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PRELIMINARY STUDY OF LANDSLIDE IN SRI MULYO, MALANG, INDONESIA USING RESISTIVITY METHOD AND DRILLING CORE DATA

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ABSTRACT: Research on landslide in Sri Mulyo Village, Dampit Subdistrict, Malang District, Indonesia has been implemented. This research is conducted to know the condition of the subsurface area for information in landslide vulnerability analysis. In addition, this research was undertaken to mitigate landslide in minimizing casualties and material losses. The study was done using resistivity method, configuration of dipole-dipole supported by drilling core lab test result. There are five resistivity measuring lines with trajectory lengths ranging from 100 m, 200 meters, and 300 meters. The results of the resistivity indicate that the subsurface lithology of Sri Mulyo Village is composed of clays (9.3-85.8 Ω.m), tuff (178-779 Ω.m) and breccia (≥ 1629 Ω.m). The sliding plane at the research area is the boundary between clays and tuffs. The result of correlation between geoelectric and drilling core data showed that the research area was dominated by a 10m depth of clay. High rainfall, clay thickness and vegetation (coffee) exhibit high levels of vulnerability to occur landslides. Possible landslide direction is from West-West to Southeast with creep avalanche type.

Keywords: Landslide, Dampit, Resistivity, Disaster Mitigation

1. INTRODUCTION

Indonesia is a country that often suffers from hydrometeorology disaster, a disaster caused by climate change and weather [1]. From the beginning of the year (January) to December 4, 2017, there were 2,175 disasters in Indonesia with a death toll of 335 people, 969 injuries, and displacing 3.22 million people. Most of the victims died from a landslide [2]. This is because many locations in Indonesia are categorized as landslide-prone areas.

Sri Mulyo Village, Dampit Subdistrict is one of the villages that are prone to a landslide in East Java Province. On January 24, 2006, a landslide destroyed one house and cracked 14 housewalls and foundation. Also, landslides resulted in 3 (three) sliding planes and 12 small avalanches disrupting road access as thick as 60 cm. The geological area of the landslide above is the weathered breccia rocks, which is above the limestone of Wonosari Formation. Regarding the angle of the slope, the landslide area has a slope of 12^0-20^0, it is not too steep. The occurrence of landslide shows that the cause is not only from the slope, but also because the area is in the normal fault zone [3].

A landslide analysis can be undertaken using a geophysical method. The geophysical method is a method to know the condition of the subsurface based on the physical parameter. Geoelectric resistivity method is one of the geophysical methods that are widely used in the field of hydrogeology, disaster mitigation, and archeology [4-7]. Several previous studies have demonstrated that the geoelectric resistivity method was sufficient for determining the subsurface condition of landslide-prone areas [3], [8-13].

The determination of a site's vulnerability is not only known based on geoelectric resistivity data, but support data is also required. In this case, the geological map of Turen Sheet and soil core samples (drilling) lab test results are used to analyze the area. The correlation between geoelectric data interpretation with geological map and core lab test can be used to analyze slope stability.

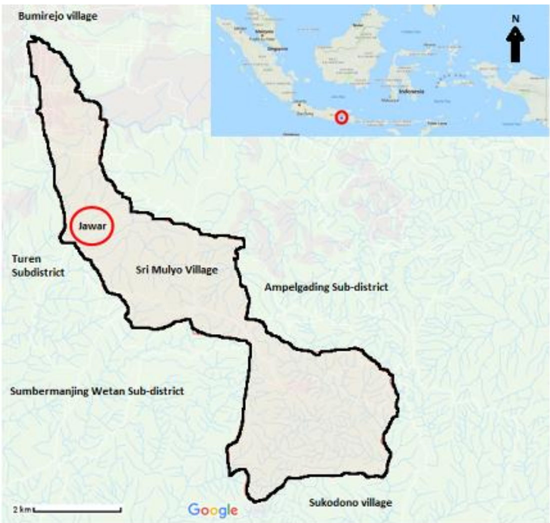
Therefore, it is important to investigate Sri Mulyo Village to know landslide vulnerability. Landslide analysis is conducted as one of the disaster mitigation efforts for areas that have experienced landslides in the past.

2. FIELD SITE STUDY

The Village of Sri Mulyo, Dampit Subdistrict (Figure 1) is geographically located at 8.2928^0 SL 112.7991^0 EL. Administratively, Sri Mulyo Village is adjacent to Bumirejo Village in the North, Ampelgading Subdistrict in the East, Sumbermanjing Wetan and Turen Subdistricts in the West, and Sukodono Village in the South. In general, the soil structure is a podzolic soil with land and mountains topography with an altitude of 400-

790 meters above sea level with a slope of less than 40%. The average annual rainfall is 5229 millimeters. The majority of the population's work is coffee and salak farmers.

Based on Geological Map of Turen Sheet [14], Sri Mulyo Village is in Wuni Formation (Figure 2). The Wuni Formation consists of breccia and andesites lava (andesitic-basaltic breccia and lava, breccia tuff, and breccia and sandy tuff breccia.) The location of Sri Mulyo Village is close to the border of many rock formations, including Wonosari Formation, Jembang Volcano Deposition and Sediment of Semeru Volcano.



(a)

(b)

Fig. 1. (a) Sri Mulyo Village, Dampit subdistrict (marked in red), (b) land subsidence on the road.

Fig. 1 (a) is Sri Mulyo village, which was already more than 7 years suffered from landslide and land subsidence. Fig. 1 (b) is part of the road in this village which suffered from fault and landslide, and then the government put some material on it.

Fig 2. Location of Sri Mulyo Village on Geological Map of Turen Sheet (marked in red)

3. METHOD

3.1 Design Survey of Resistivity Method

The geoelectric resistivity method essentially utilizes the earth's electrical properties with the subsurface rocks resistivity as the parameter. This method is an active method, where the current is injected into the earth through two current electrodes (C1 and C2) and the resulting potential are captured by two potential electrodes (P1 and P2). Considering the geometry factor of the configuration used, pseudo rocks subsurface resistivity can be calculated.

This research uses the dipole-dipole configuration (Figure 3). The current electrodes (C1 C2) and the potential electrodes (P1 P2) have spaces "a". Initially, C1 C2 and P1 P2 has a distance "a". After this first measurement, P1 P2 electrode is moved to the right until the maximum distance. In this condition, distance between C1 C2 and P1 P2 becomes "na", where "n" is integer number. Furthermore, the C1 C2 is moved to the right as far as "a". And "P1 P2" moves back to the left as far as "a" of C1 C2. Then, P1 P2 is moved to the right to the maximum distance.

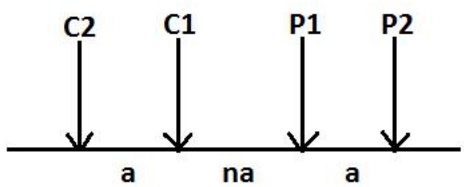


Fig. 3. Dipole-dipole configuration

The geometry factor of dipole-dipole configuration can be obtained through the equation:

$$k = n\pi a(n+1)(n+2) \quad (1)$$

Apparent resistivity can be obtained by the equation:

$$\rho_a = k\,\Delta V / I \quad (2)$$

with, a as spacing between electrodes (m), ΔV potential difference (mV), I the injected current (mA), n the integer number, ρ_a apparent resistivity (ohm.m), and k geometrical factor (m).

The research was conducted at Sri Mulyo Village in March-April 2015 at coordinates of 08^0 18' 44.86" - 08^0 11' 05.16" SL and 112^0 49' 22.02"- 112^0 41' 56.47" WL. There are five measuring lines of geoelectric resistivity method (Figure 4). Line 1, 2, and 3 with track lengths of 180 meters, 200 meters, and 100 meters respectively, and electrode spaces (a) of 10 meters. Lines 1 (red), 2 (yellow) and 3 (green) are measured from the Southeast to the Northwest. Line 4 is 200 meters long with an electrode spacing of 10 meters, and line 5 is 300 meters long with 15 meters of the electrode spacing. Line 4 and 5 are measured from Southwest to the Northeast

Figure 4 also shows the core drilling points used as samples for lab tests in the determination of soil characteristics. The drilling is performed at two points, namely point 1, located on the 60 m trajectory path of line 1 (red ballon), and point 2 at 70 m of line 2. The drilling results are used as the supporting data of landslide analysis of geoelectric resistivity method. Geoelectric data processing is conducted using Re2dinv software. Interpretation is made through correlation with the Turen Geology Map Sheet.

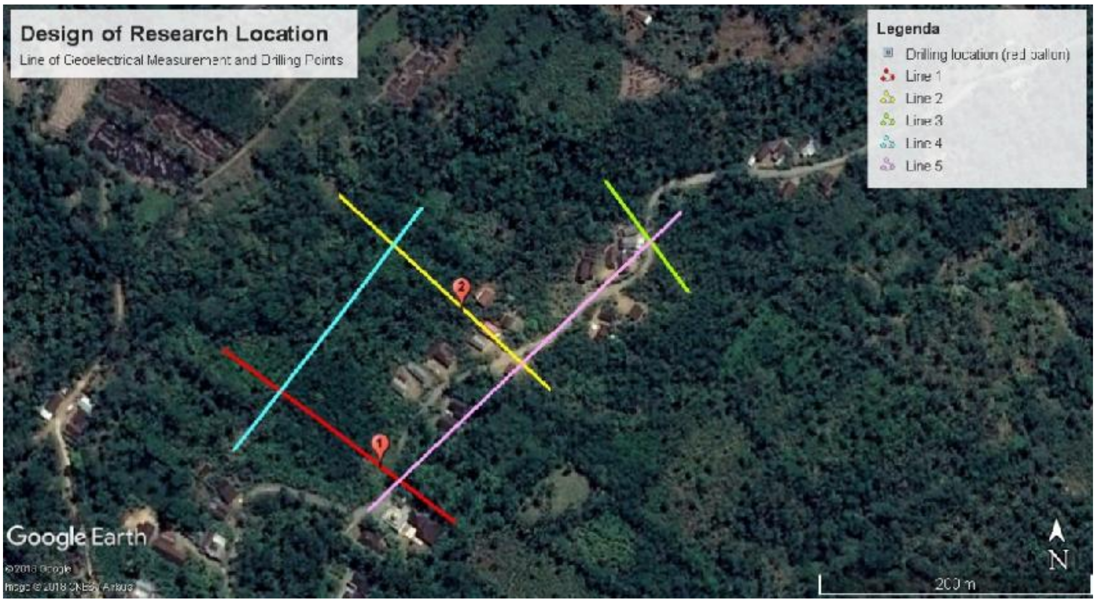


Fig 4. Geoelectric Resistivity Method Survey Measurement Design

3.2 Data Processing

Data obtained from the field is processed using Res2dinv software. This software uses inversion method. Where, in principle, this method will find a subsurface model in accordance with the measurement data in the field. The Res2dinv program uses the iteration method, which starts from the initial model, then the program will look for models where the apparent resistivity value is calculated close to the measured value. The iterative inversion method used is a smoothness-constrained method whose equations are as follows:

$$(J^T J + uF)d = J^T g - uFr$$

Where, F is a smoothing matrix, J the Jacobian matrix of partial derivatives, r is a vector containing the logarithm of the model resistivity values, u is the damping vector, d is perturbation vector model, and g the discrepancy vector.

The data which is ready to be processed in Res2dinv, is inputted first in Microsoft Excel software to calculated the apparent sub-surface resistivity value using equations (1) and (2) that have been previously written. Then the data entered in notepad (Figure 5). After that, the data which is ready to be processed, then is entered in Res2dinv software. The result obtained is a resistivity section of subsurface rocks in 2D form. The 2D cross-section will show the resistivity range from low to high. The information that can be obtained is the distribution of resistivity value of the rock and the depth. This information will give an overview of the range of resistivity, by adjusting to the reference resistivity table and taking into account the type of rock present in the Geological Map. Turen Geology map sheet is used in this investigation.

Name of survey line		
Smallest electrode spacing		
Array type (dipole-dipole = 3)		
Total number of measurements		
Type of x-location datum points (1 for mid-point)		
Flag for IP data (enter 0 for resistuvity data only)		
Middle point	Electrode Spacing	Apparent resistivity value
Spacing of topography		
Total number of topography		
Topography Spacing	Elevation	
1		
0,0,0,0		

(a)

```
line 1
10
3
9
1
0
15      10      1       123.9672
25      10      1       994.9404
35      10      1       39.7524
45      10      1       34.1004
55      10      1       33.1584
65      10      1       31.086
75      10      1       15.8256
85      10      1       2.0724
95      10      1       106.6344
5
21
0       323.5
10      322.5
20      320.5
30      318.5
40      316.5
1
0,0,0,0
```

(b)

Fig. 5. (a) How to input of the data in notepad, (b) Sample of data input in notepad

4. RESULT AND DISCUSSION

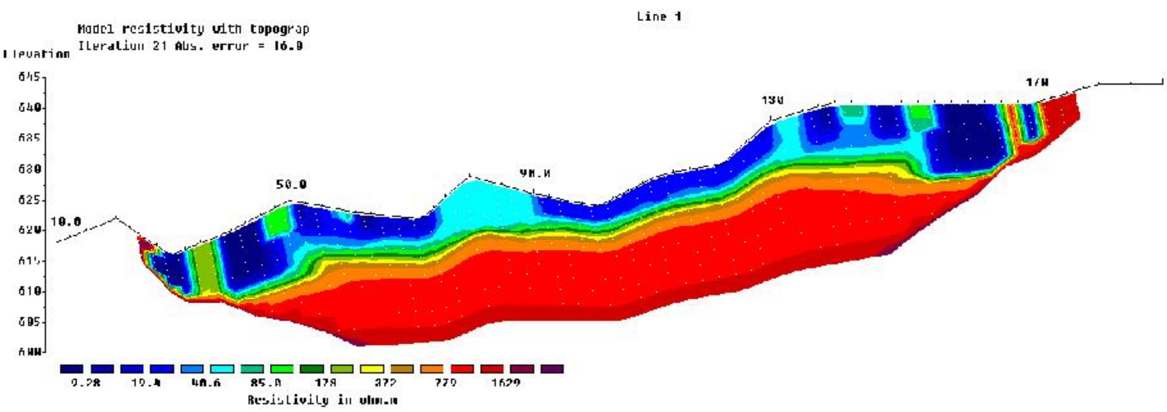


Fig 6. 2D Resistivity Line 1 (red line in the fig 4)

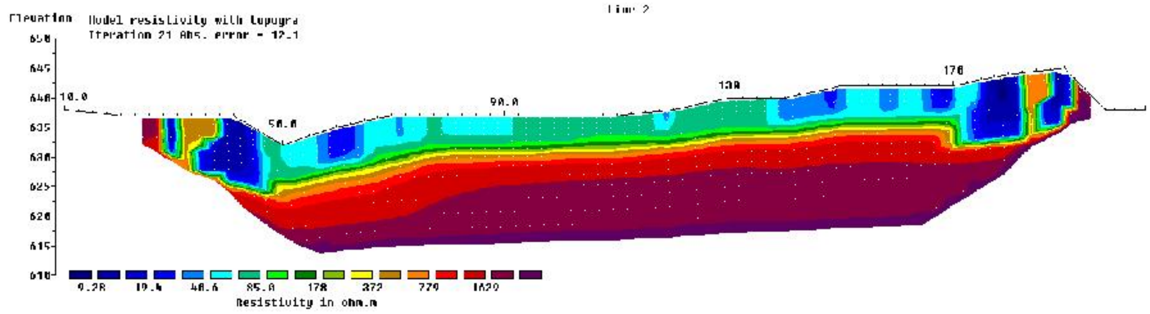


Fig 7. 2D Resistivity Line 2 (yellow line in fig 4)

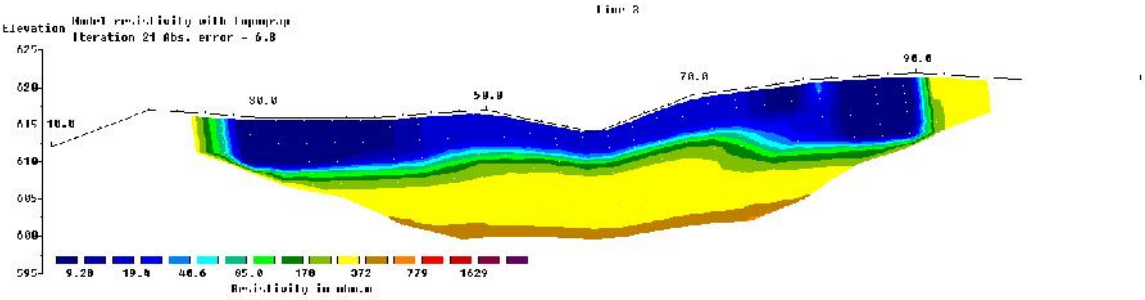


Fig 8. 2D Resistivity Line 3 (green line in fig 4)

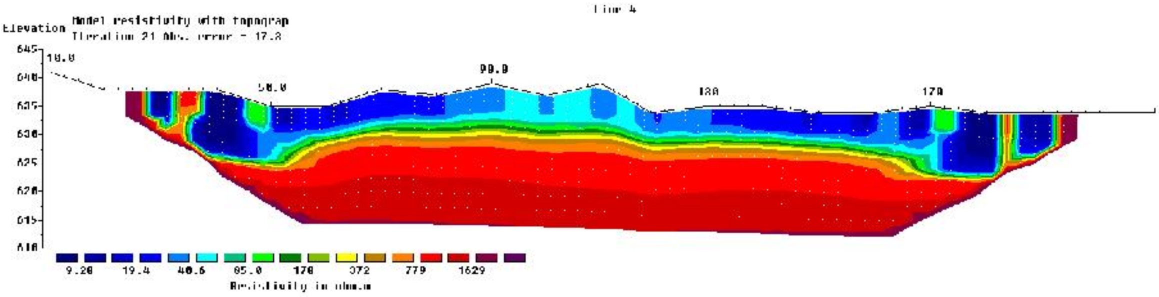


Fig 9. 2D Resistivity Line 4 (blue line in fig 4)

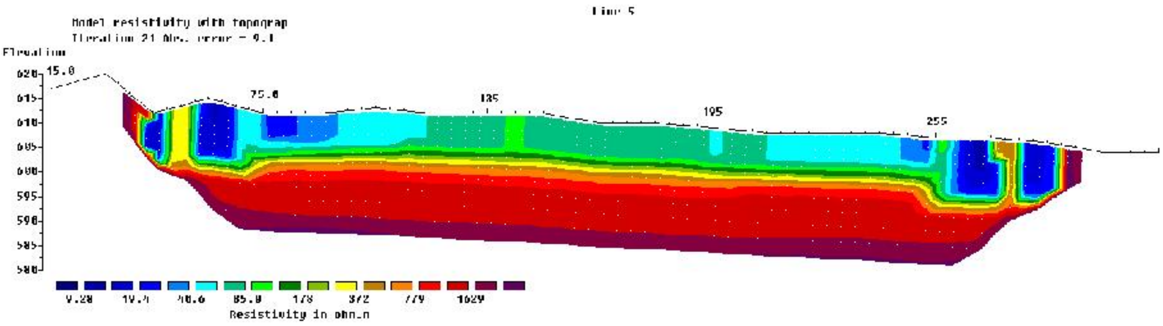


Fig 10. 2D Resistivity Line 5 (purple line in fig 4)

Based on the result of geoelectric resistivity data processing and information of Turen Geological Map Sheet, Sri Mulyo village, Dampit Subdistrict is composed of three layers of rock. Three layers of existing rock in the study location are divided into three ranges of resistivity value, i.e. low, medium and high resistivity. Local lithology is composed of clay (9.3 - 85.9 Ω.m) which is for the range of low resistivity, tuff (178-779 8 Ω.m) for the range of medium resistivity and breccia (≥ 1629 Ω.m) which is the high resistivity. Fig. 6, Fig. 7, Fig. 8, Fig. 9 and Fig. 10 are a 2D cross-section of the geoelectric resistivity data processing, where dotted lines indicate the estimation of the sliding plane at the study area. The sliding plane in this study is the boundary area between clays and tuffs.

Figure 11 shows the presence of clay dominance on the three parallel line measurements. Clay appears to dominate to a depth of about 10 meters in the subsurface. This indicates that the weight of the soil during rainfall will be higher because the infiltration of rainwater into the soil does not easily escape due to the very low permeability of the clay. As a result, the boundary field between the clay and tuff will become slippery over time, and when the slope is unable to withstand large loads, there will be a movement of land down the slopes commonly referred to as landslides. Potential occurrence of landslides is also higher due to vegetation that is located above the surface of the research area in the form of the seasonal crop (coffee). This type of plant has roots that are not strong to bind the grains of the soil thus enlarging landslide potential.

Figures 12 and 13 show the correlation between the geoelectric and drilling data. The drilling was carried out on two line measurements, namely line 1 and line 2 with a depth of 8 meters, indicating that up to a depth of 8 meters, the soil is dominated by clay. This is by the interpretation of geoelectric data from the five measurement lines stating that to a depth of 10 meters, clay dominates the research area. The correlation of the five measuring lines shows that the direction of the landslide, from the Northwest to the Southeast, is due to the height difference between line 4 and 5. As the sliding plane is relatively flat and the research area as not steep, then the type of landslide in the research area is of the creep type. This type of avalanche is the type that moves slowly down the slope.

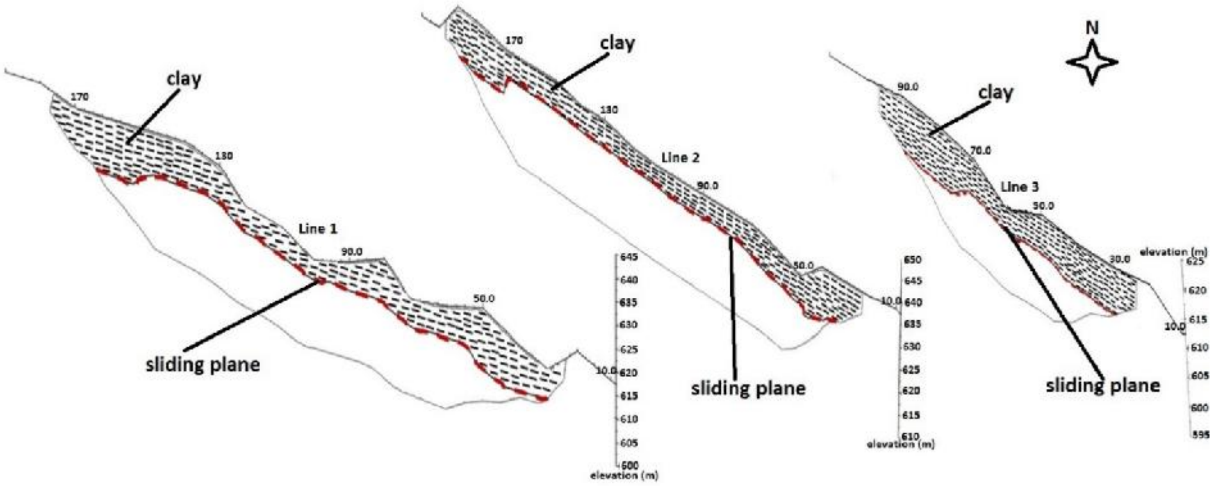


Fig 11. Correlation of 2D Resistivity Sections of Line 1, Line 2 and Line 3

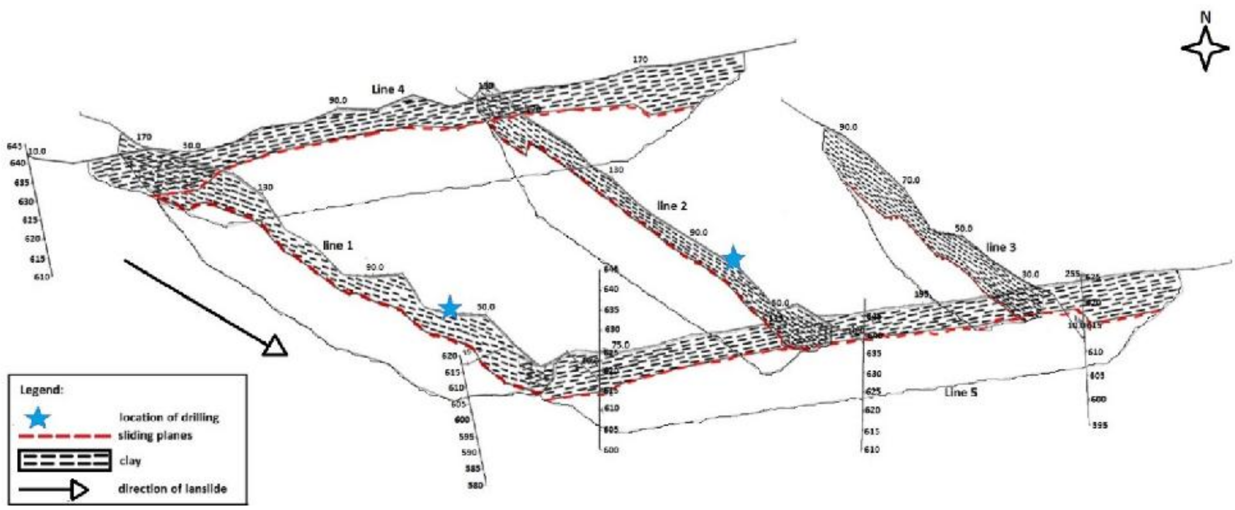
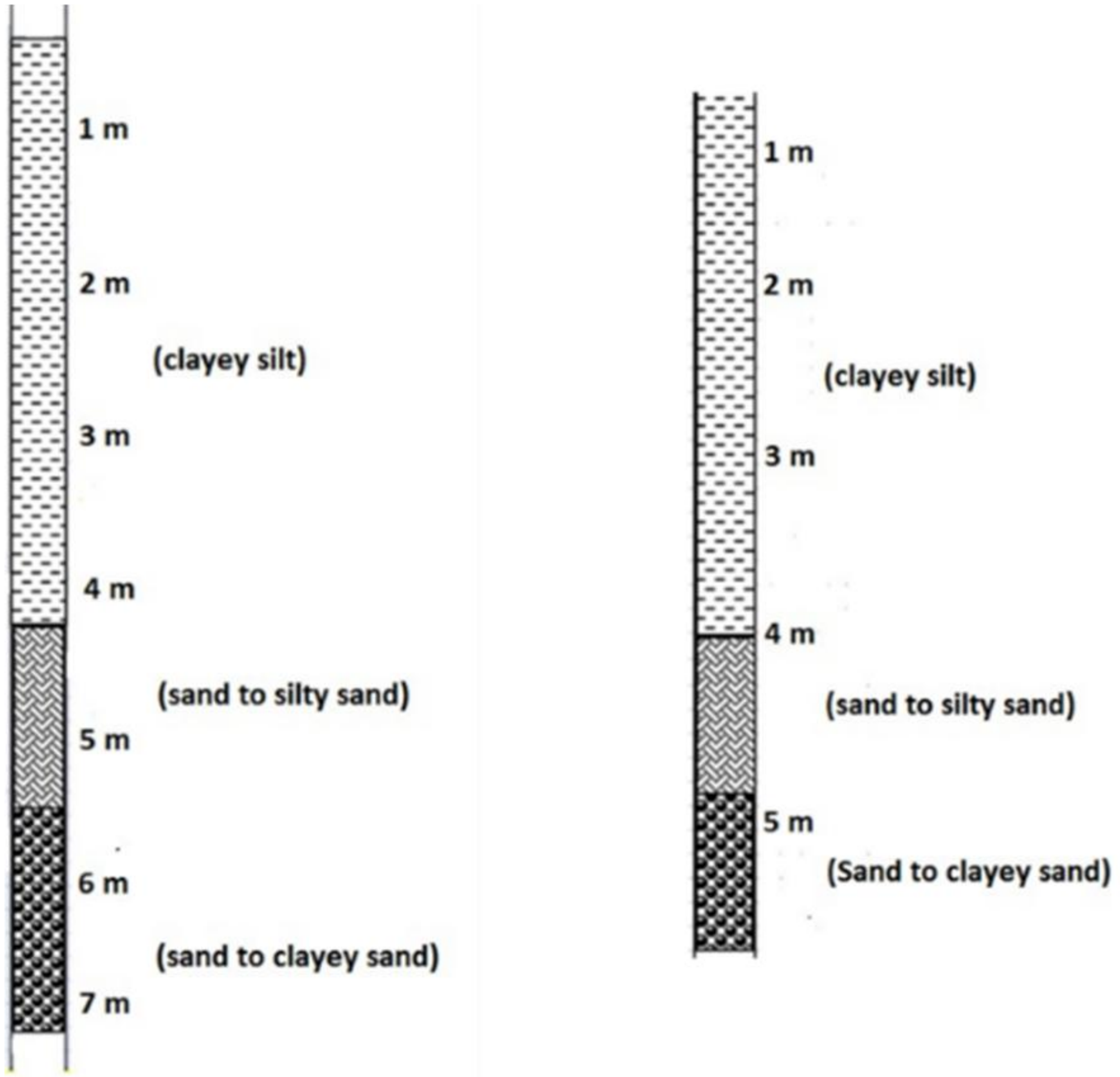


Fig12 . 2D Resistivity and Drilling Point Correlation



(a) (b)

Fig 12. Soil Sampling Test Results (a) Line 1 and (b) Line 2

Based on the data correlation, there is a large landslide potential as the clay has exceeded 5 meters with annual rainfall average of 5299 mm / year that increases the soil weight when it rains. Also, the inadequate carrying capacity of vegetation in the research areas is a supporting factor. The results of this study may be one of the considerations of local government in disaster mitigation at the research area to minimize the casualties and losses due to landslides

5. CONCLUSION

The results of this study indicate that the geoelectric resistivity method can provide a good overview for investigation in landslide potential areas. The results of the correlation of geoelectric resistivity with drilling data showed the location of the study was dominated by clay to a depth of about 10 meters. The level of vulnerability of landslides in Sri Mulyo Village, Dampit sub-district is high. This study is expected to become one of local government's reference in landslide mitigation efforts. One solution can be by replacing a seasonal plant to strengthen the binding of the grain of the soil.

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