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Classification of Disaster Risk Areas on Mount Ruang Using Vegetation Index Calculations and Landsat-8 Satellite Imagery

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ABSTRACT

Mount Ruang is located in Tagulandang District, Siau Tagulandang Biaro Islands Regency, North Sulawesi, with an elevation of 725 meters or 2,379 feet, at coordinates 2°18' N / 125°22' E. In April 2024, a significant eruption was re-recorded. Ruang Island is the peak of the volcano rising from the Sulawesi Sea. Most of its inhabitants are farmers, and land use in an area is influenced by population growth and activities. The eruption of Mount Ruang has caused changes in land function. In this study, classification was conducted using the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI). The data were sourced from Landsat 8 imagery from 2022 to 2024, specifically bands 4 and 5. The results of this study conclude that from 2022 to 2024, the vegetation index calculations were very significant. Classification calculations before and after the eruption showed that the NDVI vegetation index in 2022 and 2023 indicated vegetated land, while in 2024, it indicated non-vegetated land. The SAVI vegetation index identified water bodies such as rivers or seas. It can be concluded that post-eruption, the land around the volcano was non-vegetated and much of the material fell into the sea.

Keywords: Space volcano eruption, Indeks vegetation, NDVI, SAVI

Introduction

Mount Ruang is located in the North Sulawesi Islands and is a Type-A stratovolcano situated on the island of the same name (Morrice et al., 1983). It falls under the administration of Tagulandang District, Siau Tagulandang Biaro Islands Regency, North Sulawesi, with an elevation of 725 meters or 2,379 feet, at coordinates 2°18' N / 125°22' E (Morrice et al., 1983). There are two villages on this volcanic island, namely Laingpatehi and Pumpente.

The summit of the volcano, which consists of a lava dome, has an elevation of 725 meters above mean sea level (before the 2024 eruption). Ruang Island is the peak of the volcano rising from the Sulawesi Sea's floor. This volcano is the southernmost in the chain of volcanoes on the Sangihe arc (Morrice et al., 1983).

The first recorded eruption of this volcano was in 1808 (Venzke, 2004). Although it is quite active with eruption intervals ranging from one to fifty years, it receives relatively less attention compared to the more active Mount Karangetang. The eruption of Mount Ruang in April 2024 is the most recent and recorded as the most spectacular eruption to date (Situmorang, 2021; CNN Indonesia, 2024).

Geological profile

As one of the volcanoes formed on the Sangihe arc, Mount Ruang is part of the chain of volcanoes created in the subduction zone where two tectonic plates converge. It is one of the four

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youngest volcanoes (formed in the Holocene epoch) in the arc, along with Mount Awu, Mount Karangetang, and Banua Wuhu.

Ruang Island, formed by the part of Mount Ruang that rises above sea level, has its base beneath the sea surface. Tagulandang Island, another volcanic island, lies to its northeast, separated by a strait just over one kilometre wide. The island is nearly circular, measuring approximately 4 by 5 km. The island is inhabited, but settlements are limited to the coastal areas. The volcano's slopes are partially used for agricultural activities by the residents.

The eruption history

According to the Global Volcanism Program (GVP) of the Smithsonian Institution, ptio recorded volcanic activity (eruptions) of Mount Ruang includes 1808 (VEI = 2), 1836 (2), 1840 (2), 1856 (1), 1870 (3?), 1871 (2), 1874 (2), 1889 (1), 1904-1905 (3), 1914 (2), 1949 (2), and September 2002 (4) (Venzke & Ball, 2004). In April 2024, another significant eruption was recorded [3]. This study aims to classify Mount Ruang using remote sensing methods and Landsat 8 imagery. The analysis uses NDVI and SAVI to classify the disaster-prone areas of Mount Ruang in Tagulandang District, Siau Tagulandang Biaro Islands Regency, North Sulawesi.

Material and Methods

Landsat 8, launched in February 11, 2013, is the eighth satellite in the Landsat program (Jagalingam et al., 2015). A joint NASA-USGS (United States Geological Survey) mission, it's designed to monitor Earth's surface. The spacecraft was built by Orbital Science Corporation, and its instruments by Ball Aerospace and NASA. NASA's Goddard Space Flight Center provided mission system engineering, development services, and launch vehicle procurement, while the USGS provided ground system development services and will conduct mission operations (Lee et al., 2018).

The satellite was built by Orbital Science Corporation, the mission's primary contractor. The spacecraft instruments were built by Ball Aerospace and NASA's Goddard Space Flight Center, and the launch was assigned to United Launch Alliance. After a 108-day review by NASA, the satellite was transferred to the USGS and officially renamed Landsat 8 in May 2013 (Taufik et al., 2019).

Table 1. LDCM satellite orbit parameters (Landsat-8) (Sitanggang, 2010)

Orbit Type	Approaching the solar synchronous circle
Height	705 km
Inclination	98,2°
Periode	99 minute
Replay Time (resolution temporal)	16 days
Time to cross the equator (local time on descending node-LTDN) nominal	10.00 A.M. until 10.15 A.M. O’clock

Table 2. Spesification Band in Citra Landsat - 8 (OLI and TIRS) (Lee et al., 2018)

Channel	Wavelength micrometer	Resolution meters
Channel 1 – Ultra Blue	0,43 - 0,45	30
Channel 2 – Blue	0,45 - 0,51	30
Channel 3 – Green	0,53 - 0,59	30
Channel 4 – Red	0,64 - 0,67	30
Channel 5 – Near Infrared (NIR)	0,85 - 0,88	30
Channel 6 – SWIR 1	1,57 - 1,65	30
Channel 7 – SWIR 2	2,11 – 2,29	30

To be continued...

Channel 8 – Panchomatic	0,50 - 0,68	15
Channel 9 – Cirrus (Thin Clouds)	1,36 - 1,38	30
Channel 10 – Thermal Infrared (TIRS) 1	10,60 - 11,19	100
Channel 11 – Thermal Infrared (TIRS) 2	11,50 – 12,51	100

Source: (USGS, 2014)

Table 3. Use of spectral bands on Landsat-8 (OLI and TIRS) (Nandi et al., 2017)

Channel	Wavelength	Data Usage
Channel 1 – Ultra Blue	0,43 - 0,45	Coastal and aerosol studies.
Channel 2 – Blue	0,45 - 0,51	Bathymometric mapping, distinguishing between land and vegetation or annual and needle-leaved trees.
Channel 3 – green	0,53 - 0,59	Analysis of vegetation peak reflectance is useful for assessing plant strength.
Channel 4 – red	0,64 - 0,67	Analysis of vegetation changes.
Channel 5 – Infrared Near (NIR)	0,85 - 0,88	Analysis of biomass content and coastline.
Channel 6 – SWIR 1	1,57 - 1,65	Better distinguish between soil moisture and vegetation; able to penetrate thin clouds.
Channel 7 – SWIR 2	2,11 – 2,29	Better distinguish between soil moisture and vegetation; able to penetrate thin clouds.
Channel 8 – Pankromatik	0,50 - 0,68	15 m spatial resolution, sharper recording results.
Channel 9 – Sirrus (Awan Tipis)	1,36 - 1,38	Detect cirrus clouds and contamination.
Channel 10 – Inframerah Panas (TIRS) 1	10,60 - 11,19	100 m spatial resolution, temperature mapping and soil moisture estimation.
Channel 11 – Inframerah Panas (TIRS) 2	11,50 – 12,51	100 m spatial resolution, temperature mapping and soil moisture estimation.

Vegetation index

The vegetation index represents the greenness of vegetations derived from digital signals of brightness values sourced from several satellite sensor data channels (Wirawan & Chernovita, 2023). The algorithm used to observe vegetation in this study is the Normalized Difference Vegetation Index (NDVI), which is a greenness index of vegetation. NDVI can indicate the green leaf biomass parameter for vegetations classifications (Dayanthi et al., 2023). The NDVI classification is presented in Table 4.

Table 4. NDVI Classification (Elgammal et al., 2014)

Class	NDVI Value	Greenness Level
1	$-1<NDVI<-0{,}03$	Land without vegetation
2	$-0{,}03<NDVI<0{,}15$	Very low vegetation
3	$0{,}16<NDVI<0{,}25$	Low vegetation
4	$0{,}26<NDVI<0{,}35$	Medium vegetation
5	$0{,}36<NDVI<1$	High vegetation

$$NDVI = \frac{NIR-RED}{NIR+RED}$$

Where:

NIR = Infrared channel reflectance value (band 5)

RED = Red channel reflectance value (band 4)

NDVI has values ranging from -1 to 1. Areas with values below 0.3 are considered non-vegetated, while areas with values above 0.3 are considered lush vegetation.

The Soil Adjusted Vegetation Index (SAVI) is an algorithm developed from NDVI, taking into account the soil background at the canopy brightness level. Table 4 explains the classification of SAVI values based on the type of Green Open Space (GOS). The SAVI formula is as follows :

$$\mathbf{SAVI} = \frac{1{,}5*(NIR-RED)}{(NIR+RED)*0{,}5}$$

Where:

NIR = Infrared channel reflectance value (Band 5)

RED = Red channel reflectance value (Band 4)

Table 5. Classification of SAVI values for density and type of green open space (Wulandari, 2020)

Class	Density	RTH type
-0,3667 sd 0,0187	Non RTH	Water bodies like Rivers etc
0,0187 sd 0,1041	Very low	Open land settlements covered with asphalt or paving and asphalt roads
0,1041 sd 0,3667	Low	Ground cover vegetation, such as on dirt roads, empty field, without asphalt or paving
0,3667 sd 0,5214	Currently	Land cover vegetation in the form of coconut plantations, gardens mixed, grass vegetation, golf courses and thatchs
0,5214 sd 0,7895	Tall	Forested vegetation

The Landsat 8 imagery data used includes bands 4 and 5, covering the period from 2022 to 2024, each for the peak periods before and after the eruption of Mount Ruang. Data processing involved atmospheric correction on the imagery data and cropping it to match the study area (Sajjad et al., 2021).

Next, an exploration of the vegetation index data using NDVI and SAVI was conducted (Simarmata et al., 2021). After obtaining the vegetation index results, the research steps are illustrated in Figure 2.

Land-sat 8 satellite imagery data was retrieved from the website https://oceancolor.gsfc.nasa.gov/cgi/browse.pl with the selection time being April 2024.

The Landsat imagery data from 2022 to 2024 is as follows:

LC09_L1TP_111058_20240514_20240514_02_T1_B4
LC09_L1TP_111058_20240514_20240514_02_T1_B5
LC09_L1TP_111058_20230514_20230514_02_T1_B4
LC09_L1TP_111058_20230514_20230514_02_T1_B5
LC08_L1TP_111059_20220501_20240504_02_T1_B4
LC08_L1TP_111059_20220501_20240504_02_T1_B5

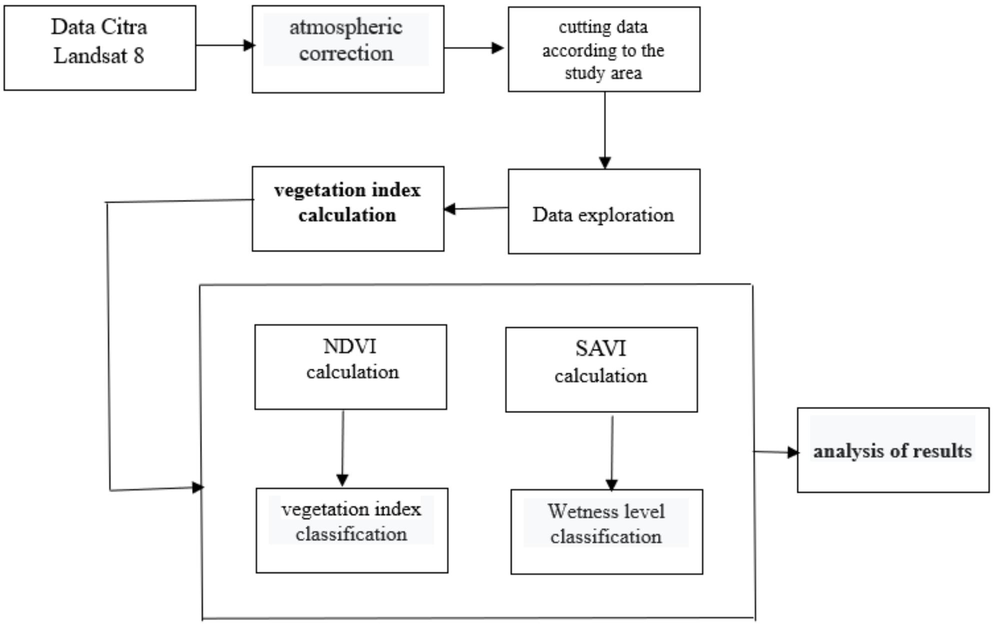

Figure 2. research flow diagram

Table 6. **E**xample of digital number, reflectance and NDVI of Landsat 8 imagery - 2022 to 2024

Pin	Longitude	Latitude	Digital number band_4	2024 Reflektan _4	NDVI 2023	NDVI 2023	NDVI 2024
pin_1	125,479774	3,3857317	6021	0,02042	0,00336	0,01714	-0,00194
pin_2	125,669044	3,3809850	6391	0,02782	-0,0014	0,00704	0,06464
pin_3	125,898260	3,3744314	13854	0,17708	-0,00636	0,03792	-0,16066
pin_4	126,112656	3,3805160	6764	0,03528	-0,00504	0,01784	-0,02462
pin_5	126,243744	3,3808990	6802	0,03604	0,01612	0,01584	-0,01934
pin_6	126,396460	3,37210440	6773	0,03546	0,00036	-0,01192	-0,01172
pin_7	126,513145	3,31953570	6791	0,03582	-0,00724	-0,01156	-0,0154
pin_8	126,373314	3,24786640	7067	0,04134	0,0043	-0,01174	-0,01552
pin_9	126,216910	3,2328070	6785	0,0357	-0,14638	0,00022	-0,01632
pin_10	126,095030	3,2251450	6540	0,0308	-0,09402	-0,01154	-0,01478
pin_11	125,985830	3,22103120	6387	0,02774	0,23416	-0,0101	-0,0068
pin_12	125,822170	3,2205312	6297	0,02594	-0,1845	0,05746	-0,00464
pin_13	125,669556	3,2273571	6256	0,02512	0,2573	-0,0098	-0,00806
pin_14	125,513270	3,2122014	6358	0,02716	-0,00492	-0,00838	-0,01342
pin_15	125,386055	3,2136528	6329	0,02658	0,05346	-0,01314	-0,00696

To be continued...

pin_16	125,366650	3,0583777	6309	0,02618	0,02076	-0,00624	-0,002
pin_17	125,506530	3,0480090	6308	0,02616	-0,30182	0,01648	-0,00352
pin_18	125,631860	3,0446174	6455	0,0291	-0,0674	0,02926	0,02748
pin_19	125,748340	3,0322410	6481	0,02962	0,30854	-0,01312	-0,00862
pin_20	125,928154	3,0254520	6521	0,03042	0,05958	-0,01286	-0,01462
pin_21	126,077260	3,0204450	6395	0,0279	-0,10642	-0,01322	-0,00816
pin_22	126,339370	3,0192244	6614	0,03228	-0,0197	0,02644	-0,00996
pin_23	126,497440	3,0084846	6891	0,03782	-0,04538	0,04574	-0,01622
pin_24	126,456070	2,8128932	17642	0,25284	0,14884	0,04058	-0,21052
pin_25	126.292.404	2,8087273	6845	0,0369	-0,01476	-0,01342	-0,01772
pin_26	126,136090	2,7863955	6260	0,0252	**Rata2 NDVI**	**Rata2 NDVI**	**Rata2 NDVI**
pin_27	125,976200	2,8025267	6562	0,03124	**0,003381**	**-0,01084**	**0,00268**
pin_28	125,770800	2,8130856	6856	0,03712	-	-	-
pin_29	125,601540	2,8234391	7196	0,04392	-	-	-
pin_30	125,461630	2,8449616	6422	0,02844	-	-	-

$$\text{NDVI} = \frac{\text{NIR}-\text{RED}}{\text{NIR}+\text{RED}}$$

Where:
NIR = Infrared channel reflectance value (band 5)
RED = Red channel reflectance value (band 4)
Analyze each value NDVI - starting the year 2022 –2024

Results and Discussion

The following formula will be used to calculate SAVI.

$$\text{SAVI} = \frac{1{,}5*(NIR-RED)}{(NIR+RED)*0{,}5}$$

Where:
NIR = Infrared channel reflectance value (Band 5)
RED = Red channel reflectance value (Band 4)

Table 7. NDVI and SAVI value

YEAR	NDVI	SAVI
2022	0,00381	-0,006490889
2023	0,004	-0,27060685
2024	-0,0197	-0,67846758

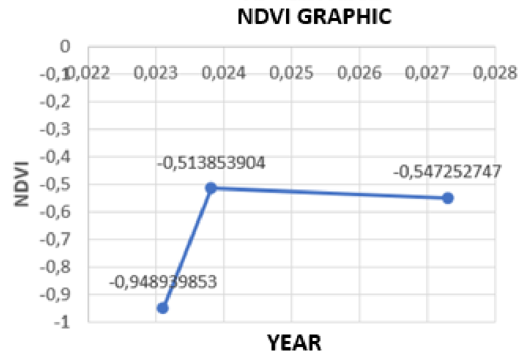

Figure 3a. NDVI Graph for 2022 – 2024

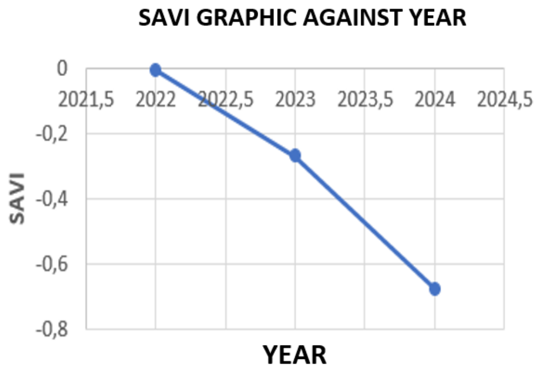

Figure 3b. SAVI Graph for 2022-2024

The findings of this study indicate that the NDVI value of -0.0197 is lower after the eruption of Mount Ruang in April 2024, classifying the land as non-vegetated. When observing Figures 3 and 6, differences in vegetation density classification are apparent.

The results of SAVI calculations at the peak of the volcanic eruption are highly significant. The calculations is starting from 2022 showed values of -0.006490889, -0.27060685 in 2023, and -0.67846758 in 2024. This indicates a classification as water bodies such as rivers or seas, as most of the volcanic material fell into the sea.

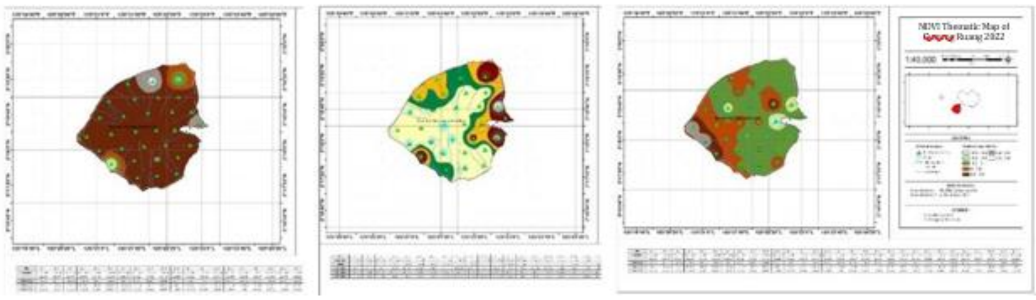

Figure 7. NDVI Mapping in 2022 – 2024 (Mount Ruang, North Sulawesi)

This study uses Landsat 8 imagery from before and after the eruption within the time frame of 2022, 2023, and 2024 as reference data to determine the condition of the vegetation indices: Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI).
Table 6 and Figures 3 and 4 show the changes in vegetation index values as follows:

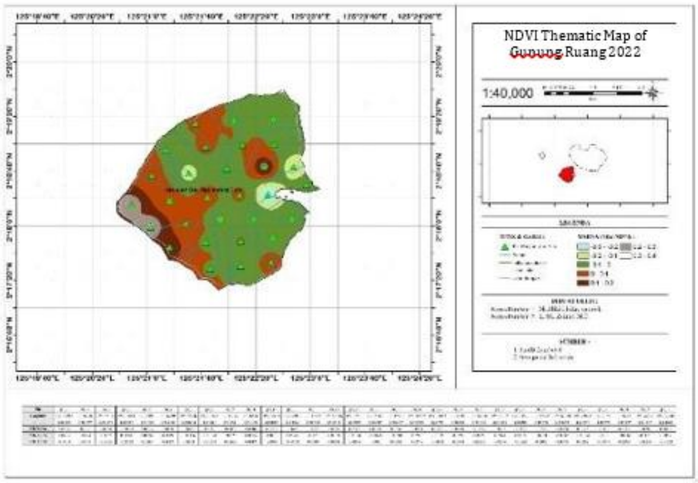

Figure 8. NDVI Mapping in 2024 (Mount Ruang, North Sulawesi)

Conclusion

The NDVI calculations depict that vegetation in the affected area severely deteriorated following the volcanic eruption. There was a significant decrease in greenness. The SAVI calculations indicate that after the eruption in 2024, the value was -0.67846758, classifying it as water bodies such as rivers or seas, consistent with the location of Mount Ruang.

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