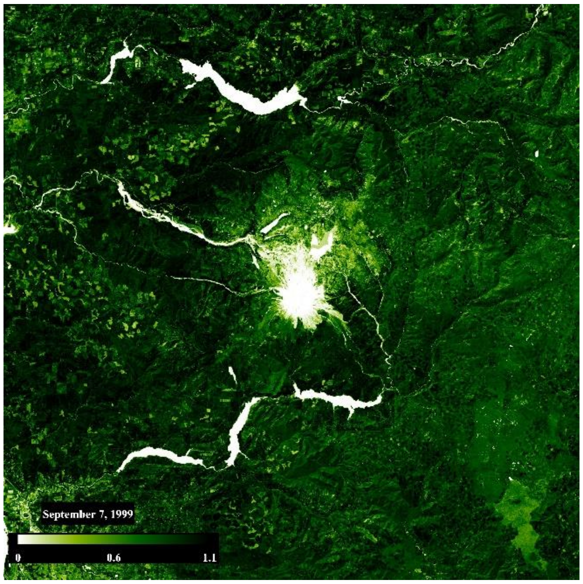

Figure 17: NDVI calculation for September 7, 1999

Figure 18 shows less vegetation than the previous figures (**Figures 16 – 17**) due to the presence of snow and clouds. The clouds seem to exhibit a greenish color and this is due to absorption of the infrared light coming from the sun. This occurs due to the fact that clouds trap some of the infrared radiation emitted from the Earth before sending it back towards the Earth and therefore warming the surface. **Figures 19** and **20** exhibit the same pattern.

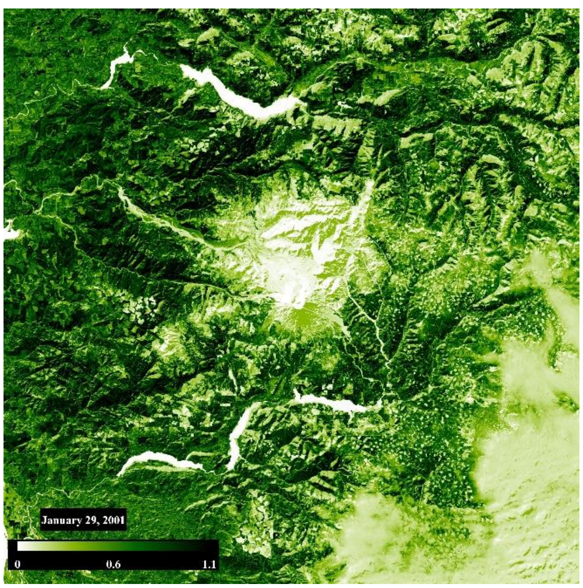

Figure 18: NDVI calculation for January 29, 2001

Figure 19 and **20** shows less vegetation due to the fact that the abundance of clouds and snow that blankets the area. Given the color ramp scale a larger concentration of vegetation in **Figure 19** compared to **Figure 20**.

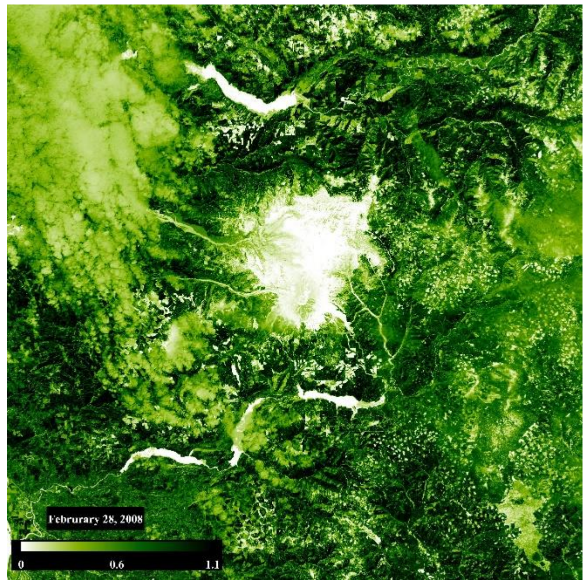

Figure 19: NDVI calculation for February 28, 2008

Figure 20: NDVI calculation for January 1, 2016

Table 2 represents the area of the crater in kilometers square for the images selected for this research. The crater seems to decreases in size after 1986 and from the years 1999 – 2016 it is at a constant rate.

Date (m/d/y)	Area (km^2)
August 26, 1986	2.721600
September 7, 1999	2.617200
January 29, 2001	2.617200
February 28, 2008	2.617200
January 1, 2016	2.617200

Table 2: Area of the crater throughout the years

5. Conclusion

Given the images that were processed of the Mt. St. Helens subsets the eruptive cycles of this volcano have no correlation with the change of the craters diameter. Seasonal conditions add a vast amount of snow during fall and winter seasons, which can create lahars if future eruptions occurred at this time. There is still regrowth of vegetation in the area even after such an extensive period of volcanic activity.

6. Recommendations

It would have been best to work on a 3-D scale of the volcano to clearly understand its topography and details of the same. Images related to prior eruptive history would be better suited to determine the vegetation and crater changes of Mt. St. Helens.

7. References

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