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The stipulation of hazard zone distribution of landslide movement based on above Earth surface parameter and under Earth surface parameter using the weighting analytical Hierarchical Process in settlement area of Trangkil, Semarang City

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ABSTRACT

The settlement area of Trangkil in Semarang City located on a steep slope topography that rest on a clay sediment, once had a landslide at the rainfall in early 2014. This area has groundwater level about 7-10 meter depth from the surface and Ground Shear Strain (GSS) more than 10^{-2} above the slip surface on clay sediment with a resistivity of (32.2-119) &!m. Mapping of the level of landslide hazard in this area is necessary for mitigation planning. Research on the distribution of danger zone with various parameter measured on the earth's surface such as slope, geology, the use of the land had been conducted a lot, but none was combining comprehensively the parameter of above the earth's surface and under the earth's surface like the value of the groundwater level and the value of GSS within the landslide danger distribution. In this study the distribution of parameter value over the earth's surface and the distribution of the parameter under the surface was overlaid using Analytical Hierarchical Process (AHP) weighting method were done to obtain the distribution of landslide hazard area classification, with the ratio consistency score of 0.028. The results showed that there were four landslide hazard zones, i.e. very low hazard zone, low hazard zone, medium hazard zone, and high hazard zone. The validation result with the slope stability analysis of the Bishop method on the high hazard zone of the landslide had a 1.37 safety factor while in low hazard zone had a 1.77.

Key words : *Trangkil, Slip area, Ground shear strain, Lands slide, Ground water level*

Introduction

Landslide is a common disaster that occurs in Semarang. Regional Board of Disaster Management (BPBD) of Semarang recorded that tere have been 92 cases of landslide up to this March 2020. Dozens of such landslide occurrences started from early January 2020 or during the rainy season. BPBD reported that in January there have been 33 cases, February 38 cases, March 30 cases, and April 12 cases of landslides (BPBD, 2020). Therefore, it needs to have a study of disaster risk to identify the high danger zone of landslide to prevent the disaster.

Based on the Map of Vulnerability Zone from Land Movement of Semarang City, Central Java Province in August 2020, Gunungpati was included in Medium - High hazard zone (Centre of Vulcanology and Geology Disaster Mitigation, 2020) and Tjahjono *et al.* (2019) stated that by scoring and spatial analysis using GIS techniques in Semarang City, the results show that the level of disparity in landslide risk is spread across 8 sub-districts in the city ranging from low, medium and high. The highest risk areas are widespread in Gunungpati sub-district, Semarang City.

In Trangkil Settlement, Semarang city on 23 January 2014 around 07.00 AM there had been a landslide case causing dozens of houses damaged and several electricity poles tilted from the land movement (BPBD, 2014).

The main criteria contributing to the landslide disaster in many regions in the world is the slope factor. Most of the previous researches focused on the factor of a slope to develop a landslide danger model. Another factor is the history of a landslide, geology, land use, lithology aspect, and drainage factor. To evaluate the susceptibility of landslide disasters (Wang *et al.,* 2017; Devkota *et al.,* 2013) used parameters above the earth's surface such as slope, plan curvature, distance to fault and distance to river.

The position of the Groundwater level and the score of GSS are two-parameter that may influence the stability as a landslide trigger. Among the main causal factors of landslides, the temporal variation of the groundwater level plays an important role on slope instability, so that it can be said that the ground water level is often the primary controlling factor in landslide occurrence.According to Alsubal *et al.* (2018), the loose soil slope fails faster than dense soil slope because of the high strength and low permeability of the dense slope. Furthermore, rainwater infiltration is not enough to trigger slope failure, rather generation of pore-water pressure from the increase in moisture content associated with the rise of ground water level is the one that create an unstable zone. The distribution of the GSS score is a value determining the vulnerability index of the sediment layer towards the deformation if an earthquake occurred (Nakamura, 2008).

The use of the AHP model produced an image showing the landslide vulnerability (Kezhri, 2011; Jazouli, 2019; Othmana *et al.,* 2011) used Geography Information System and Multi-Criteria Decision Making Analytical technique to map landslide danger zone based on AHP and Feizizadeh *et al.* (2011) used AHP to determine the weight of each parameter used in mapping the landslide danger in Bostan Abad, Iran.

The potential and specific requirement of the input data analysis of landslide depends on the map scale. Danger analysis is not frequently conducted based on the mapping requirement especially when the analysis is based on the map interpretation since the phenomenon of accuracy probability is very hard to achieve in the area with medium to national scale map. Big scale danger zone map (< 1:10.000) enables stability score variable evaluation as the factor triggering the landslide (Soeters and Western, 1996).

Rainfall and earthquakes are the triggers for the landslides (Othmana *et al*., 2011). The parameter above the surface and under the earth's surface could be used to determine the mitigation steps in handling the danger of landslide so that it could be used to prevent the achievement of land/sediment saturation level, in other words, almost all landslide occurrences were triggered by the entrance of water into sediment layers, in this case, the factor of rainfall played a role in triggering a landslide. In this study, because the location is a narrow area that has the same rainfall load (there is no variation in rainfall in the same area), the distribution of parameter values above the surface and below the surface is used as a landslide hazard zone mapping.

The objective of the research is to determine the landslide danger zone based on the parameter above the surface and under the earth's surface used AHP that could be used by planners and decision-makers to plan the land use and slope maintenance.

Materials and Methods

The Sudy Area

The settlement area of Trangkil in Semarang City located on a steep slope topography and regarding to geographical position it is located between (07^o 01′ 47.7" – 07^o 02′ 04,0") geographical longitude and (110^o 23′ 16.5" – 110^o 23′ 37,7" geographical latitude that rest on a clay sediment, once had a landslide at the rainfall in early 2014. This location is known that there are three lithological units in the area, namely clay, breccias and silt units. The clay unit is the lowest rock stratigraphically in the form of blackish gray clay, compact, slightly soft, and easily crushed. The Trangkil area is located in the Kaligetas formation (Qpkg), this formation is in the form of volcanic breccias, lava flows, tuff, tuff sandstones and clay.

Study method

Parameter above the surface

Information about the slope tilt is obtained using remote sensing image in the form of data extraction activity of digital elevation model (DEM) from ASTER GDEM image, then was entered into a software of Geographic Information System to be conducted the derivative 3D spatial modeling in the form of the slope to identify the information of slope tilt. The results of this slope are verified in the field using the Topographic Abney Level tool based on each predetermined sample point. Data correction is carried out if there was data different from the result processed by DEM towards the result data of field verification.

Lithology information is obtained from deductive analysis result through a physical approach from secondary data in the form of land use, land shape data, geology data, topography data, and ground data. Such land-use data is used to identify all human activities occurring on the ground. There are characteristics of compatibility of physical conditions and human activities from land-use data that can provide deduction information, for example, agricultural land use and/or several moors are usually located in the alluvial zone with alluvial soil types. A landform is used to identify any kind of geomorphology physical condition in the area to make physical data as an inventory and help the process of determining lithology information. Geology data obtained from the Geology map to identify the geotechnical bedrockthe lithology layer on it, and the process developed in the area. Topography data is used since each lithology has varied special characteristics towards the level of the earth's surface as the consequence of the geomorphology process occurred to it so that it could help its interpretation process. Data on land is required to identify the type of land occurring in the region as well as its composition. It needs to be identified since the process of land occurrence generally is the result of weathering from each kind of the main sediment, so that by identifying the type of land in the researched area, the materials that made it could also be identified. The logical reasoning of such data is then analyzed deductively to identify the existing lithology types in the researched area. Field checks and verification were then performed by taking the sample of soil to see the texture and to observe as well as identify the sediment distributed across the researched area to be fitted with each characteristic of lithology type based on the existing reference and literature.

Information on the land use from the RBI map was updated with the aspect of visual interpretation of land covering using high spatial resolution satellite image i.e. Geo-Eye with the current acquisition data. Field checks and verification were conducted on the result of the processed data based on each sample point determined. Data correction is performed if there was a data different from the result of processed land and land covering towards the data of field verification result.

Determining Parameter under the Surface

Determination of the depth and slip surface used the Two-Dimensional Geo-Electrical Resistivity Method of Dipole-Dipole Configuration. By knowing the resistivity value and the depth of the slip surface it will be known whether the groundwater level is above or below the slip surface. If the distribution of the groundwater level is above the slip surface, the area is prone to landslides Maze (2017).

Data parameters measured in determining the position of shallow groundwater level are location coordinate, the height of the well's tip, the height of the groundwater level from the tip of the well. The position of groundwater is the height of the groundwater level subtracted by the height of the well's tip.

Nakamura (1989) developed a concept of HVSR by assuming that microtremor is dominated by shifting waves and ignoring the surface wave

(Rayleigh and Love wave). This HVSR is considered common with the transfer function between the wave vibration on sediment and bedrock. It means the amplitude and the peak frequency of HVSR represents the amplification and the local frequency.

The vulnerability index has been applied by Nakamura *et al*. (2000) and Huang and Tseng (2002) showing that building damages are directly proportional to the seismic vulnerability index. Therefore, to conduct zoning of building damage from an earthquake, measurement and microtremor analysis could be done by applying equation $K_g = \frac{A_m}{f_0}$ and perform an empirical approach to estimate Ground Shear Strain and the result is shown in equation y = Kg × a(10)$^{-6}$ Remarks: cˆ is Ground Shear Strain, K_g is seismic vulnerability index, and α is the maximum ground velocity (gal). GSS score is the score determining the sediment layer vulnerability index towards the occurrence of deformation if the vibration occurred during the earthquake.

Determining Landslide Hazard Zone

Field mapping was carried out to take the reference point including the sample taking to obtain data about the factor influencing the occurrence of a landslide. Zoning performed in this area was based on the parameter above the surface which was a slope, lithological fracture, land use, and parameter under the surface of the earth which is the shallow groundwater level and the score of ground shear strain influencing the landslide. AHP weighting method has been implemented by Othmana *et al.* (2011) and Feizizadeh, *et al.* (2011). The overlay between the parameter above the surface and parameter under the surface is formulated using the AHP weighting method producing a zoning map of landslide hazard which is divided into 4 landslide hazard zone with the formula of:

Lh = (0.36 × sl+0.28 × Lf + 0.18 × Lu + 0.13 × Gl + 0.5 × Gs)

where, *Lh* is Landslide hazard, sl is score of slope distribution, *Lf* is score of distribution of lithologicalfracture, *Lu* is score of land use distribution, *Gl* is score of GWL distribution, G_s is score of GSS distribution, with the ratio consistency score of 0.028.

The distribution results in the research location produced four landslide area zones, i.e. very little, little, medium, and high from the landslide danger based on the Regulation by the Minister of Energy and Mineral Resources Number: 15 in 2011 about the Guidance of Mitigation of Volcano Disaster, Ground Shifting, Earthquake, and Tsunami.

The result of this distribution is validated by estimating the score of security factor from the level of landslide using the Bishopmethod.

Results

Slope tilt distribution is divided into five class, they are flat (0-8%), sloping (8-15%), rather steep (15-25%), steep (25-45%), and very steep (≥ 45 %), settlement allotment is on the slope tilt of rather steep to very steep as seen in Figure 1.

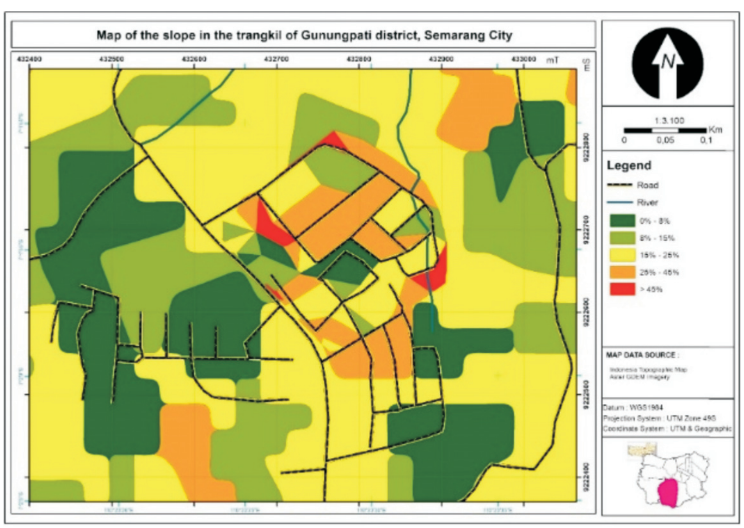

Fig. 1. Slope Distribution

Based on the observation on the field and shallow drilling, it is identified that there are three lithology units in such area clay units, breccia units, and gravel silt units. In terms of stratigraphy, clay unit is the lowest sediment in the form of blackish gray clay, compact, rather soft, and easily wrecked. Breccia unit has a dark gray color, medium to a soft sand matrix, a fragment of 5 - 30 cm, form an angle, open neat and andesite. Gravel sand silt unit has brownish-gray, consists of sand silt with gravel. Based on the drilling data, lithology is seen in the condition of rather apart, gravel is andesite and clay, carrying wood, trash, fractions, red brick, trash cans, and the thickness is decreasing to the northeast forming a pattern.

As seen in Figure 2, fractions in the land could be seen in some locations with different densities. In the eastern part of the research area, fraction density is bigger than in the middle or in the western part. In the eastern part, the fraction density is ranged between 3.6 /m - 4.5 /m. While in the middle, it is ranged between 1.9/m to 2.1/m, while in the west, there has not been found any land fraction.

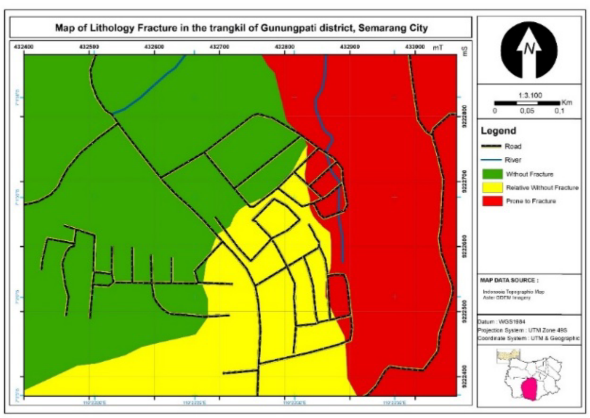

Fig. 2. Lithological Fracture Distribution

The research location consisted of 5 land uses such as plantation, bush, settlement, and rice field. Each showed the level of contribution to landslide respectively got higher as shown in Figure 3.

At the measuring location at the coordinate of 110°23’30.1" EL 07°01’55.7" SL with the elevation of 139 MSL (Figure 4), from the modeling result, the upper layer was topsoil sediment with a thickness of (7-10) m with the resistivity of (1.23-8.72) Ωm, spread at some parts which is the result of weathering of volcanic brecciat, the second layer was volcanic breccia sediment with the thickness of 1 meter

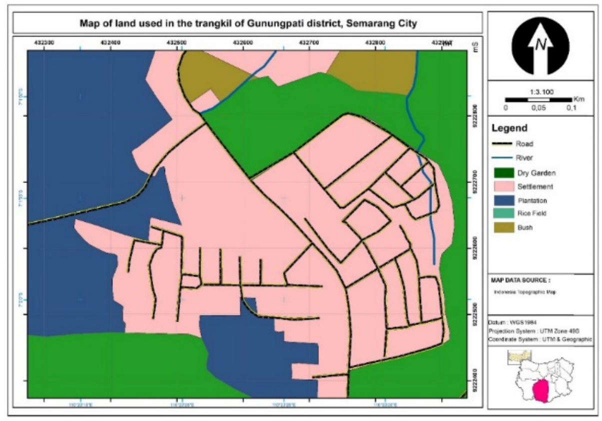

Fig. 3. Land Use Distribution

with the resistivity of (8.72 - 32.2) Ωm, the third layer was in the form of clay sediment with the thickness of 3 meters with the resistivity of (32,2-119) Ωmas shown in Figure 4.

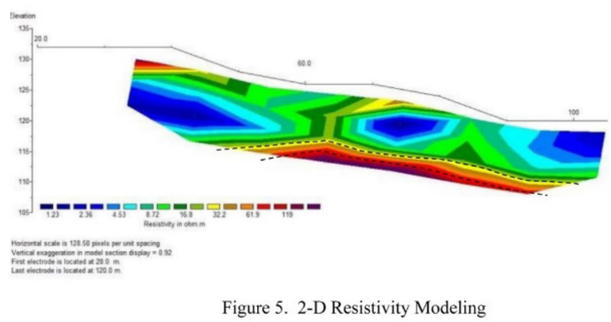

Fig. 4. 2-D Resitivity Modeling

The presence of Groundwater level in the research is about 0 - 5.6 m below the local ground surface, while the slide surface was based on the measurement result of resistivity in 7-10 m depth, so that all groundwater level was above the slip surface. Since the water would be saturated and became heavier, they would easily slide. Based on the presence of such a slip surface, all areas were considered as the area of vulnerable to landslide, due to the position of groundwater in all areas were above the slip surface.

The map of Gwl distribution of the research sitecould be seen in Figure 5 based on Table 1, the smaller the Gwl score the easier the land to slide.

GSS score is calculated based on seismic vulnerability index, and the peak ground acceleration. The map of Gwl distribution of the research site could be seen in Figure 6 based on Table 2.

The overlay parameter of the observation above

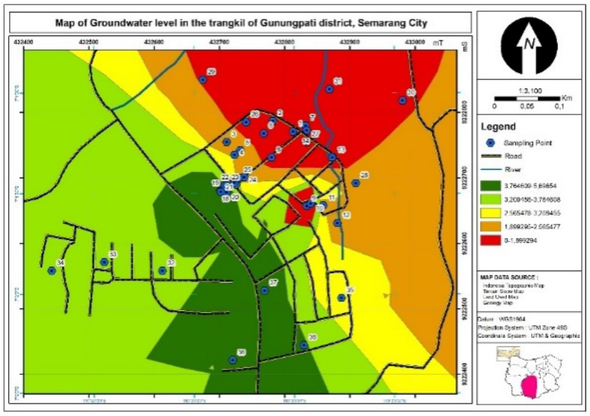

Fig. 5. Map of Gwl distribution

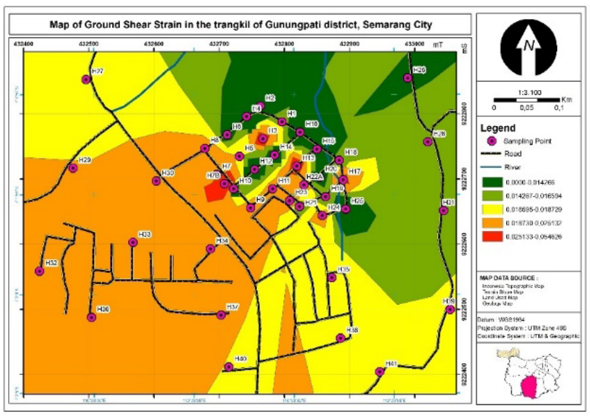

Fig. 6. Map of GSS Score Distribution

the earth surface and the parameter of under the earth's surface results in four landslide area zones, i.e. very little, little, medium, and high from the landslide danger based on the Regulation by the Minister of Energy and Mineral Resources Number: 15 in 2011 about the Guidance of Mitigation of Volcano Disaster, Ground Shifting, Earthquake, and Tsunami as shown in Figure 7.

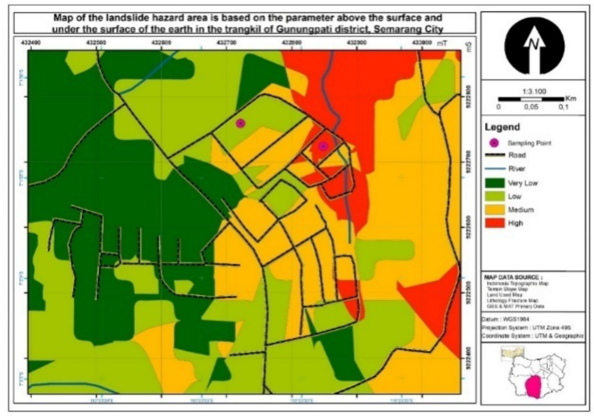

Fig. 7. The Distribution of the landslide area is based on the parameter above the surface and under the surface of the earth

Discussion

Claystone in the research site has a megascopic appearance with gray, the grain size of clay (<1/256 mm), carbonated cement since when HCL was

Table 1. Result of measurement of groundwater level in the study area

No	Easting	Northing	Gwl(m)	No	Easting	Northing	Gwl(m)
1	432813	9222771	2	20	432711	9222678	5,1
2	432782	9222787	2	21	432702	9222679	6,6
3	432711	9222755	2,15	22	432708	9222689	3,5
4	432723	9222735	2,5	23	432711	9222689	3,5
5	432732	9222742	2,9	24	432738	9222701	2,1
6	432768	9222768	1	25	432730	9222700	1
7	432832	9222780	0	26	432741	9222785	1,13
8	432780	9222731	1,5	27	432834	9222755	1,3
9	432834	9222657	5	28	432909	92226692	1
10	432840	9222661	5,5	29	432674	9222850	1,9
11	432859	9222658	1,8	30	432981	9222818	1,9
12	432881	9222631	2	31	432868	9222835	1,4
13	432873	9222731	1,5	32	432613	9222558	3,7
14	432834	9222773	1,5	33	432524	9222571	3,7
15	432726	9222690	3,7	34	432443	9222558	3,6
16	432723	9222693	1,5	35	432887	9222516	3,0
17	432714	9222687	3,5	36	432830	9222445	3,8
18	432709	9222685	4	37	432769	9222528	4,0
19	432701	9222680	5	38	432720	9222422	4,1

dropped, some froth appeared, highly weathered condition. This sediment has a distribution of 10% in the eastern part of the research. This unit was revealed under Volcanic breccia beside a seasonal river that only had water only during the rainy season. Claystone sediment is water-resistant sediment (impermeable) since it could not let water pass through which possibly could become the landslide surface. From the interpretation, fracture distribution could be described as Figure 2.

From the resistivity measurement result of Figure 4, it could be seen that the field on clay sediment with a resistivity of (32.2-119) Ωm at (7-10) m. The results obtained showed that the low resistivity contrast (ρ <20 ohm-m) was the material that was slipping and the relatively high resistivity contrast (ρ> 30 ohm-m) was alluvial and clay material which was not involved in landslides or slips surface.

The distribution of groundwater-level shows that in the northern part and some parts in the settlement were more shallow so that having such a high water table area with the shallow groundwater surface, the risk of disaster would also be high, it was strengthened by Maze's statement (2017) that the area having shallow Gwl is the one with the most building damage after the earthquake, the closer groundwater level to the slope, the smaller its safety factor score. The smaller score of the safety factor shows that the area easily slides.

Based on the calculation result of GSS score (γ) in the research site on the very risky level of having damage if the earthquake attacked for having γ score in the range of $(1,48\text{-}5,72)10^{-2}$ (Nakamura, 1997), Based on that, the distribution mapping of score γ based on the five classes like in figure 8, where GSS score is higher than and it would be easier to slide if the earthquake attacked.

The enhancement power of ground shock (amplification factor) is a response of the sediment layer, in this case, the surface layer, towards the wave (earthquake), amplification factor described how enhanced the wave when it passed through certain media. Wave enhancement when it passed through a media is directly proportional to the comparison between spectral horizontal to spectral vertical. GSS (Ground Shear Strain) or seismic index vulnerability is used in this research to determine the level of vulnerability of the ground layer towards deformation during the earthquake (Sato *et al.,* 2004)

The relationship between the Ground Shear Strain (γ) score towards the level of danger had been compiled by Ishihara (1978) Op.cit. Nakamura (1997) who stated that area which had a score of cˆ $> 10^{-2}$, occurred big deformation and collapsed.

Table 2. The results of the calculation of the GSS value in the study area

No	Location code	Easting	North	GSS	No	Location code	Easting	North	GSS
1	H1	432796	9222788	0,0164	22	H2	432763	9222812	0,005
2	H3	432767	9222762	0,0327	23	H4	432742	9222796	0,0089
3	H5	432731	9222735	0,0189	24	H6	432712	9222768	0,0127
4	H7	432696	9222707	0,015	25	H8	432678	9222747	0,0215
5	H7B	432708	9222693	0,0572	26	H10	432722	9222685	0,0049
6	H9	432748	9222656	0,0203	27	H12	432754	9222715	0,005
7	H11	432782	9222685	0,0197	28	H14	432785	9222737	0,0088
8	H13	432819	9222720	0,0355	29	H16	432824	9222772	0,0089
9	H15	432850	9222746	0,0048	30	H18	432884	9222729	0,0146
10	H17	432890	9222699	0,0279	31	H20	432854	9222703	0,0074
11	H19	432863	9222673	0,0146	32	H22A	432830	9222691	0,0205
12	H21	432823	9222658	0,0125	33	H24	432858	9222644	0,0213
13	H23	432808	9222667	0,0247	34	H26	432989	9222855	0,0141
14	H25	432894	9222654	0,0049	35	H28	433019	9222757	0,0156
15	H27	432495	9222853	0,0176	36	H30	432603	9222697	0,0207
16	H29	432475	9222717	0,0193	37	H32	432424	9222559	0,0206
17	H31	433044	9222652	0,0160	38	H34	432687	9222593	0,0205
18	H33	432568	9222603	0,0211	39	H36	432504	9222488	0,0194
19	H35	432873	9222549	0,0176	40	H38	432886	9222456	0,0180
20	H37	432703	9222491	0,0200	41	H40	432715	9222412	0,0187
21	H39	433054	9222500	0,0167	42	H41	432946	9222404	0,0180

Based on the score of the GSS area that had a score of 0.0251 - 0.0546 had a very high risk of landslide and the area was located in a settlement area and the building had been constructed (Figure 6).

The overlay parameter of the observation above the earth surface parameter consists of three parameters: geology, slope, and land use, while the parameter of under the earth's surface is the score of distribution of groundwater and the GSS score used the calculation of the weight of criteria with the ration of consistency of 0.028. This score stated that the consistency ratio of the assessment result comparing the weight was 2.8%. Therefore, the assessment above could be accepted since it was less than 10% (Saaty, 2004), Figure 7 is the result. There was a medium danger area of landslide and a high danger area of a landslide in the settlement area.

Safety factor (SF) is the comparison between the existing shift tension and the one causing the landslide. This would influence the slope stability, according to Westen (2017) if SF <= 1 showed that slope was unstable, 1 < SF <= 1.5 meant that the slope is at the point of failure (critical), SF > 1.5 showed that the slope was stable.

Based on the data of technical characteristics of sediment showed the western part had the cohesion of 0.28 kg/cm^2 with the internal friction angle of 18^o, while in the Eastern part of 0.11 kg/cm^2 with the internal friction angle of 26^o. The analysis of slope stability with the score of SF> 1.5 which means that the landslide did not occur to provide the result that slope tilt of 43%, in the western part, the safety factor score obtained was 1.772 which means that the slope was stable. While in the Eastern part with the common slope provides the safety factor of 1.372 showing that the slope close to critical, according to Westen (1997) safety factor between 1 and 1,5 slope is at the point of failure (critical). Based on such an explanation, the Eastern part of the research location was very vulnerable to a landslide.

Conclusion

The method to determine the area of landslide danger used the parameter above the surface and under the surface of the earth at the research location produced four zones of the landslide area, they were very little zone, little, medium, and high zone. The zone that had the shallow groundwater level (0-1.8999 m) and the biggest score of GSS (0.0251 - 0.0546) in the area contributed to the high zone from the landslide danger. The validation result on the high landslide zone had a safety factor of 1.37 while in the low zone of the landslide had a safety factor score of 1.77. This safety factor score shows the level of landslide danger, the smaller the score of the safety factor the easier the landslide to occur in the area.

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References

Alsubal, S., Sapari, N. and Harahap, I.S.H. 2018. The Rise of Groundwater Due to Rainfall and the Control of Landslide by Zero-Energy Groundwater Withdrawal System, *International Journal of Engineering & Technology.* 7 (2.29) : 921-926.

BPBD, 2020. Annual Disaster Data of Semarang City, Semarang City, Regional Board of Disaster Management

BPBD, 2014. Annual Disaster Data of Semarang City, Semarang City, Regional Board of Disaster Management

Devkota, K.C., Regmi, A.D., Pourghasemi, H.R., Yoshida, K., Pradhan, B., Ryu, I.C., Dhital, M.R. and Althuwaynee, O.F. 2013. Landslide susceptibility mapping using certainty factor, index of entropy and logistic regression models in GIS and their comparison at Mugling–Narayanghat road section in Nepal Himalaya. *Journal Nat Hazards.* 65 : 135–165.

Feizizadeh, B., Blaschke, T. and Rafiq, L. 2011. GIS-Based Landslide Susceptibility Mapping: A Case Study InBostan Abad County, Iran. *Procceding International Symposium on Geo-Information for Disaster Management*, https://www.researchgate.net/publication/234059759

Huang, H.C. and Tseng, Y.S. 2002. Characteristics of soil liquefaction using H/V of micro tremors in Yuan-Lin Area, Taiwan. *Journal TAO.* 13 (3) : 325-338

Jazouli, A.E., Barakat, A. and Khellouk, R. 2019. GIS-multicriteria evaluation using AHP for landslide susceptibility mapping in Oum Er Rbia high basin (Morocco). *Geoenvironmental Disasters*. https://doi.org/10.1186/s40677-019-0119-7.

Khezri, S. 2011. Landslide susceptibility in the Zab Basin, northwest of Iran. *Procedia Social and Behavioral Sciences.* 19 : 726–731

Mase, L.Z. 2017. Liquefaction Potential Analysis Along Coastal Area of Bengkulu Province due to the 2007

Mw 8.6 Bengkulu Earthquake. *Journal of Engineering and Technological Sciences*. 49 (6) : 721-736.

Minister of Energy and Mineral Resources Number: 15 in 2011 about the Guidance of Mitigation of Volcano Disaster, Ground Shifting, Earthquake, and Tsunami. Appendix II, 1-6.

Nakamura, Y. 1989. A Method for Dynamic Characteristics Estimations of Subsurface Using Micro tremors on the ground Surface. *Journal QR RTRI.* 30 : 25-33.

Nakamura, Y., Gurler, E.D., Saita, J., Rovelli, A. and Donati, S. 2000. Vulnerability Investigation of Roman Colosseum Using Microtremor. *Procceding Prepared for 12th WCEE 2000 in Auckland*, New Zealand, 1-8

Nakamura, Y. 2000. Clear identification of fundamental idea of Nakamura's technique and its applications. *Proc XII World Conf. Earthquake Engineering*, *New Zealand.* 2656 : 1-8

Nakamura, Y. 1997. Seismic Vulnerability Indices For Ground and Structures Using Microtremor. *Procceding World Congress on Railway Research*, Florence, Italy, November, 1-7

Nakamura, Y. 2008. On The H/V Spectrum. *Procceding The 14th World Conference on Earthquake Engineering*, October 12-17, Beijing, China.

Othmana, A.N., Naim, W.M. and Noraini, S. 2011. GIS Based Multi-Criteria Decision Making for Landslide Hazard Zonation. *Procceding Asia Pacific International Conference on Environment-Behaviour Studies*, Salamis Bay Conti Resort Hotel, Famagusta, North Cyprus, 7-9 December , 595-602

Saaty, T.L. 2004. Decision Making – The Analytic Hierarchy and Network Processes (AHP/ANP). *Journal of Systems Science And Systems Engineering*. 13 (1) : March. 1-35.

Sato, T., Nakamura, Y. and Saita, J. 2004. Evaluation of The Amplification Characteristics of Subsurface Using Microtremor and Strong Motion: *Procceding The Studies at Mexico City. 13th World Conference on Earthquake Engineering Vancouver*, B.C., Canada August 1-6, Paper No. 862.

Soeters, R. and Van Western, C.J. 1996. Slope instability Recognition, analysis and zonation, https://www.researchgate.net/publication/209803184/ Accessed on 27 Juni 2020, 10.35 PM

Thanden, R.E., Sumadirdja, H., Richards, P.W., Sutisna, K. and Amin, T.C. 1996. *Geological Map Of The Magelang And Semarang Sheets Jawa*. Second Edition (Bandung: Geological Research and Development Centre)

The Centre of Vulcanology and Geology Disaster Mitigation, Geological Agency, Ministry of Energy and Mineral Resources of the Republic of Indonesia., 2020.

Tjahjono, H., Suripin, S. and Kismartini, K. 2019. Spatial Analysis on Landslide Disaster Risk in the Semarang City, Central Java, Indonesia. *Disaster Advances.* 12 (7) : 49-58.

Wang, F., Xu, P., Wang, C., Wang, N. and Jiang, N. 2017. Application of a GIS Based Slope Unit Method for Landslide Susceptibility Mapping along the Longzi River, Southeastern Tibetan Plateau, China. ISPRS *International Journal of Geo-Information.* 6 : 172.

Westen, van. C.J. 1997. ILWIS 2. 1 for Windows The Integrated Land and Water Information System. Applications Guide,"Deterministic landslide hazard zonation", ILWIS Department, International Institute for Aerospace Survey & Earth Sciences Enschede, The Netherlands, https://www.itc.nl/ilwis/applications-guide/application-6/. Accessed on 10 November 2020 at 09.05 PM.