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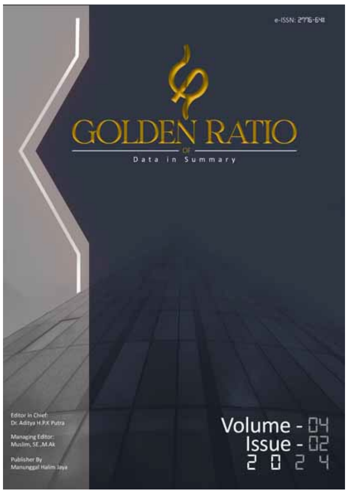


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DESCRIPTIVE OF QUANTITATIVE DATA | SUPPLEMENTARY

# Utilization of Sentinel Image Multitemporal Data for Landslide Potential Identification in Pujon Sub-District

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**Abstract:** Landslides are one of the most common disasters in Indonesia. Landslides are often triggered by high rainfall and occur for several days. Unstable soil structure is very easy to experience landslides. The case study of this research is in Pujon Sub-district, Malang Regency. Pujon sub-district has a hilly and highland topography. Its hilly-mountainous relief and steep slopes cause Pujon Sub-district to experience frequent natural disasters, especially landslides. The research was conducted by processing Sentinel 1 image using DInSAR method to obtain data on land surface change and weighting scoring method to obtain information on landslide prone areas. The processing of DInSAR method produces the value of vertical land surface change. The largest increase in land surface with a displacement value of 0.2972 m. And the largest land subsidence is -0.2234 m. Such movement can be an indicator of landslide occurrence. The GIS method produces 3 classes of landslide vulnerability level, namely low, medium and high in each year in Pujon sub-district. The average landslide prone area in the last 5 years is 15081.1331 ha. The processing results of DInSAR method and weighting scoring method can describe the landslide prone areas in Pujon Sub-district which is expected to be useful for landslide mitigation efforts.

Keywords: Landslide, Mitigation, Sentinel.

## 1. INTRODUCTION

A natural disaster is a disaster caused by an event or series of events caused by nature that results in a major impact on the human population. One of the disasters that often occur in Indonesia is landslides. Landslide is a type of mass movement of soil or rock, or a mixture of both, out or down a slope due to disruption of the stability of the soil or rock that makes up the slope. Over the last 5 years, BNPB (Disaster Management Agency) recorded 4,244 total landslides. These disasters caused a lot of damage and casualties. According to the National Disaster Management Agency (2017), landslides are often triggered by high rainfall that occurs for several days. Unstable soil structures are very prone to landslides. Landslides can also be triggered by earthquake tremors that topple the soil structure above.

Pujon sub-district is one of the areas in Malang Regency. It has a hilly and highland topography. Its hilly-mountainous relief and steep slopes cause Pujon Sub-district to frequently experience natural disasters, especially landslides. On February 28, 2023, there was a landslide in Sukomulyo Village, Pujon Subdistrict which resulted in the temporary closure of access for both two-wheeled and four-wheeled vehicles (detikJatim, 2023). Information about areas with the potential for landslides needs to be provided so that disaster mitigation efforts can be carried out. Therefore, it is necessary to analyze areas with the potential for landslides and periodic monitoring to estimate the potential for such disasters as a mitigation effort. Some ways to monitor and analyze potential landslide areas are by utilizing Differential Interferometry Synthetics Aperture Radar or DInSAR technology using Sentinel 1 satellite imagery and Geographic Information System (GIS) method.

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Sentinel 1 image processing with the DInSAR method is utilized to obtain information on land surface changes or land movement. Azeriansyah et al. (2017) analyzed vertical land movement in Ngesrep Village using a pair of Sentinel-1A images in September 2016 and in April 2017. The results showed that Ngesrep Village has the highest landslide vulnerability level of 11.95% with an average land subsidence value of -0.0587 ± 1.308m. According to Isnawati et al. (2009) landslide prone map can be obtained from image data processing and Geographic Information System (GIS) can be utilized to map landslide vulnerability. Using landslide parameters and supporting data are processed and analyzed using geographic information system-based technology. The DInSAR method produces land movement values and scoring along with weighting of each parameter causing landslides to map landslide prone areas which can be done effectively and efficiently which can be used for landslide mitigation efforts. The objective of this research is to determine the change of land surface from 2019 to 2023 in Pujon sub-district. The next objective is to identify potential landslide prone areas in Pujon Sub-district which will then present information on potential landslide prone areas as a disaster mitigation effort.

## 2. RESEARCH DESIGN AND METHOD

This research uses a case study in Pujon Sub-district, Malang District, East Java. Pujon District is geographically located at 7˚21'-7˚31' South latitude and 110˚10'-111˚40' East longitude. This research uses DInSAR method to obtain the value of land surface change and GIS scoring and weighting method to map landslide prone areas in Pujon sub-district. The materials and tools needed in this research are SAR Sentinel 1 satellite images of Pujon District in 2019-2023. Land cover data 2019-2023 Pujon sub-district. Rainfall data 2019-2023 Pujon sub-district. Spatial data of soil types, geological spatial data, spatial data of regional administrative boundaries, spatial data of slope of Pujon Subdistrict. The tools used are laptop, SNAP Software, ArcGIS Software. The data analysis method used in this research is quantitative. Data is processed by calculations assisted by software that is appropriate for the case discussed. The GIS analysis performed involves mathematical, statistical, logical, or model operations applied to spatial data to produce appropriate outputs

## 3. RESULT AND DISCUSSION

### *3.1. DInSAR Processing Results*

The data obtained consists of two paired radar images, each of which acts as a master and slave. The master image is a SAR image taken at an earlier time than the slave image. The align interferogram process is an alignment process to combine phase and amplitude information from two overlapping and clearly correlated SLC images. The following are the *displacement* values in the research area.

A

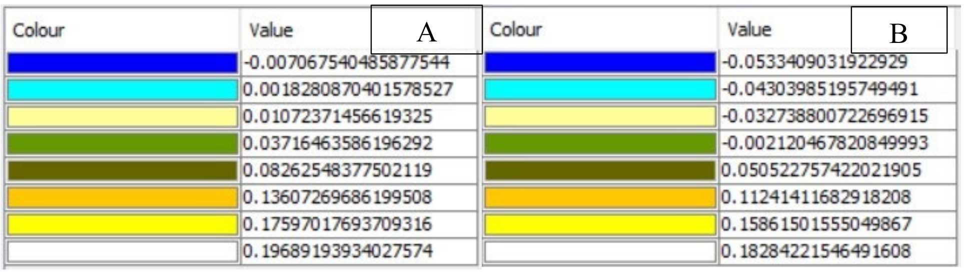
| Colour | Value |
|---|---|
| | -0.024757845909333472 |
| | -0.0158285239182897 12 |
| | -0.006899201927244698 |
| | 0.019641871122273065 |
| | 0.0652749136269810 7 |
| | 0.1189245717068404 8 |
| | 0.15897317369463415 |
| | 0.17997418262530118 |

B

| Colour | Value |
|---|---|
| | -0.174904067509 4875 |
| | -0.1706163328277396 |
| | -0.166328598145991 7 |
| | -0.15358394860604346 |
| | -0.131671604177503 8 |
| | -0.10590979383584224 |
| | -0.08667901910616044 |
| | -0.0765946303436067 |

**Figure 1. Displacement values for 2019-2020 and 2020-2021**

Part (A) shows the displacement value of the research area in 2019-2020 in the range of -0.0247 m to 0.1799 m. Then in 2020-2021 the displacement value is in the range of -0.0765 m to -0.1749 m as shown in Figure 1. part (B).



| Colour | Value (A) | Colour | Value (B) |
|---|---|---|---|
| | -0.007067540485877544 | | -0.0533409031922929 |
| | 0.0018280870401578527 | | -0.04303985195749491 |
| | 0.01072371456619325 | | -0.03273880072269691 5 |
| | 0.03716463586196292 | | -0.002120467820849993 |
| | 0.08262548377502119 | | 0.050522757422021905 |
| | 0.13607269686199508 | | 0.11241411682918208 |
| | 0.17597017693709316 | | 0.1586150155049867 |
| | 0.19689193934027574 | | 0.18284221546491608 |

**Figure 2. Displacement values for 2021-2022 and 2022-2023**

The displacement value for 2021-2022 shown in Figure 2. part (A) has a value range of -0.0070 m to 0.1968 m. Figure 2. part (B) shows the displacement value in 2022-2023 in the range of -0.0533 m to 0.1828 m. With the help of ArcGIS *software*, the range value of land surface change is obtained. The following is the range value.

**Table 1. Land surface change range values**

| Class | Range of Land Level Change per Year (m) | |
|---|---|---|
| | September 13, 2019-February 28, 2020 | March 23, 2020-February 10, 2021 |
| 1 | -0,087046854 - 0,008736211 | -0,223477647 - -0,151797795 |
| 2 | 0,008736211 - 0,046509814 | -0,151797795 - -0,128231817 |
| 3 | 0,046509814 - 0,085632475 | -0,128231817 - -0,104665838 |
| 4 | 0,085632475 - 0,13689665 | -0,104665838 - -0,066371123 |
| 5 | 0,13689665 - 0,256962746 | -0,066371123 - 0,026910875 |
| Class | Range of Land Level Change per Year (m) | |
| | April 23, 2021-March 1, 2022 | February 5, 2022-April 1, 2023 |
| 1 | -0,072070152 - 0,03066799 | -0,115242779 - -0,0133233 |
| 2 | 0,03066799 - 0,07252427 | -0,0133233 - 0,031974247 |
| 3 | 0,07252427 - 0,113112177 | 0,031974247 - 0,085360641 |
| 4 | 0,113112177 - 0,157505201 | 0,085360641 - 0,161395808 |
| 5 | 0,157505201 - 0,251364738 | 0,161395808 - 0,297288448 |

Negative values indicate that there is a decrease in land level, while positive values indicate an increase in land level. In 2019-2020 there was a decrease in land level of -0.0087 m and an increase in land level of 0.2569 m. Then in 2020-2021 there was the largest land subsidence at a value of 0.2234 m and the smallest decrease of 0.0269 m. In 2021-2022 there was a decrease and increase in land level. The decrease occurred by 0.0720 m while the increase occurred up to 0.2513 m. And in 2022-2023 there was also a decrease and increase in land level, the smallest decrease occurred by 0.0133 m and the largest by 0.1152 m. The increase in land level reached 0.2972 m. The largest land subsidence ranged from -0.1517 to -0.2234 m which occurred in 2020-2021. And for the largest increase in land level ranged from 0.1575 - 0.2513 m which occurred in 2021-2022.

**Table 2. Displacement values at 20 random sample points**

| Point | DInSAR Displacement (September 13, 2019-February 28, 2020) (m) | Point | DInSAR Displacement (March 23, 2020-February 10, 2021) (m) |
|---|---|---|---|
| 1 | 0,025 | 1 | -0,149 |
| 2 | 0,004 | 2 | -0,123 |
| 3 | -0,027 | 3 | -0,057 |
| 4 | -0,015 | 4 | -0,075 |
| 5 | 0,033 | 5 | -0,124 |
| 6 | 0,024 | 6 | -0,142 |
| 7 | 0,069 | 7 | -0,134 |

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| Point | DInSAR Displacement (September 13, 2019-February 28, 2020) (m) | Point | DInSAR Displacement (March 23, 2020-February 10, 2021) (m) |
|---|---|---|---|
| 8 | 0,067 | 8 | -0,146 |
| 9 | 0,053 | 9 | -0,148 |
| 10 | 0,126 | 10 | -0,134 |
| 11 | 0,021 | 11 | -0,144 |
| 12 | 0,048 | 12 | -0,127 |
| 13 | 0,060 | 13 | -0,171 |
| 14 | 0,075 | 14 | -0,149 |
| 15 | 0,093 | 15 | -0,184 |
| 16 | 0,107 | 16 | -0,140 |
| 17 | 0,084 | 17 | -0,122 |
| 18 | 0,087 | 18 | -0,116 |
| 19 | 0,021 | 19 | -0,158 |
| 20 | 0,030 | 20 | -0,142 |
| Point | DInSAR Displacement (April 23, 2021-March 01, 2022) (m) | Point | DInSAR Displacement (February 5, 2022-April 1, 2023) (m) |
| 1 | 0,021 | 1 | 0,063 |
| 2 | 0,059 | 2 | -0,021 |
| 3 | 0,028 | 3 | 0,190 |
| 4 | -0,001 | 4 | 0,140 |
| 5 | 0,038 | 5 | 0,031 |
| 6 | 0,012 | 6 | -0,005 |
| 7 | 0,070 | 7 | -0,030 |
| 8 | 0,065 | 8 | 0,029 |
| 9 | 0,073 | 9 | 0,032 |
| 10 | 0,114 | 10 | 0,029 |
| 11 | 0,157 | 11 | 0,032 |
| 12 | 0,093 | 12 | 0,014 |
| 13 | 0,105 | 13 | -0,012 |
| 14 | 0,083 | 14 | 0,023 |
| 15 | 0,094 | 15 | -0,015 |
| 16 | 0,111 | 16 | 0,031 |
| 17 | 0,096 | 17 | -0,032 |
| 18 | 0,081 | 18 | 0,065 |
| 19 | 0,122 | 19 | 0,066 |
| 20 | 0,041 | 20 | 0,023 |

In 2019-2020 the *displacement* value is in the range -0.0870 m to 0.2569 m. Then in 2020-2021 the *displacement* value is in the range -0.0269 m to -0.2234 m. The *displacement* value in 2021-2022 has a value range of -0.0720 m to 0.2513 m. And the *displacement* value in 2022-2023 is in the range of -0.0133 m to 0.2972 m. The identification of changes in land surface at 20 random sample points was also carried out to see the magnitude of the deformation value at each point. The largest land subsidence value occurred at point 13 in 2020-2021 amounting to -0.171 m. and the largest increase in land surface was at a value of 0.157 m which occurred at point 11 in 2021-2022.

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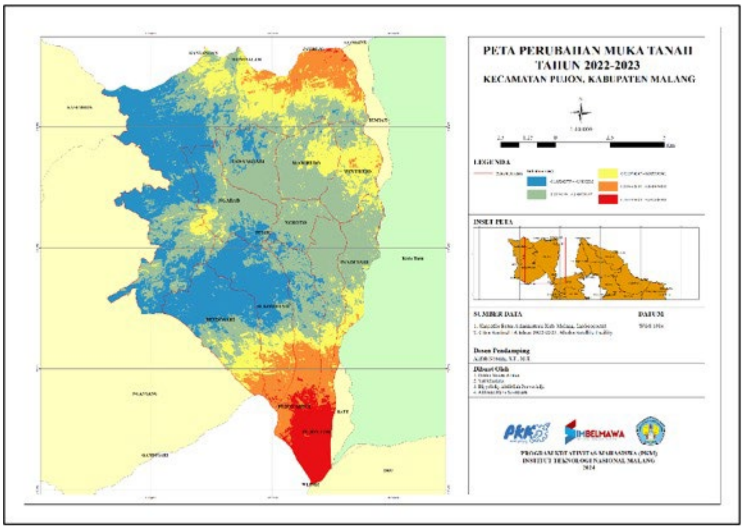


**Figure 3. Land surface change map**

Processing of GIS scoring and weighting method based on parameters that cause landslides, such as rainfall, slope, land cover, soil and rock types can be utilized to identify landslide prone areas in Pujon Sub-district. The class of landslide vulnerability level is determined based on the class interval value calculated from the scoring and weighting method. The processing results are as follows.

**Table 3. Landslide Prone Level in Pujon Sub-district**

| Level of Insecurity | Class Interval (%) | | | | |
|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 |
| Low | 1,9-2,57 | 2,20-2,97 | 2,5-3,17 | 2,3-3,03 | 1,9-2,67 |
| Medium | 2,58-3,24 | 2,98-3,74 | 3,18-3,84 | 3,04-3,77 | 2,68-3,44 |
| High | ≥3,25 | ≥3,75 | ≥3,84 | ≥3,78 | ≥3,45 |

The interval value of each class in each year is always different. The higher the value, the higher the landslide potential or categorized in high class. Vice versa, if the interval value is low, the level of landslide prone is also low.

**Table 4. Landslide Vulnerability Level in Pujon Sub-district**

| Level of Insecurity | Area per Year (ha) | | | | |
|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 |
| Low | 1333,633 | 2180,435 | 1229,258 | 687,219 | 1968,609 |
| Medium | 12215,667 | 12465,721 | 13226,314 | 13772,223 | 12030,328 |
| High | 1532,086 | 435,545 | 625,620 | 621,750 | 1082,160 |
| Total Area | 15081,3853 | 15081,7007 | 15081,1919 | 15081,1917 | 15081,0969 |

Based on the processing of GIS scoring and weighting method, 3 classes of landslide vulnerability level were obtained, namely low, medium and high class. To obtain landslide prone areas, it is necessary to consider several parameters, including rainfall per year, slope, soil type, rock type or geology, and land cover per year. In the last 5 years, the area with the widest landslide-prone area was in 2020 with an area of 15081.7007 ha. There was a decrease of 0.2884 ha of landslide prone area in 2023 from 2019.

The results of processing with scoring and weighting methods resulted in 3 classes of landslide vulnerability level, namely low, medium and high. The total area of landslide prone area in 2019 is 15081.3853 ha. While the total area prone to landslides in 2023 is 15081.0969 ha. It can be concluded that there has been a decrease of 0.2884 ha of landslide prone area in 2023 from 2019. The processing results of the GIS method were further validated using news data of landslide events from BPBD Malang District. According to the data from BPBD Malang Regency, one of them is that

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throughout 2023 there have been 11 landslide incidents in Pujon Sub-district. A total of 1 incident each occurred in Ngroto, Pujon Lor, Pujon Kidul and Bendosari villages. And 7 landslides occurred in Sukomulyo Village. In the processing of GIS method, most of Sukomulyo urban village, Pujon sub-district consists of high and medium landslide prone areas.

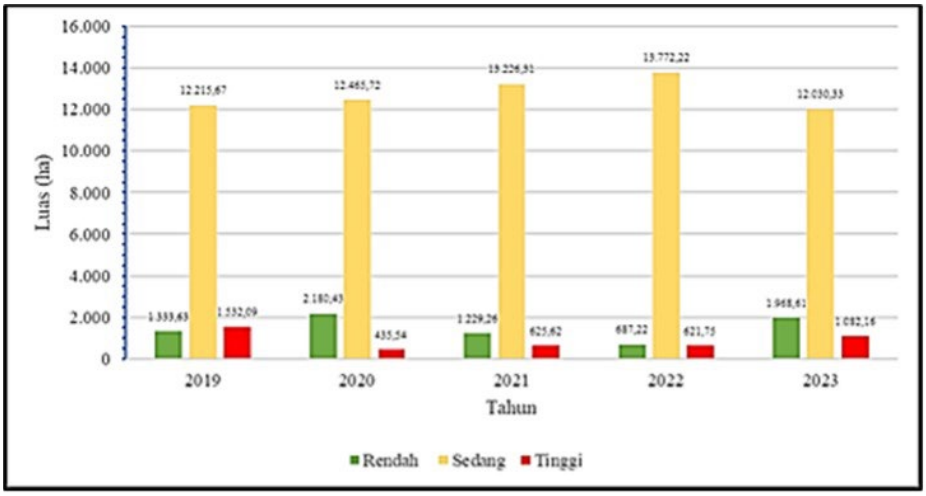


**Figure 4. Diagram of Landslide Vulnerability Level by Year**

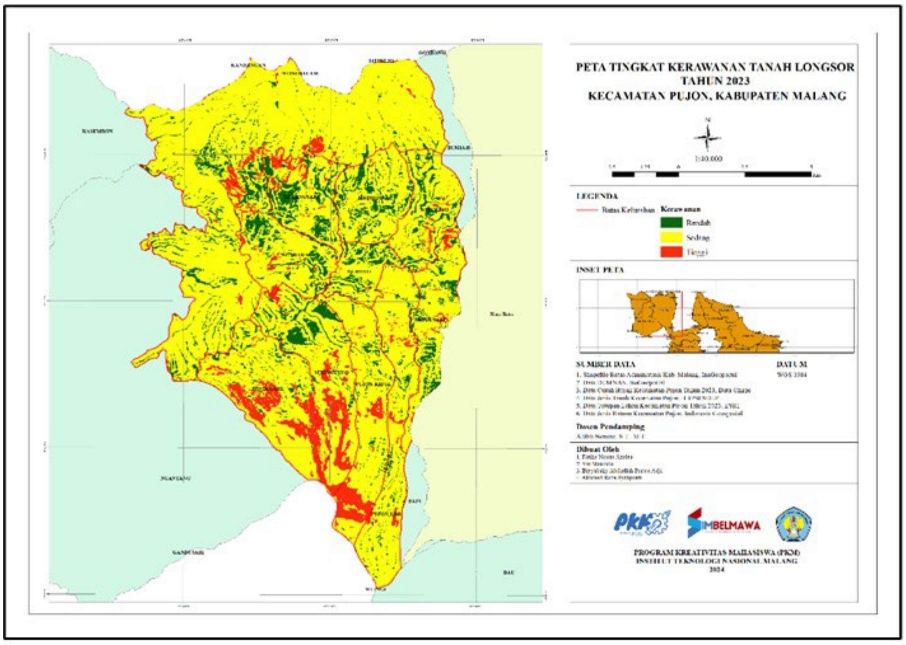


**Figure 5: Landslide vulnerability map**

## 4. CONCLUSIONS

Processing of Sentinel 1 SAR images using the DInSAR method with the help of SNAP software can produce vertical land surface change values. The largest increase in land surface occurred in the 2022–2023-year range with a displacement value of 0.2972 m. The largest land subsidence value is -0.2234 m which occurred in 2020-2021. The displacement values above illustrate the amount of change or vertical movement of the land surface. Such movement could be an indicator of landslide occurrence in the area.

Processing of GIS method of scoring and weighting produces data of landslide prone areas. The processing resulted in 3 classes of landslide prone areas for each year. There has been a decrease in landslide prone area of 0.2884 ha in 2023 from 2019. The processing results of DInSAR method

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and weighting scoring method can describe the landslide prone areas in Pujon Sub-district. Furthermore, the information can be presented in the form of a map that can make it easier to understand the information in it. In addition, the resulting map can be one of the considerations for a decision as a disaster mitigation effort.

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