SIM-Analytical landslides prone area by using Sentinel- 2 Satellite

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Analytical landslides prone area by using Sentinel-2 Satellite Imagery and geological data in Google Earth Engine (a case study of Cinomati Street, Bantul Regency, Daerah Istimewa Yogyakarta Province, Indonesia)

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Abstract. The incidence of landslides and the fact that a large number of people live in areas vulnerable to landslides lead to a high death toll in Java Island, Indonesia – more than 1,112 people in the period 1999 to 2005. The study site has an area of 55.56 hectares, along Cinomati Street, Dlingo, and Pleret Sub District, Bantul District, Daerah Istimewa Yogyakarta Province, Indonesia. The methods that use in this study are, Sentinel-2 Imagenery and Geological data. The purpose of this study is to determine the landslides prone area in the study site. The methods used in this study are Sentinel-2 Satellite Imagery and geological data. Along the Cinomati road based on geological data, it has a weak area that has the potential for landslides from the continuation of the Opak fault and rock formation boundaries. Landslide area are locations with complex geological conditions and sparse vegetation. In other rare vegetation besides the location of landslides, it also needs to be aware of other potential landslides, because this research is limited to sentinel images with a density of 10m^2.

1. Introduction

The incidence of landslides and the fact that a large number of people live in areas vulnerable to landslides lead to a high death toll in Java Island, Indonesia – more than 1,112 people in the period 1999 to 2005. In Java subduction has an influence on its geological history. Oblique subduction in Java has characteristics such as displaced and fractured terraces, major strike-slip faults, folding and thrusting. Landslides frequently occur in Java, with mountainous areas and a humid tropical climate. A number of factors supporting landslides in Java are as follows: first, Java has rough terrain consisting of cliffs, hills, and mountains; second, heavy rainfall is prevalent from October to April; third, 36 of 129 Indonesian volcanoes are located in Java, producing highly weathered volcanic materials [1]. The high rainfall intensity and high seismic activity rendered Java one of the most susceptible regions for landslides, especially in the mountainous southern regions. Assessment of both seismic and landslide hazards in Southern Yogyakarta has been well created. Some studies have identified the features of Yogyakarta seismic and landslide hazards [2].

The study site located roughly one hundred kilometres north of the Java Subduction Zone. Java Island has a complex geology and geomorphology. The northern zone is dominated by the folded area, the middle is dominated by the active volcanic arc, and the southern part of Java is dominated by the elevated southern mountain, including the study area (Southeast part of Yogyakarta City). The study area is generally a part of the Graben of the Bantul. The Opak river flows through the middle part of the study area, which is often correlated with typical Opak Fault [2].

Geological approaches define the tectonic motion, basin settings, and lithological features [3]. Landslide geologic considerations include lithology [4], geological structure, and rock weathering [5]. In the current morphological, it is important to understand the causes of landslides. Present morphological and rock conditions may clarify the past morphological conditions such as the rocks that formed it or lithology, the geological structure, the existing erosion, and sedimentation processes [6].The ability to monitor landslides at many points of an urban slope where there are dangerous areas could be a very useful way to assess the degree of hazard and thus predict and/or prevent accidents and deaths [7].

The purpose of this study is to determine the landslides prone area in the study site. The methods used in this study are Sentinel-2 Satellite Imagery and geological data. A similar study [8] conducted in another location, in the Jou-Jou mountain area, Taiwan, was supported by geological data in the form of the lithology of gravel, rock, and sandstone which was also influenced by water erosion. In Addition, the vegetation index can also be used as a reference in identification to monitor and assess the location of landslides based on satellite image data, where vegetation can act as a reinforcing medium on the slopes through the roots of the vegetation. Sentinel-2 is a satellite constellation of the European Space Agency that monitors the land environment on the surface of the earth. Sentinel-2 satellites have a 10 m spatial resolution The Constellation Sentinel-2 has a 5-day revisit period at the Equator and is widely distributed to the general public. A benefit of this optical remote sensing picture is that it has more spectral details and is more sensitive to landslide-related disturbances [9]. Furthermore, geological data describing the regional geological conditions are important for the identification of landslides [10]. This study should be able to help local governments to provide landslides early warning systems.

2. Methods

The study site has an area of 55.56 hectares, along Cinomati Street, Dlingo, and Pleret Sub District, Bantul District, Daerah Istimewa Yogyakarta Province, Indonesia (Figure 1).
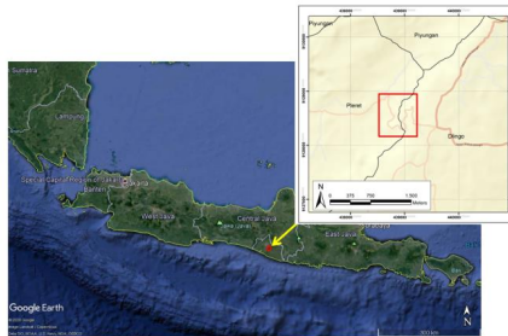

Figure 1. The study site.

The methods that use in this study are analysis Sentinel-2 Imaginary with Google Earth Engine and analysis Geological data based on recent research. Google has archived many datasets, one of which is sentinel-2 satellite imagery. Google Earth Engine is a map computation platform that provides data on

the earth's surface at high spatial and temporal resolution, which can be used to measure changes in the earth's surface, be it forests, agricultural land, and the surface with a certain period of time [10].
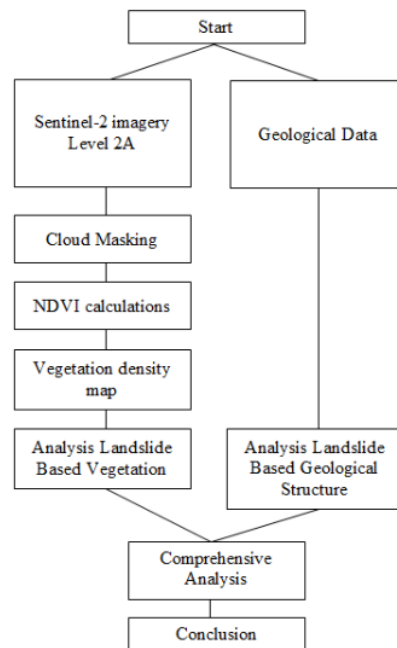

Figure 2. Research flow diagram.

The data processing procedure uses sentinel-2 imagery processed on the google earth engine with javascript programming, cloud masking filtering is performed on the image to eliminate the clouds surrounding the study field, where the NVDI (Vegetation Index) algorithm has been used to correct the level 2a sentinel-2 satellite images used in this analysis, the radiometric BOA (Bottom Of Atmosphere) and the geometric for vegetation index. Unlike standardisation). The band used in the measurement in the sentinel-2 picture is band 8 (NIR) and band 4 (Red) having the same spatial resolution of 10 metres. The band used in the measurement in the sentinel-2 picture is band 8 (NIR) and band 4 (Red) having the same spatial resolution of 10 metres square.

The NDVI measurement is obtained from the standardization difference between the red band and the near infrared band, divided by the number of the two bands in the picture. We can see the NDVI algorithm in equation (1).

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (1)$$

Legend :
NIR : Closer Infrared Band
Red : Red Band

The NDVI value varies from -1 to +1 with the higher the value the higher the density of the vegetation. The maximum set of classifications is illustrated in Table 1 [11].

Table 1. NDVI classification

Distance of NDVI	The Vegetation Cluster
$-1 \leq NDVI < 0.2$	Non-Vegetation
$0.2 < NDVI < 0.4$	Rare Vegetation
$0.4 < NDVI < 0.6$	Moderate Vegetation
$0.6 < NDVI \leq 1$	Steep Vegetation

3. Results and discussion

3.1. Landslide potential based on NDVI data

The study site shows the alignment with the major fault, namely Opak Fault based on the regional geological map of Yogyakarta sheet (Figure 3). Based on the geological map, the study site consists the Semilir Formation (Tmse) and Nglanggeran Formation (Tmn). The study site is in the boundary of both formations (Figure 3). Research area is located in border of Yogyakarta low land and Southern Mountain Zone. There is a main fault bordered in western part of research area, specific named by Opak Fault (Figure 3). In the previous information, it was known that the research location was in lineament with the Opak fault, where the continuity of the Opak fault was in the southern part of the study location, in a location close to the fault area. The minor fault of Opak segment in research area is interpreted as Right Slip Fault [12]. This fault movement has same movement with the Watugajah Fault in the Subzone of Baturagung [6] but this fault started to active at Middle Plistocene [13].
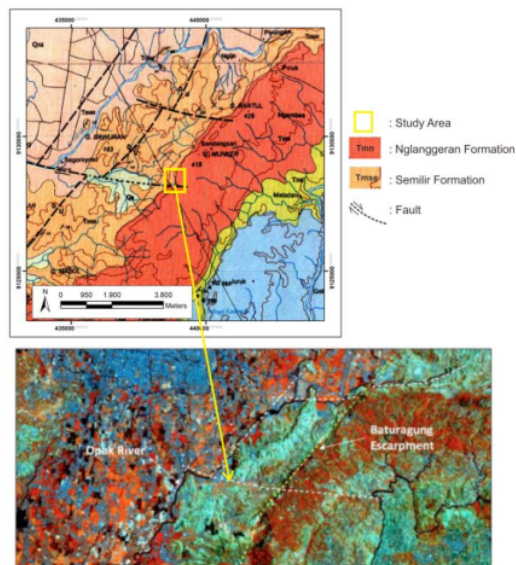

Figure 3. The geological map of Yogyakarta (top), source: systematic geological map of Java, sheet Yogyakarta 1408-2 & 1407-5, scale 1:100,000, and Opak River Escarpt Linieament (bottom) [2].

The number of connections or the density of the connection would be denser [2]. This indicates that the location has weak areas that are easily weathered and eroded or parts that have complex levels of structure. Apart from being located in the continuity of the fault, based on the geological map of the Yogyakarta sheet, it also shows that the location is located on the border of Semilir Formation (Tmse) and Ngelanggeran Formation (Tmn). Semilir Formation is consisted of tuff, pumice breccias, lapilistone (Surono et al, 1992). The age of Semilir Formation based on U-Pb method is about 20 million ago (Early Miocene) (Smyth, 2005).

Rainfall water can enter the soil and rock gaps through rock fractures that are caused by numerous fractures and position faults such that areas with a steep slope become unstable, this is due to a rise in soil unit weight due to water infiltration, Two adjacent materials with opposing material types also form the slip plane [14]. Normally landslides will be in the direction of the slope.
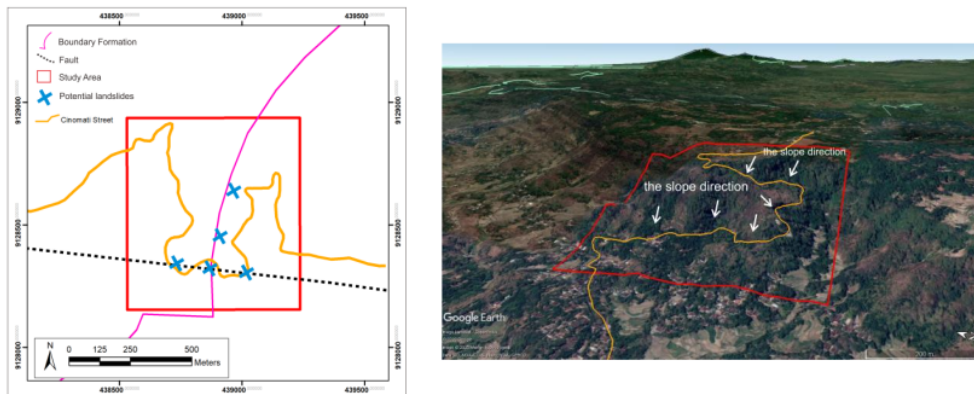

Figure 4. Landslide potential based on geological data (left) and slope direction on study site area by using Google Earth 3D terrain imagery (right).

3.2. Landslide potential based on NDVI data

Based on the results of the GEE satellite imagery NDVI processing in 2020, 4 classes have been obtained, namely non-vegetation, sparse vegetation, moderate vegetation, and dense vegetation. In 2020, the non-vegetation showed in no colour (transparent), sparse vegetation showed in red colour, moderate vegetation showed in yellow colour and the dense vegetation showed in green colour (Figure 4).
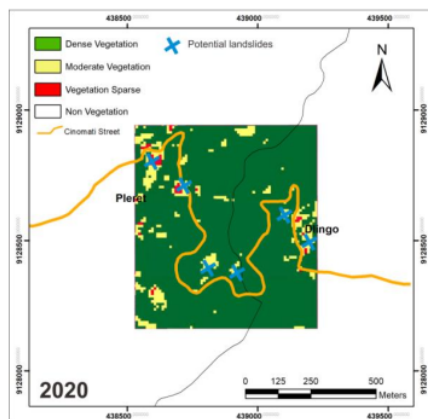

Figure 5. The Vegetation density of 2020 based on Sentinel-2 imagery processed with NDVI algorithm and potential landslide.

The classification data is taken from 5-9 months of the year, which is the dry season as an ideal time to monitor the main vegetation so that it is not obscured by grass. Even though in 2020 it has not been fully covered along the road with dense vegetation with a percentage of 91%, with some spot vegetation being 8% medium and light vegetation 1% with an area as shown in (Table 2). Locations along roads that have light to moderate vegetation are considered to have little slope reinforcement

compared to dense vegetation, this is a parameter in determining the location of potential landslides based on vegetation density.

Table 2. The kind of closure land use and areal

Year	Non Vegetation	Sparse Vegetation	Moderate Vegetation	Dense Vegetation
2020	0	0.510	4,604	49,713

3.3. Landslide prone area based both potential data

At the landslide location it is also an intersection between the geological structure lines and the rock formation boundaries, so that the weak area of the geological condition is supported by vegetation conditions that rarely cause landslides in this location. The rare vegetation causes the soil could not storage the water safely that the landslide occurs in many times especially at raining season. The weak area become easy to weathered by rainfall.
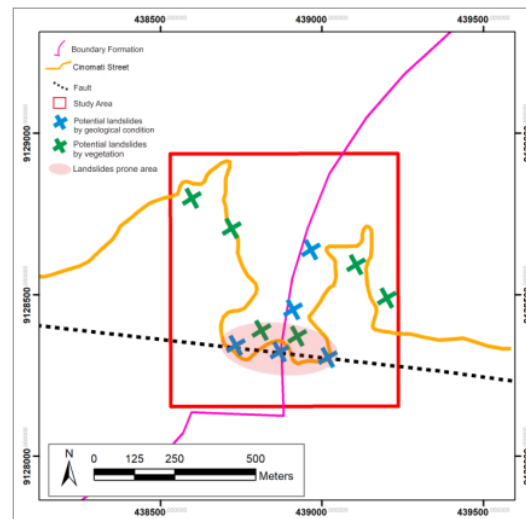

Figure 6. Geological data combine with NDVI data.

4. Conclusions

Along the Cinomati road based on geological data, it has a weak area that has the potential for landslides from the continuation of the Opak fault (minor fault) and rock formation boundaries. Landslide area are locations with complex geological conditions and sparse vegetation. In other rare vegetation besides the location of landslides, it also needs to be aware of other potential landslides, because this research is limited to sentinel images with a density of 10 and does not discuss topographic slope conditions. The rare vegetation also causes the soil could not storage the water safely that the landslide occurs in many times especially at raining season

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