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Landslides Risk Analysis on Pacitan – Ponorogo National Road Section of East Java Province

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ABSTRACT

Landslide is a natural event that at this time the occurrence is increasing. Landslide natural disasters can occur due to land use patterns that do not follow the rules of environmental sustainability, such as deforestation and the collection of natural resources that exceed their carrying capacity. This research was obtained that the threat, vulnerability of landslides on the national road section of Pacitan - Ponorogo obtained from the results of risky analysis is a very high risk. The result of the risk of very high level of Landslide is found at km 13+900 - 14 +000, km 12+500 - 12+600, km 27+201 - 28+051, km 27+200 - km 27+300, km 33+300 - 33+500, km 12+500 - 13+500. The level of Landslide risk on the Pacitan – Ponorogo National road is very varied, some are medium risk, medium risk, high risk to very high risk. Landslide handling techniques on the National road section of Pacitan - Ponorogo to be more effective and efficient because the conditions and value of Landslide risk are different, it will be better to handle in accordance with the level of Landslide risk in each location.

Keywords*: landslides, risk analysis, road, natural disasters, environmental sustainability.*
Paper type: Research paper

INTRODUCTION

The existence of reliable transportation infrastructure will be able to support development and growth in a region. The threat of natural disasters and the stability of road bodies in landslide-prone areas is a problem that can result in damage to road bodies and even the sudden disconnection of road bodies, resulting in transportation services becoming paralyzed. [1], [2], [3] The problem of soil erosion has been widely studied by previous researchers with various approaches such as using mapping, GIS, radar, spatial and so on. [4], [5], [6]

With regard to this as an effort to identify areas prone to land slides will be given parameters to assess the level of risk of landslides on the Pacitan - Ponorogo road section of East Java Province. With the mapping and assessment of the Landslide is expected to avoid the sudden paralysis of transportation services, which is the time for emergency or temporary handling to be replaced with permanent handling / prevention. [7], [8], [9] The purpose of this study was to identify the level of land slide risk for road construction that occurred on the Pacitan Ponorogo road section.

LIBRARY OVERVIEW

Based on Regulation, landslide is a process of moving the mass of soil / rock in an oblique direction from its original position, so that it is separated from the steady mass due to the influence of gravity with the type of movement in the form of rotation and translation. [10], [11] Landslides are natural disasters that can actually be foreseen. The greatest influence of nature that causes such landslides is rainfall. With rainfall that exceeds the limits and geological order that is vulnerable to landslides, then this landslide disaster will be easy to occur. [12], [13], [14],

Land slides are natural phenomena in the form of soil mass movements in search of a new balance due to external disturbances that cause a decrease in soil shear strength and an increase in soil stress. In general, landslides are caused by a decrease in the shear strength parameter of the soil and an increase in soil stress. [15] The decrease in the shear strength parameters of the soil was caused by the increase in soil water content and the decrease in the bond between soil grains. The retaining force in supporting slope stability is determined by the shear strength. The shear strength of the soil is the internal strength of the soil in resisting shear along the failure plane. The failure of the soil material is caused by a critical combination of the normal stress and the shear stress. [4], [14], [7]

Landslide is a sudden displacement of a large amount of land which usually occurs during the rainy season. [16] So what is meant by landslide disaster is the sudden displacement of a large plot of land which can be caused by natural or

non-natural factors and causes casualties, environmental damage, property losses, psychological impacts. Landslide is the displacement of slope-forming material in the form of rock, debris, soil, or a mixture of these materials, moving down or out of the slope. [17], [18], [19] The process of landslides can be explained as follows: water that seeps into the soil will increase the weight of the soil. If the water penetrates to the impermeable soil which acts as a slip plane, then the soil becomes slippery and the weathered soil above it will move along the slope and out of the slope. [20], [21] According to the regulation, states that landslides can also be referred to as ground movements. Defined as a mass of soil or a mixture of clay, gravel, sand, and gravel as well as boulder and silt, which moves along the slope or off the slope due to the earth's gravity. [10], [11]

RESEARCH METHODS

The location of this activity is in the western part of East Java National Road, namely on the Pacitan and Ponorogo roads. National Road is a road that is under the supervision or authority of the National Road Implementation Center VIII. The condition of the National Road section of Pacitan and Ponorogo is a road with hill terrain.

What is meant by the data source in this study is the subject from which the data can be obtained. Based on the source, the data is divided into two, namely primary data and secondary data. Basically, data collection depends on the availability of data, both secondary and primary data. Secondary data is data that is already available from the results of data collection conducted by others that are usually obtained in the form of tables, graphs or in the form of statistical data. Secondary data is basically obtained from related agencies.

The application of this weighting rank method is used to determine the selection of alternative road handling to the location obtained from determining the level of risk to landslide insecurity after obtaining information as shown in Figure 10 after roads and bridges or other infrastructure buildings are overlayer so that it can be known whether it is at: low level of insecurity, moderate insecurity or high insecurity.

Due to the presence of slopes that are already known to be in the zone of vulnerability or high Landslide insecurity. then there are 5 classes of studies that need to be reviewed starting from the review of the type of Landslide, calcifying the Landslide, the impact caused, the potential for handling and advice on countermeasures. The assessment of this study may one day be modified in accordance with the review that needs to be reviewed further. The assessment of the 5 classes of this study was conducted in consecutive stages (from 1 to 5) and of course based on the dominant factors that will be assessed on the impact directly due to the Landslide. In connection with the impact directly caused by the Landslide on road and bridge infrastructure buildings, of course, the ease of access is reviewed based on the dominant parameters affecting. Classification of landslide type and risk level as shown in Table 1. [11]

TABLE 1. CLASSIFICATION OF LANDSLIDE TYPE AND RISK LEVEL

No	The level of danger of road users both soil and rock to the presence of infrastructure	Weight score	Risk level
1	Hazard classification 1, In the event of an Landslide the traffic cannot pass	5	Very high
2	Hazard classification 2, In case of landslide is limited to only pedestrians who can pass	4	high
3	Hazard classification 3, In case of landslide of small vehicles, up to IIIc class that can pass through	3	Medium
4	Hazard classification 4, In case of moderate vehicle and bus landslides, up to class IIIb and possibly class IIIa that can pass through	2	Light
5	Hazard classification 5, In case of landslide vehicles up to medium trucks s / d class II that can pass	1	Tolerance settings
6	Safe classification, all types of vehicles up to class I	0	Safe

Source: Pt M-01-2002-B [11]

The assessment applied is to the impact of the Landslide on road damage and is shown in Table 2 against one of several assessments of the parameters that affect. For example, the ground vulnerability parameter is used from several other parameters that could be affected.

TABLE 2. TABLE OF IMPACTS ON ROAD DAMAGE RESULTING FROM THE ASSESSMENT OF ANY OF THE PARAMETERS AFFECTING

No	Hazard Level of Road Users	Weight score	Risk level
1	The entire body of the landslide road (wide influence)	5	Very high
2	There is an influence, disrupting the flow of traffic	4	high

3	Slightly disrupting the smooth flow of traffic	3	Medium
4	Partial road closure (can be removed)	2	Light
5	Slightly disrupts drainage smoothness	1	Tolerance settings
6	There's not enough meaningful influence	0	Safe

Source: Pt M-01-2002-B [11]

Parameter sorting is based on technical studies that are believed to be the dominant parameters in influencing the level of resistance to landslides by providing weighting based on scores for each in an area. For the determination of the area to the level of landslide prone is generally used the most dominant against Landslides and for example used 8 parameters, namely: rainfall, slope, land use, soil permeability, soil texture, depth of solum (ability to permeate water) and the geology of structures and types of soil / rocks that dominate the slope area. Score system of each parameter of land type and weighting parameter as shown in Table 3 dan Table 4.

TABLE 3. SCORE SYSTEM OF EACH PARAMETER

No		Parameters	Score	No		Parameters	Score
I		Rainfall		II		Slope (Degrees)	
	a.	>2500 mm	5		a.	>45	5
	b.	2000 - 2500 mm	4		b.	25 - 45	4
	c.	1500 - 2000 mm	3		c.	15 - 25	3
	d.	1000-1500 mm	2		d.	8 - 15	2
	e.	<1000 mm	1		e.	0 - 8	1
III		Soil permeability		IV		Soil texture	
	a.	Well	5		a.	Clay	5
	b.	Moderate, Poor	3		b.	Slit	3
	c.	Excessive - tidak	1		c.	Sandy	1
V		Land cover		VII		Geological structure (%)	
	a.	Rice fields	5		a.	> 90	5
	b.	Settlements	4		b.	70 - 90	4
	c.	Forests, plantations	3		c.	50 - 70	3
	d.	Shrubs, open land	2		d.	30 - 50	2
	e.	Pastures	1		e.	10 - 30	1
	f.	Waters	0		f.	<10	0
VII		Solum Depth (cm)		VIII		Soil/rock type	
	a.	>90	4		a.	Rock	4
	b.	60 - 90	3		b.	rocks and soil	3
	c.	25 - 60	2		c.	soil and rocks	2
	d.	<25	1		d.	Land	1

Source: Pt M-01-2002-B [11]

TABLE 4. WEIGHTING OF EACH PARAMETER

No	Parameters	Weights
I	Rainfall (mm)	3
II	Slope (Degrees)	2
III	Soil permeability	2
IV	Tekstur tanah	1
V	Land cover	1
VI	Geological Structure (%)	1
VII	Solum depth (cm)	1
VIII	Soil/rock type	1

Source: Pt M-01-2002-B [11]

Observation of landslide locations is carried out at several locations, which have occurred landslide disaster or not. Observations are made including observation of physical character and character of human activity at that

point. The observation location was conducted on the Pacitan – Ponorogo road. Analysis is done by making visual observations.

Initial Investigation

Initial investment is carried out to determine the condition of the landslide. This stage is necessary to determine the test, the test that must be done in order to be able to conduct further studies. In addition, a field review was conducted to formulate initial hypotheses on the causes of loosening.

Analysis of soil hazard insecurity

Quantification of landslide hazard insecurity analysis is done by assessing each parameter of the risk level of Landslide. The results of the assessment obtained from each assessment will be multiplied by the score that has been determined in the analysis book of the Landslide in module 3. From the result of multiplication of a tail with weight on each component assessed, it will be obtained a number that will be used as a parameter to determine the level of risk of such loosening. To do the calculation there is already a formula that will be used to assess the level of risk of shortness. The formula for the level of Landslide risk is already in module 2 on surveying slopes and Landslides and managing slopes. The Landslide risk assessment formula is displayed in the following formula (4).

$$LRLV = \sum(S1.B1 + S2.B2 + S3.B3 + S4.B4 + S5.B5 + S6.B6 + S7.B7 + S8.B8 + S9.B9 + S10.B10) \quad \text{.....(4)}$$

Where:
LRSV = Landslide Risk Level Value.
S1 = Score on hazard level assessment of road users both soil and rocks against the presence of infrastructure (Traffic)
B1 = Weight on hazard level assessment of road users both soil and rock to the presence of infrastructure (Traffic)
S2 = Score on Hazard Level of road user (Road Agency)
B2 = Weight at Hazard Level of road users (Road Agency)
S3 = Score on Rainfall assessment (mm)
B3 = Weight on Rainfall assessment (mm)
S4 = Score on Slope Slope assessment (Derajad)
B4 = Weight on Slope assessment (%)
S5 = Score on Soil Permeability assessment
B5 = Weight on Soil Permeability assessment
S6 = Score on Soil Vulnerability Texture assessment
B6 = Weight on Soil Vulnerability Texture assessment
S7 = Score on Land Cover Condition assessment
B7 = Weight on land cover condition assessment
S8 = Score on Geological Structure assessment
B8 = Weight on geological structure assessment
S9 = Score on Solum Depth assessment (surface water absorption, cm)
B9 = Weight on Solum Depth assessment (surface water absorption, cm)
S10 = Score on soil/rock type assessment
B10 = Weight on soil/rock type assessment.

The result of the summation of scores and weights on each of the assessment parameters will get a number that can be read with the assessment scale. Limitation of the assessment of the level of risk of Landslide of the value obtained will be the determinant. The distribution of the limit value of the landslide risk level is as follows:

a. value of more than 40 is the value of the level of shortness in very high risk.
b. value of more than 30 – 40 is the value of the level of shortness in high risk.
c. value of more than 20 – 30 is the value of the level of shortness in the medium risk.
d. value of more than 10 – 20 is the value of the level of shortness in low risk.
e. value of less than 10 is the value of the level of shortness in a very low risk.

With these parameters, the result of multiplication of the score multiplied by the weight on each component of the assessment of the Landslide will be obtained the result of the level of risk of Landslide.

This research flow chart will explain about the process in conducting research. In the flow chart can be seen clearly the start of research and step by step until the research can be completed. Flow chart of this research can be seen as shown in Figure 1.

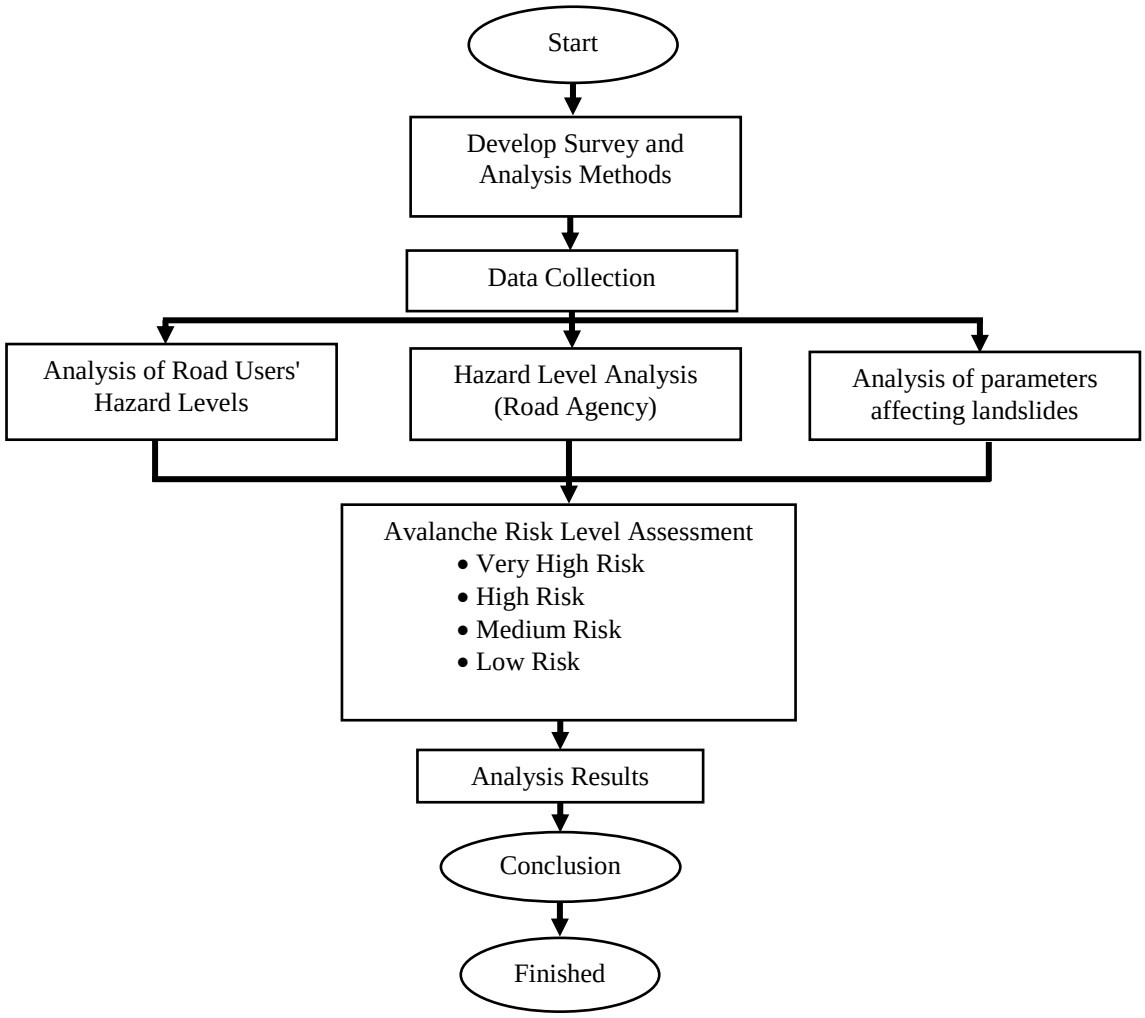

Fig. 1. Research flow chart

RESULTS OF ANALYSIS AND DISCUSSION

The results of the survey of Landslide conditions will be visually obtained the level of assessment of Landslide conditions. The level of assessment of Landslide conditions obtained from visual observation surveys will determine the level of Landslide risk. The assessment results for Landslide risk are as follows:

From the survey results on the location of Glonggong National Road - Bts. Pacitan City km 282+300 - 282+400 as shown above, it can be assessed for:

1) The level of danger for road users, both soil and rock, to the existence of infrastructure (traffic) is that it is a hazard for large vehicles
2) Danger level of road users (Road Agency)
3) Assessment of Rainfall
4) Assessment of Slope
5) Assessment of Soil Permeability
6) Assessment of Soil Vulnerability Texture
7) Assessment of Land Cover Conditions
8) Assessment of Geological Structure
9) Assessment of Solum Depth
10) Assessment of soil/rock type

Calculation of the level of risk of Landslide is done by multiplying the results of the assessment of conditions in the field with weights on each component of the assessment. The weight of each assessment component is certainly different according to the soil type in module 2 of the slope survey and Landslide and slope management. The weights of each assessment component are as follows: Hazard Level of road users both soil and rock to the existence of infrastructure (Traffic) assessment weight 1, Hazard Level of road users (Road Body) assessment weight 1, Rainfall Parameter (mm) assessment weight 3, Slope Parameter (%) assessment weight 2 Soil permeability parameter assessment weight 2 Soil texture parameter assessment weight 1, Land cover parameter assessment weight 1, Geological Structure Parameter (%) Valuation weight 1, Solum depth parameter (cm) assessment weight 1, Soil type parameter/rock rating weight 1. The formula for determining the assessment is as follows:

From the calculation of the level of risk of Landslide, a weight score will be obtained from each location of the Landslide. By obtaining the Landslide risk level, it will be known the category of Landslide risk in each landslide site on the Pacitan – Ponorogo National road. The result of calculating the level of risk of Landslide at the Landslide site of Glonggong National Road - Bts. Pacitan city km 282+300 - 282+400 obtained a value of 34 Landslide risk levels. According to table 18 in Module 2 of the Slope and Landslide Survey and Slope Management falls into the category of high risk levels. The data of the category of Landslide risk level on the Glonggong National Road - Bts. Pacitan City.

Analysis the level of risk of Landslide on the Glonggong National road - Bts. Pacitan city can be known the number of each scale of assessment of the level of risk of Landslide. The level of risk from the analysis on the national road section of Pacitan - Ponorogo from 25 points can be sorted according to the category of risk level of Landslide. The results of the category of security risk level will be conducted by analysts and made diagram as shown in Table 5.

TABLE 5. TOTAL LANDSLIDE RISK LEVEL

Risk Level	Amount	Unit
Very high risk level	6	Location
High risk level	5	Location
Medium risk level	13	Location
Low risk level	1	Location
Amount	25	Location

Source: Analysis Results

From the picture above can be known for each level of risk of Landslide. The level of risk of Landslide from 25 points of location on the National road section of Pacitan - Ponorogo can be known for low risk as much as 1 location point or 4%, while the medium risk as much as 13 locations or 52 %, high risk as much as 5 locations or 20% while the risk is very high as much as 6 locations or 24%. The result of processing the level of Landslide risk on the National road section can be concluded that the level of Landslide risk is dominated by the medium Landslide risk level of 52%. The results of this study almost have similarities with previous studies that have been carried out by several researchers, both regarding the assessment method and the approach method used. [22], [23], [24]

CONCLUSION

1) The threat of landslides on the National road section of Pacitan - Ponorogo from the results of risky analysis is a very high risk. The result of the risk of very high level of Landslide is found at km 13+900 - 14 +000, km 12+500 - 12+600, km 27+201 - 28+051, km 27+200 - km 27+300, km 33+300 - 33+500, km 12+500 - 13+500
2) The level of Landslide risk on the national road section of Pacitan - Ponorogo is very varied, some are medium risk, medium risk, high risk to very high risk.

REFERENCES

[1] I. Rahim, S. M. Ali, and M. Aslam, "GIS Based Landslide Susceptibility Mapping with Application of Analytical Hierarchy Process in District Ghizer, Gilgit Baltistan Pakistan," *J. Geosci. Environ. Prot.*, vol. 06, no. 02, 2018, doi: 10.4236/gep.2018.62003.

[2] C. W. Tseng *et al.*, "Application of high-resolution radar rain data to the predictive analysis of landslide susceptibility under climate change in the Laonong Watershed, Taiwan," *Remote Sens.*, vol. 12, no. 23, 2020, doi: 10.3390/rs12233855.

[3] U. Sur, P. Singh, P. K. Rai, and J. K. Thakur, "Landslide probability mapping by considering fuzzy numerical risk factor (FNRF) and landscape change for road corridor of Uttarakhand, India," *Environ. Dev. Sustain.*, 2021, doi: 10.1007/s10668-021-01226-1.

[4] F. Kadi, F. Yildirim, and E. Saralioglu, "Risk analysis of forest roads using landslide susceptibility maps and generation of the optimum forest road route: a case study in Macka, Turkey," *Geocarto Int.*, 2019, doi:

10.1080/10106049.2019.1659424.
[5] Y. Jiao *et al.*, "Performance evaluation for four GIS-based models purposed to predict and map landslide susceptibility: A case study at a World Heritage site in Southwest China," *Catena*, vol. 183, 2019, doi: 10.1016/j.catena.2019.104221.
[6] L. Gigović, S. Drobnjak, and D. Pamučar, "The application of the hybrid GIS spatial multi-criteria decision analysis best–worst methodology for landslide susceptibility mapping," *ISPRS Int. J. Geo-Information*, vol. 8, no. 2, 2019, doi: 10.3390/ijgi8020079.
[7] C. Y. Lin, C. Y. Lin, and C. Chompuchan, "Risk-based models for potential large-scale landslide monitoring and management in Taiwan," *Geomatics, Nat. Hazards Risk*, vol. 8, no. 2, 2017, doi: 10.1080/19475705.2017.1345797.
[8] S. Sarkar, K. Pandit, N. Dahiya, and P. Chandna, "Quantified landslide hazard assessment based on finite element slope stability analysis for Uttarkashi–Gangnani Highway in Indian Himalayas," *Nat. Hazards*, vol. 106, no. 3, 2021, doi: 10.1007/s11069-021-04518-x.
[9] O. F. Althuwaynee and B. Pradhan, "Semi-quantitative landslide risk assessment using GIS-based exposure analysis in Kuala Lumpur City," *Geomatics, Nat. Hazards Risk*, vol. 8, no. 2, 2017, doi: 10.1080/19475705.2016.1255670.
[10] AASHTO, *Manual on Subsurface Investigations, American Association of State Highway and Transportation Officials, Washington, DC, USA.* 1998.
[11] Pt M-01-2002-B, *Panduan geoteknik 3, timbunan jalan pada tanah lunak : Penyelidikan tanah lunak, pengujian laboratorium.* 2002.
[12] E. Wahyudianto, "Analysis and Risk Study on Landslide Hazard Frequency at Road Corridor of Batu City – Kediri Regency Border," *J. Civ. Eng. Forum*, vol. 4, no. 3, 2018, doi: 10.22146/jcef.37446.
[13] L. Hao *et al.*, "Constructing a complete landslide inventory dataset for the 2018 monsoon disaster in Kerala, India, for land use change analysis," *Earth Syst. Sci. Data*, vol. 12, no. 4, 2020, doi: 10.5194/essd-12-2899-2020.
[14] R. Mind'je *et al.*, "Landslide susceptibility and influencing factors analysis in Rwanda," *Environ. Dev. Sustain.*, vol. 22, no. 8, 2020, doi: 10.1007/s10668-019-00557-4.
[15] A. T. Sudjianto, *Mekanika Tanah I (Konsep Dasar dan Pengukuran Laboratorium)*. 2020.
[16] K. Martinović, K. Gavin, C. Reale, and C. Mangan, "Rainfall thresholds as a landslide indicator for engineered slopes on the Irish Rail network," *Geomorphology*, vol. 306, 2018, doi: 10.1016/j.geomorph.2018.01.006.
[17] M. Mukhlis, Y. Yunus, and S. M. Saleh, "Analisis Perkerasan Lentur di Atas Tanah Ekspansif," *J. Arsip Rekayasa Sipil dan Perenc.*, vol. 2, no. 1, 2019, doi: 10.24815/jarsp.v2i1.13203.
[18] M. Yusri, A. Suraji, and A. Halim, "Analisis Kerusakan Jalan Menggunakan Metode Pavement Condition Index (PCI) Dan Surface Distress Indek (SDI)," *Teknik*, no. Ciastech, 2019.
[19] A. Suraji, A. T. Sudjianto, and R. Riman, "Analysis of Road Surface Defects Using Road Condition Index Method on the Caruban-Ngawi Road Segment," *J. Sci. Appl. Eng.*, vol. 1, no. 2, 2018, doi: 10.31328/jsae.v1i2.887.
[20] M. Juliev, M. Mergili, I. Mondal, B. Nurtaev, A. Pulatov, and J. Hübl, "Comparative analysis of statistical methods for landslide susceptibility mapping in the Bostanlik District, Uzbekistan," *Sci. Total Environ.*, vol. 653, 2019, doi: 10.1016/j.scitotenv.2018.10.431.
[21] P. Ou *et al.*, "Assessment of Landslide Hazard in Jiangxi Using Geo-information Technology," *Front. Earth Sci.*, vol. 9, 2021, doi: 10.3389/feart.2021.648342.
[22] D. Kubwimana *et al.*, "Characteristics and Distribution of Landslides in the Populated Hillslopes of Bujumbura, Burundi," *Geosciences*, vol. 11, no. 6, 2021, doi: 10.3390/geosciences11060259.
[23] Y. Cao, X. Wei, W. Fan, Y. Nan, W. Xiong, and S. Zhang, "Landslide susceptibility assessment using the Weight of Evidence method: A case study in Xunyang area, China," *PLoS One*, vol. 16, no. 1 January, 2021, doi: 10.1371/journal.pone.0245668.
[24] C. Ambrosi, T. Strozzi, C. Scapozza, and U. Wegmüller, "Landslide hazard assessment in the Himalayas (Nepal and Bhutan) based on Earth-Observation data," *Eng. Geol.*, vol. 237, 2018, doi: 10.1016/j.enggeo.2018.02.020.