Accuracy Assessment Of GIS-Based Map For land-slide Susceptibility For A Railway Track

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Abstract. Geographic Information System (GIS) based maps of landslide susceptibility can be used to identify the landscape potency for an area or segment of a railway line. The accuracy of landslide susceptibility maps needs validation to ensure the information provided by the GIS map is reliable. This study aims to validate GIS-based maps of landslide susceptibility of the railway line from Station Prupuk to Station Purwokerto. The validation uses historical data and field documentation of landslide events along the railway line. The accuracy of the landslide susceptibility map in the study area with historical data is 93.75%. The result means the model formulated from DVMBG 2004 can map the landslide vulnerability in the railway line area. Field identification of landslide events location shows that the measurements needed to reinforce the critical area have been made to reduce potential landslide risk, including rail piles, bamboo piles, stone retaining walls, gabion, soil bags, and drainage normalization.

Keywords: accuracy assessment, landslide susceptibility, GIS map, railway track

1 INTRODUCTION

Geographic Information System (GIS) can be used to prepare and analyze detailed maps to identify and monitor the landslide vulnerability of an area, road, and railway. Various studies have developed the identification of the landslide-vulnerable regions using GIS. Landslide vulnerability zones for large areas mapping has been carried out which produces a percentage of sites and criteria of landslide susceptibility [1][2][3][4][5][6][7][8]. A landslide susceptibility map can also be implemented for a railway line [9] [10].

The accuracy of landslide Geographic Information System (GIS) maps needs an assessment to ensure the information provided by the GIS map is reliable. The reliable map can provide consideration to the users for mitigation strategies about the potential risks and vulnerabilities in a particular area. Accurate maps enable effective risk management and mitigation strategies, helping authorities, planners, and communities to take appropriate measures to reduce the impact of landslides, such as implementing structural reinforcements, land-use regulations, or evacuation plans. Accurate GIS maps can inform the planning and development of infrastructure, such as roads, railway tracks, buildings, and other critical facilities.

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Assessment of the accuracy of a landslide vulnerability based on a GIS map can employ various methods, such as field validation [11], comparison with historical data [12] [13], remote sensing techniques [14], and ground truth [15]. These techniques help evaluate the precision and reliability of the GIS data, thus ensuring that the maps accurately reflect the actual conditions of the terrain.

Landslides occurred on many segments of the railway line between the Purwokerto and Prupuk [16]. It means the railway track section between Purwokerto Station and Prupuk Station was vulnerable to landslides, especially in during heavy rainfall. Landslide vulnerability maps using GIS application have provided details of railway track section vulnerability divided into a very high, high, medium, low, and very low category using the DVMBG 2004 landslide prediction model as shown in Figure 1 [10]. The model parameters and percentage to the prediction of landslide vulnerability were rainfall (30%), Slope inclination (15%), Lithology (20%), Soil Types (20%), and Land use (15%) [13].

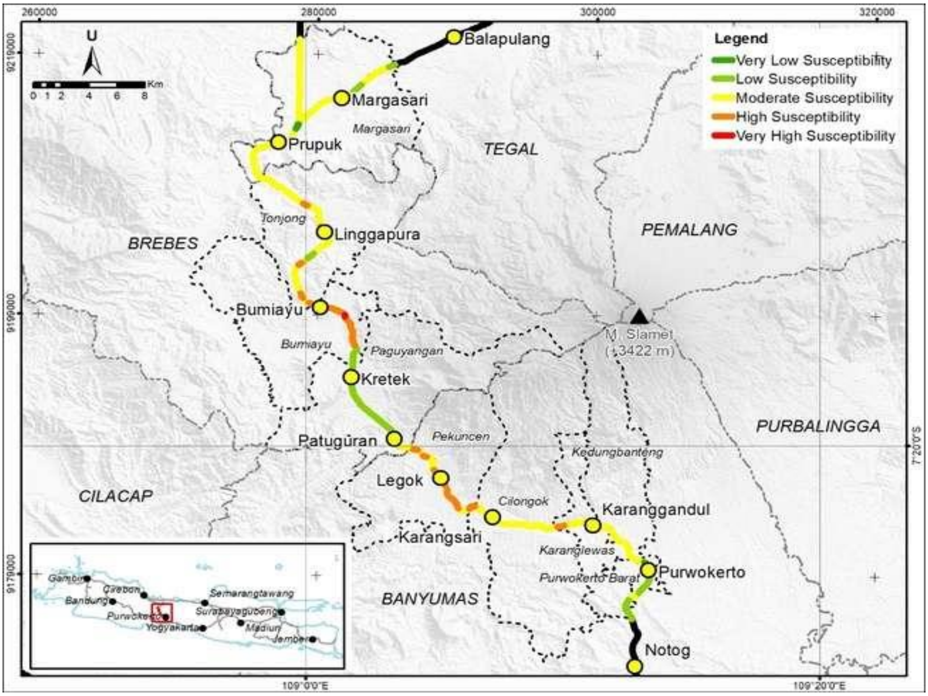

Fig. 1. Landslide Susceptibility of Railway Line

Landslide history data along the study location can be used to validate the accuracy of the model. This study tried to compare the GIS-based landslide vulnerability map with the historical data of the landslide occurrence along the Railway line between Station Prupuk and Station Purwokerto and to investigate the detailed location of landslide occurrence and its vulnerability. This study also identifies the mitigation for landslide-vulnerable areas.

2 METHOD

A map of the landslide vulnerability was produced using GIS software, which shows the vulnerability rate for the study area consisting of very high, high, medium, low, and very low. The maps generated the detailed segmented location of the railway line and its vulnerability to get the Station Kilometres (0+000) along the railway and the length of each segment with the characteristics of landslide susceptibility.

The validation of the model used historical data from the last ten years along the railway line between Station Prupuk and Station Purwokerto. The inventory data included kilometers of landslide occurrence, time, documentation, and reinforcement for the location. A Map of Historical data validation was produced by plotting the occurrence of data along the railway line. A binary value of 1 is given for compatible data where the landslide occurred on medium, high, and very high susceptibility to getting the compatibility of the landslide vulnerability map, and a value of 0 is given for non-compatible data where the landslide occurred in low and very low landslide susceptibility. The map accuracy was obtained by dividing the total compatibility number by the entire occurrence of the landslide [12].

For the anticipation of the next event for a landslide, the reinforcement status for the landslide occurrences is used to determine the level of landslide anticipation for the railway line from the documentation of field survey in the location of landslide occurrence.

3 RESULTS

3.1 Detail Location of Landslide Vulnerability

Landslide vulnerability maps provided in Figure 1 consist of The location of the landslide susceptibility indicated by a different color, which varies along the railway. The location is detailed using GIS software to get the kilometer and the length from the vulnerability classification shown in Table 1.

Table 1. Detailed Location of Landslide Vulnerability

Station	Kilometers (KM)	Landslide Susceptibility	Distance (m)
Prupuk	293+937	Very Low	315
	294+252	Medium	3.931
District Boundaries	298+183	Medium	3.477
	301+660	High	313
	301+973	Medium	2.136

Station	Kilometers (KM)	Landslide Susceptibility	Distance (m)
	304+109	High	600
Linggapura	304+709	High	102
	304+811	Medium	2.093
	306+904	Low	522
	307+426	Medium	572
	307+998	High	258
	308+256	Medium	2.374
	310+630	High	350
	310+980	Medium	628
	311+608	High	952
Bumiayu	312+560	Medium	617
	313+177	High	94
	313+271	Medium	205
	313+476	High	501
	313+977	Medium	214
	314+191	High	202
	314+393	Very High	117
	314+510	High	965
	315+475	Medium	204
	315+679	High	1.246
	316+925	Medium	177

Station	Kilometers (KM)	Landslide Susceptibility	Distance (m)
	317+102		
		Low	2.456
Kretek	319+558		
		Low	5.916
Patuguran	325+474		
		Low	406
	325+880		
		Medium	1.049
District Boundaries	326+929		
		Medium	250
	327+179		
		High	350
	327+529		
		Medium	583
	328+112		
		High	284
	328+396		
		Medium	1.306
	329+702		
		High	550
	330+252		
		Medium	265
Legok	330+517		
		High	676
	331+156		
		Medium	383
	331+539		
		High	1.655
	333+194		
		Medium	897
	334+091		
		High	516
	334+607		
		Medium	1.556
Karangsari	336+163		
		Medium	5.012
	341+175		
		High	467
	341+642		
		Medium	1.864
	343+506		
		High	147

Station	Kilometers (KM)	Landslide Susceptibility	Distance (m)
	343+653		
		Medium	275
Karanggandul	343+928		
		Medium	5.334
	349+262		
		Very Low	299
	349+561		
		Low	394
Purwokerto	349+955		
Total			56.055

Table 1 shows the kilometers and distance of the railway, located on very low, low, medium, high, and very high landslide susceptibility. The location and length of each railway segment vary between each susceptibility criteria. The table can mark the railway track location and check the field condition to reduce future landslide occurrence, especially for high and very high landslide vulnerability.

3.2 Landslide Historical Data

For the validation objective, the occurrence of landslides along the railway track was collected for the last ten years. The data was obtained from Regional Railway Operator DAOP 5 PT. KAI includes kilometers of landslide occurrence, time, documentation, and reinforcement for the location. The landslide occurrence historical data is shown in Table 2.

Table 2. Landslide Occurrence Historical Data

No	Kilometers (KM)	Railway Line	Time of Occurrence
1	301+900/000	Upstream	November 2016
2	304+500/600	Downstream	November 2021
3	304+700/800	Upstream	November 2021
4	305+500/600	Downstream	January 2021
5	305+900/306+000	Downstream	February 2021
6	315+100/200	Downstream	March 2021
7	322+700/800	Downstream	January 2017
8	326+900/000	Upstream	Juni 2017
9	327+600/700	Upstream	September 2018
10	332+3/4	Upstream	August 2022
11	333+3/4	Downstream	October 2021

No	Kilometers (KM)	Railway Line	Time of Occurrence
12	336+6/7	Downstream	November 2021
13	338+1/2	Upstream	October 2021
14	339+600/800	Upstream	November 2014
15	339+600/800	Downstream	November 2020
16	339+600/800	Downstream	March 2022

Table 2 shows the location of landslide for the last ten years along the Prupuk and Purwokerto Station. The upstream location means the train travels away from the KM 0 (left of the railway), and the downstream means the train travels approach the KM 0 (right side of the line). The kilometer location of the landslide occurrence was compared with the landslide susceptibility mapping from Table 1, resulting in Table 3. The location is also plotted on the GIS map to get the visual location of the occurrence, as in Figure 2.

Fig. 2. Historical Landslide Data Validation Maps

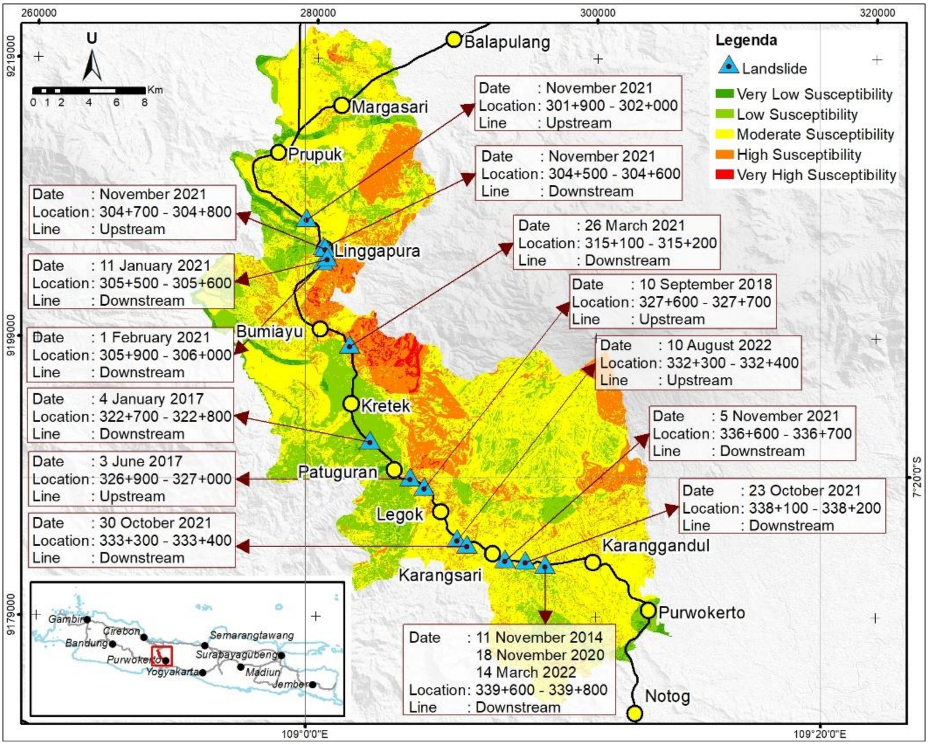

Table 3. Landslide Historical Data Validation

No	Kilometre (KM)	Categories of Landslide Vulnerability	Compatibility	Value
1	301+900/000	High	Yes	1
2	304+500/600	High	Yes	1
3	304+700/800	High	Yes	1
4	305+500/600	Medium	Yes	1
5	305+900/306+000	Medium	Yes	1
6	315+100/200	High	Yes	1
7	322+700/800	Low	No	0
8	326+900/000	Medium	Yes	1
9	327+600/700	Medium	Yes	1
10	332+3/4	High	Yes	1
11	333+3/4	High	Yes	1
12	336+6/7	Medium	Yes	1
13	338+1/2	Medium	Yes	1
14	339+600/800	Medium	Yes	1
15	339+600/800	Medium	Yes	1
16	339+600/800	Medium	Yes	1
	Total			15

Table 3 and Figure 2 show that six landslides occurred in a highly vulnerable area (40%), eight landslides occurred in a medium vulnerable area (53%), and one landslide happened in a low susceptibility area (7%). The accuracy level of the landslide vulnerability maps was obtained by calculating the total points that are compatible divided by the total landslide event. The accuracy of the landslide vulnerability map in the study area with historical data was 93.75%. It means the model formulated from DVMBG 2004 and data from online resources were capable of mapping the landslide vulnerability in the railway line area.

As a comparison, a study using the DVMBG 2004 model resulted in 82.54% and 64.59% for data from 2014 and 2018, respectively [12]. Another study resulted in 68% accuracy for the model compared to the Minister of Public Works Regulation Model [17] and the Puslittanak 2014 Model [13]. The result of this study is similar to other GIS map validation, which resulted in a 75% compatibility level with actual landslide conditions.

3.3 Reinforcement for Landslide Occurrence

Anticipation of landslides for the vulnerable segment of the railway is needed to reduce the potency and impact, which will disrupt railway operations. The reinforcement status for the landslide occurrences can be obtained by field survey and documentation. The results of field identification are shown in Table 3 and Figure 3.

Table 4. Mitigation of Potential Landslide Based on Historical Events

No	Kilometre (KM)	Reinforcement
1	301+900/000	Stone retaining wall and drainage normalization
2	304+500/600	Rail piles, stone retaining walls, and drainage normalization
3	304+700/800	Rail piles, stone retaining walls, and drainage normalization
4	305+900/306+000	Bamboo piles and drainage normalization
5	315+100/200	Bamboo piles, stone retaining walls, and drainage normalization
6	322+700/800	Rail piles and drainage normalization
7	326+900/000	Bamboo piles, stone retaining walls, soil bags, and drainage normalization
8	327+600/700	Bamboo piles, soil bags, and drainage normalization
9	336+6/7	Rail piles and gabion reinforcement
10	332+3/4	Rail piles, stone retaining walls
11	333+3/4	Bamboo piles and soil bags
12	338+1/2	Bamboo piles and soil bags
13	339+600/800	Rail piles, stone retaining walls, and drainage normalization
14	339+600/800	Rail piles, stone retaining walls, and drainage normalization
15	339+600/800	Rail piles, stone retaining walls, and drainage normalization

Fig. 3. Documentation of Reinforcement for Landslide Events

Table 4 and Figure 3 show that the Regional Railway Operators (DAOP) have mitigated possible future landslide probability on the location of landslide occurrence. The reinforcement includes rail piles, bamboo piles, stone retaining walls, gabion, soil bags, and drainage normalization. The mitigation can be continued to all medium, high, and very high landslide susceptibility categories along the railway line. The drainage normalization was also key for landslide mitigation along the railway line. The field data shows that a landslide occurred due to an overflow of water on the KM 322+700/800 drainage system, which is classified as low landslide susceptibility according to the maps.

To enhance the landslide susceptibility maps with spatial analysis by integration of remote sensing data to enhance the precision of the spatial analysis, providing a more comprehensive and accurate representation of the landscape by utilizing advanced remote sensing technologies, such as LiDAR (Light Detection and Ranging) and satellite imagery to capture detailed topographic information [18]. Regular updates are also needed to ensure the GIS map remains relevant and accurate, providing stakeholders with the most up-to-date information for effective decision-making and risk management [19].

4 CONCLUSION

The validation of a landslide GIS map based on historical events is paramount for ensuring the accuracy and reliability of the maps and related data. By examining past landslide occurrences, this study resulted in 93.75% accuracy of the GIS landslide susceptibility map using a Formula from DVMBG (2004). The field identification of landslide events location along the railway line shows that the measurements needed to reinforce the critical area have been made to potential landslide risk, including rail piles, bamboo piles, stone retaining walls, gabion, soil bags, and drainage normalization.

Implementing a system for continuous monitoring and updating of the GIS map to account for any changes in the landscape and to incorporate new data as it becomes available. It must engage civil engineers, geologists, environmental engineers, and other domain experts to refine and validate the GIS map.

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