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Mitigation and Emergency Management System of Landslide in Ponorogo District, Indonesia

Arif Basofi#, Arna Fariza#, Imam Mustafa Kamal#

#*Informatics and Computer Engineering Dept, Politeknik Elektronika Negeri Surabaya, Surabaya, Indonesia*
E-mail: ariv@pens.ac.id, arna@pens.ac.id, kamal@it.student.pens.ac.id

***Abstract*— Ponorogo district, in East Java Province, is one area that is often hit by landslides. In addition to threatening the safety of residents, this landslide caused dozens of houses and public infrastructure to be damaged. The losses caused by this landslide disaster also reached billions of rupiah each year. Integrated of emergency mitigation and response systems for landslides are needed to provide information accurately and widely to the community. This paper proposes a new framework of mitigation and emergency system for landslide in Ponorogo district. The system can analyze, display, explore and store vulnerability data based on web GIS application. The information generated from the mitigation system is a landslide susceptibility map using the analytical hierarchy process (AHP) - Natural break method. The landslide susceptibility index is produced based on 4 factors that cause landslides including slope, soil type, land use and rainfall. The map displays 4 levels of vulnerability including very low, low, moderate and high. The mitigation system is equipped with information features for the community about handling landslides. Pearson's Chi-squared test showed the classification class of vulnerability was declared very significant result. Emergency system information in the form of alternative route information and nearest evacuation sites.**

***Keywords*— Mitigation, emergency, landslide vulnerability, analytical hierarchy process, natural break.**

I. Introduction

Most areas of Indonesia are areas prone to land movement or landslides. Because, the tectonic position of the territory of Indonesia is flanked by three main plates of the world which are always active at speeds of 1 to 13 cm per year. In addition, the characteristics of the Indonesian region consisting of high and low plains, high rainfall, and being in the ring of fire are indeed very prone to landslides. Throughout 2017, the national disaster management agency (called BNPB or Badan Nasional Penanggulangan Bencana) recorded 2,175 disaster events in Indonesia. Disaster events in Indonesia are increasing from year to year. As many as 95 percent of disaster events in Indonesia are hydrometeorological disasters, namely disasters that are affected by weather such as landslides, droughts, tornadoes, forest and land fires and extreme weather [1]. During 2017, there were 438 occurrences of landslides in Indonesia. The impact of landslides caused 95 deaths, 132 people injured, 43,416 people suffered and displaced, and more than 1,500 housing units were damaged [2].

Landslide is one the natural disaster that routinely occur in Indonesia. Ponorogo district, in East Java Province, is one area that is often hit by landslides, especially in the rainy season. Besides high rainfall, landslides in Ponorogo are also caused by the steep slope of the cliff, the rock structure in the form of weathering of volcanoes and improper land use. In addition to threatening the safety of residents, this landslide caused dozens of houses and public infrastructure to be damaged. The losses caused by this landslide disaster also reached billions of rupiah each year. Integrated of emergency mitigation and response systems for landslides are needed to provide information accurately and widely to the community.

BNPB stated that Geographic Information System (GIS) technology can be used widely by the government to support disaster emergency response activities that play an important role in mitigating potential risks that are disastrous. The warning system have been used in Tuscany to gather, analyze, display, explore, interpret and store rainfall data, thus representing a potential support using web GIS [3]. A landslide information system (LIS) have been built to comprise a smartphone and an administrative interface and database [4]. The interface of the smartphone app is powered by the highly-customizable Google Maps platform, which is overlaid with real-time landslide data. The visualization showed published landslides and areas that are susceptible and contributed user to enhance landslide reports. Yalcin et al (2011) compare frequency ratio method, AHP, statistic bivarian, logistics regression, Wi dan Wf for mapping the landslide prone area in Trabzon, Turki for 50 areas of active landslide [5].Pourghasemi et al (2012) have produced landslides susceptibility maps of hazard landslides-prone area in Iran by using both fuzzy logic and analytical hierarchy process (AHP) models according to slope degree, aspect, plan curvature, altitude, lithology, land use, distance from rivers, distance from roads, distance from faults, stream power index, slope length, and topographic wetness index factors [6]. Kayastha et al (2013) mapped vulnerable areas of landslides in Tinau, Nepal, based on tapographic data of slope angle, slope shape, relative rock, distance from river, geology, land use, rainfall and hydrology, distance from crease syncline, distance from anticline folds with the AHP method [7]. Previously, Kamal et al (2015) determined prone areas of landslides in Ponorogo using AHP according to 4 criteria factors including slope, soil type, land use and rainfall. Natural breaks classification is used to obtain classification map landslides-prone areas using the natural breaks [8].

This paper proposes a new framework of mitigation and emergency system for landslide in Ponorogo district. The system can analyze, display, explore and store vulnerability data based on web GIS application. The information generated from the mitigation system is a landslide susceptibility map using the AHP-Natural break method. The landslide susceptibility index is produced based on 4 factors that cause landslides including slope, soil type, land use and rainfall. The map displays 4 levels of vulnerability including very low, low, moderate and high. The mitigation system is equipped with information features for the community about handling landslides. Emergency system information in the form of alternative route information and nearest evacuation sites.

II. Study Area

Fig. 1 Ponorogo administration map

The study area is located in the Ponorogo district. Ponorogo district is located in the southwestern part of the East Java. The district is located at coordinates 111 ° 17 '- 111 ° 52' BT and 7 ° 49 '- 8 ° 20' LS with an altitude between 92 to 2,563 meters above sea level. It has an area of 1,371.78 km² which is divided into 2 sub-areas, the highland area which covers the sub-districts of Ngrayun, Sooko, Pulung and Ngebel, the rest are lowland areas. It has a tropical climate that has dry and rainy seasons. The highest rainfall occurs in December, January and February. The lowest rainfall occurs in July, August and September. Temperatures in Ponorogo Regency throughout the year are relatively the same as the highest average temperature of 32.2 ° C and the lowest average temperature of 23.9 ° C. It consists of 21 sub-districts which are divided into 279 villages and 26 villages.

III. Methodology

Figure 2 shows the diagram system of mitigation and emergency system of landslide. Detailed explanation of block diagram system are as follows:

a. Data are collected and stored in the database that consists of base map (Ponorogo district and villages), land use, slope, soil type, rainfall, evacuation point and street roads.
b. Data variables of land use, slope, soil type and rainfall are conducted a statistical analysis process to find correlation between landslide history data and all variables affecting landslide vulnerability. The results of this correlation serve as a consideration in determining the weight of comparison AHP criteria.
c. AHP modeling is presented to solve multi criteria decision making of landslide susceptibility using weight based on statistical analysis of criteria. AHP process obtain priority values from landslide susceptibility for each village.
d. The priority values of village from the AHP calculation are used as input to classify the landslide susceptibility index using natural breaks algorithm. This process result high, medium, low and very low of landslide susceptibility areas.
e. The system provides general information and recommendations for mitigating landslides from each class of landslide susceptibility
f. The evacuation system provides information to the user of the nearest evacuation place to the village that is in the middle or middle class and displays the route to the evacuation place closest to the user.
g. The system provides information and recommended route recommendations complete with travel time and estimated distance to be traveled.
h. The system displays landslide susceptibility mapping, evacuation and alternative routes using web-based google maps.An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A. *Statistical Analysis*

The correlation statistical analysis is used to know the influence of the parameter to landslide. The output of this process used to considerate the matrix that used for parameter comparison in AHP. In order to calculate the correlation value, we use SPSS (Statistical Product and Service Solutions) software. The data was collected from Development Planning Agency at Sub-National Level (Badan Perencanaan dan Pembangunan Daerah) dan public works service (Dinas Pekerjaan Umum) Ponorogo district. The result from each parameter shown in Table 1. This value used to build the comparison matrix between each parameter in AHP. Based on Table 1, parameter that has the highest value is slope and is followed by geology, land use and rainfall.

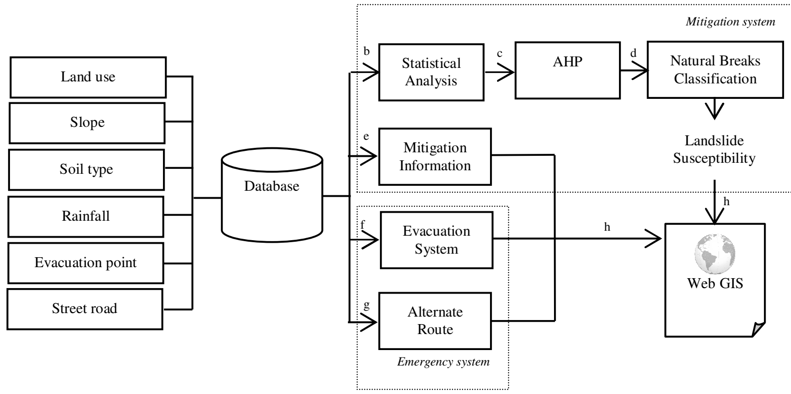


Fig. 2 System design

TABLE I
COMPARISON CORRELATION VALUE BETWEEN VARIABLE

Variable Name	Correlation Technique	Correlation Value	Approximation Value	Correlation Level
Rainfall	Pearson Product Moment	0.401	0.015	Medium
Landuse	Contingency coefficient	0.543	0.000	Medium
Geology	Contingency coefficient	0.679	0.000	Strong
Slope	Spearman Rank	0.686	0.000	Strong

B. Analytical Hierarchy Process Analysis

Analytical Hierarchy Process (AHP) is a multicriteria decision making (MCDM) model developed by Thomas L. Saaty. AHP describes complex multi-factor or multi-criteria issues into a hierarchy [9]. The hierarchical tree can be seen in Figure 3. There are 4 criterias to determine landslide-prone areas, they are land use, rainfall, slope angle and soil type (geology). Land use is decomposed into 4 sub criteria, consist of land use that are paddy farming, non-paddy farming, settlement and forest. Rainfall consists of 3 range, consist of less than 100mm, 100-199 mm and more than 200 mm. Slope consists of class 1 (0-8 degree), class 2 (9-15 degree), class 3 (16-25 degree), class 4 (26-45 degree) and class 5 (more than 45 degree). Soil type or geology consists of alluvium, limestone, volcanic quaternary, young volcanic quaternary, old volcanic quaternary, pliosin and diocytes deposits.

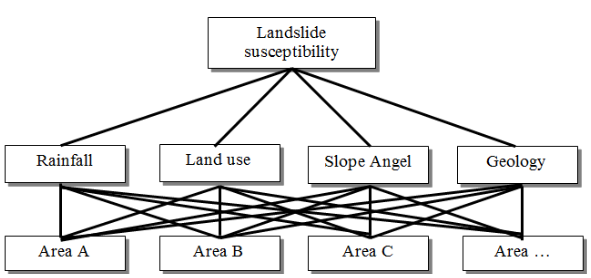


Fig. 3 Hierarchy tree to determine landslide susceptibility value

Each parameter was given weight value then build the matrix, normalization matrix, calculate the eigen vector and calculate landslide index. The results of pairwise comparison matrix and vector eigenvalues after matrix normalization process can be seen in Table 2.

In AHP, comparison factor is created using scale 1 to 9 if the factor has direct relation and scale from 1/2 to 1/9 if the factor has inverse relation. An important feature of AHP is that it is possible to specify inconsistencies rank with a consistency index (CI) according to largest eigen value λ_{max} and matrix comparison sequence N, which is defined as

$$\mathrm{CI} = \frac{\lambda_{max} - N}{N - 1} \tag{1}$$

Saaty (1980) developed the average random consistency index (RI) for different matrices and defined the consistency ratio (CR) as the consistency index ratio (CI) and the random consistency index (RI) [9]. The CR value is produced from division between CI (Consistency Index) and RI (Random Consistency Index). If CR is greater than 0.1, the matrix comparison is inconsistent and should be revised. Table 3 shown the CR value for each parameter that have value less than 0.1. this value has satisfied the specification to make the matrix consistent.

C. Natural Breaks Classification

Natural breaks classification is obtained by maximizing the variance between the classes and minimizing the variance in the class. This method also known as Goodness Variance Fit (GVF). GVF is an indicator of how good the classification is. This is related to both of the variance from the array average and the class average. GVF increases when the value of most deviated class from the average array changes to the class that is most deviated from the array average. In a certain range, when GVF reaches maximum, that is, when the variance of the class average reaches a minimum, the classification process is achieved (Jenks 1967) [10]. In this way, a natural cluster group is created. The steps of natural breaks classification algorithm are

1. Select attributes, x, should be classified and set the number of classes required k.
2. A set of k-1 random values or class boundaries are generated in the range [min {x}, {max x}]. This is used as an initial class boundary.

TABLE 2
PAIR-WISE COMPARISON MATRIX AND EIGEN VALUE AFTER NORMALIZATION

Causative factors and Classes within each factors	Pair-wise comparison matrix [1]	[2]	[3]	[4]	[5]	[6]	[7]	Eigen Value
All criteria								
[1] Soil type	1							0.557890
[2] Slope	1/3	1						0.263350
[3] Land use	1/5	1/3	1					0.121870
[4] Rainfall	1/7	1/5	1/3	1				0.056890
Classes within each factors								
Geology								
[1] Alluvium	1							0.030481
[2] Limestone	2	1						0.044485
[3] Volcanic Quaternary	3	3	1					0.074471
[4] Young Volcanic Quaternary	3	2	2	1				0.086569
[5] Old Volcanic Quaternary	5	3	2	2	1			0.117083
[6] Pliosin Deposits	9	7	7	5	5	1		0.419604
[7] Diocytes Deposits	5	5	3	3	5	1/3	1	0.227308
Slope								
[1] 0-8%	1							0.035102
[2] 9-15%	3	1						0.068303
[3] 16-25%	5	3	1					0.143201
[4] 26-45%	7	5	2	1				0.242698
[5] > 45%	9	7	5	3	1			0.510696
Landuse								
[1] Paddy Farming	1							0.043694
[2] Non-paddy farming	9	1						0.519399
[3] Settlement	3	1/5	1					0.112678
[4] Forest	9	1/2	3	1				0.324229
Rainfall								
[1] < 100	1							0.142857
[2] 100-199	2	1						0.285714
[3] > 200	4	2	1					0.571429

3. The average value for each initial class is calculated and the sum of the squared deviations of the class members from the average value is calculated. The total sum of squared deviations (TSSD) is recorded
4. The individual values in each class are then systematically assigned to adjacent classes by adjusting the class boundaries to see if TSSD can be reduced. This is an iterative process, which ends when the TSSD improvement falls below the threshold, when in the class variance as small as possible and between the class variance as large as possible.

TABLE 3
COMPARISON OF ORDO MATRIX (N), ALPHA-MAX VALUE, CONSISTENCY INDEX CI, RANDOM CONSISTENCY INDEX RI AND CONSISTENCY RATIO CR FOR EACH CRITERIA.

Causative factors	N	λ_{max}	CI	RI	CR
All variables	4	4.176680	0.058890	0.9	0.065440
Soil type	7	7.602694	0.100449	1.32	0.076098
Slope	5	5.303270	0.075817	1.12	0.067694
Land use	4	4.070407	0.023469	0.9	0.026077
Rainfall	3	3	0	0.58	0

IV. RESULT AND DISCUSSION

In this section we discuss about the result and analysis of AHP-Natural breaks classification result, mitigation information, evacuation and alternate route system.

A. *AHP-Natural Breaks Classification Result*

The Landslide Susceptibility Index (LSI) or region i is calculated using the following formula

$$\mathrm{LSI} = \sum_{j=1}^{n} W_j w_{ij} \tag{2}$$

Where W_j is the weight value of criterion j, w_{ij} is the weight value of each region based on factor j.

LSI from all of the data have very low average and standard deviation, the average is 0,001358736 and the standard deviation is 0,000498121. It explains that the LSI data has high homogeneity.

TABLE 4
NUMBER OF VILLAGE AND LANDSLIDE POINT USING NATURAL BREAKS

Susceptibility Class	landslide susceptibility index (LSI)		Number of villages		Number of Landslide points	
	Low Class	*High Class*	*Amount*	*%*	*Amount*	*%*
Very Low	0.000824	0.001118	172	54	0	0
Low	0.001118	0.001468	40	13	1	2
Medium	0.001468	0.002030	67	21	20	37
High	0.002030	0.002943	37	12	33	61

Based on Table 4, the LSI of 0.000824 - 0.0001118 is categorized in very low vulnerability classes with the number of villages in this class of 172 (54% of the total villages), and this class has no landslide points. The low vulnerability class has LSI value between 0.001118 - 0.001468 the number of villages in this class is 40 (13% of the total village), while the number of landslide points is 1 (2% of the total landslide point). The vulnerability class currently has an LSI in the range 0.001468 - 0.002030, the number of villages in this class is 67 (21%), whereas the number of landslides 20 (37% of the existing landslide point), and the high vulnerability class has LSI between 0.002030 - 0.002943 number of villages in class as many as 37 (12%), while the number of landslide points 33 (61% of existing landslide points).

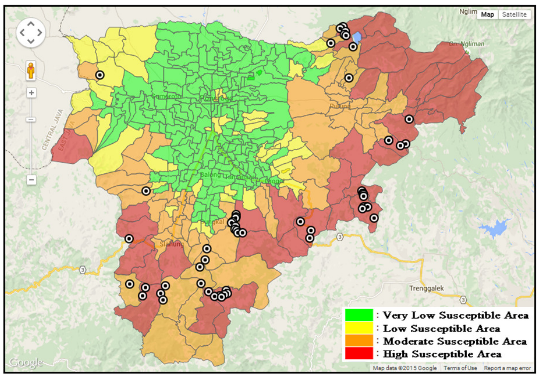


Fig. 4 Landslide susceptibility map using Natural Breaks classification

The results of the Natural Breaks classification show that the landslide hazard map produced is quite good. In Figure 4 shows almost all the landslide points (white-black circle) are in the class of high vulnerability (red) and medium vulnerability class (orange).

Classification with Natural Breaks were tested using statistical analysis. The significance and effectiveness of landslide hazard statistical maps can be tested using the Pearson Chi-Squared test [5]. Test based on historical data with the number of landslide events (with landslide points) and the number of no landslide events for each class of vulnerability as shown in Table 5.

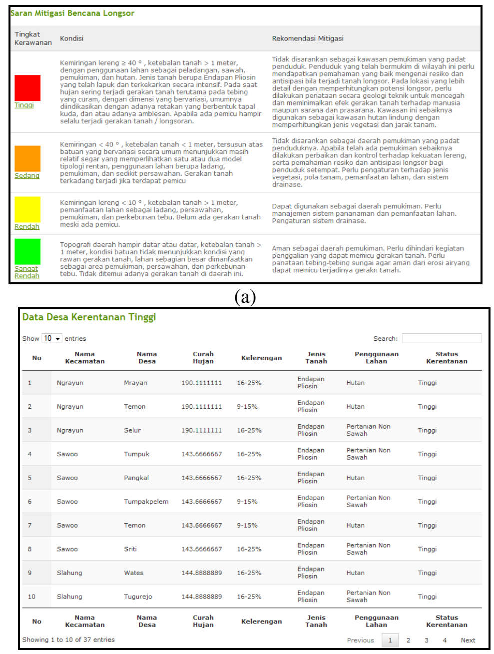
Based on Table 5, the cell value of Oi is the value derived from the existing landslide data point from each village in each class. While the value of cell Ei is the value of random spatial distribution, obtained from the formula Ei = (Total Oi × Amount $'Oi$) / Oi. The Chi-Squared (x^2) is the value obtained from (3)

$$\frac{(Oi + Ei)^2}{Ei} \tag{3}$$

The x2 value is 184,9166, which is the result of calculating the Chi-Squared value in the Total column ' (bottom right corner of Table 5). This value is compared with the Chi-Squared standard distribution of the distribution of squares using three degrees of freedom, at the 0.05 the significance level, only 7.815. Because the x2 value is greater than the theoretical chi-squared value, it can be concluded that there is a very significant result of landslide susceptibility classes.

B. Mitigation Information

Information and recommendations for landslide mitigation that used in this system are sourced from standard operating procedures for handling landslide-prone areas issued by the regional disaster management agency (Badan Penanggulangan Bencana Daerah) of Ponorogo district. It explains the general conditions and treatment recommendations for the villages in each landslide vulnerability class.



Saran Mitigasi Bencana Longsor

Tingkat Kerawanan	Kondisi	Rekomendasi Mitigasi
Tinggi	Kemiringan lereng ≥ 40 ° , ketebalan tanah > 1 meter, dengan penggunaan lahan sebagai peladangan, sawah, pemukiman, dan hutan. Jenis tanah berupa Endapan Pliosin yang telah lapuk dan terkekarkan secara intensif. Pada saat hujan sering terjadi gerakan tanah terutama pada tebing yang curam, dengan dimensi yang bervariasi, umumnya diindikasikan dengan adanya retakan yang berbentuk tapal kuda, dan atau adanya amblesan. Apabila ada pemicu hampir selalu terjadi gerakan tanah / longsoran.	Tidak disarankan sebagai kawasan pemukiman yang padat penduduk. Penduduk yang telah bermukim di wilayah ini perlu mendapatkan pemahaman yang baik mengenai resiko dan antisipasi bila terjadi tanah longsor. Pada lokasi yang lebih detail dengan memperhitungkan potensi longsor, perlu dilakukan penataan secara geologi teknik untuk mencegah dan meminimalkan efek gerakan tanah terhadap manusia maupun sarana dan prasarana. Kawasan ini sebaiknya digunakan sebagai kawasan hutan lindung dengan memperhitungkan jenis vegetasi dan jarak tanam.
Sedang	Kemiringan < 40 ° , ketebalan tanah < 1 meter, tersusun atas batuan yang bervariasi secara umum menunjukkan masih relatif segar yang memperlihatkan satu atau dua model tipologi rentan, penggunaan lahan berupa ladang, pemukiman, dan sedikit persawahan. Gerakan tanah terkadang terjadi jika terdapat pemicu	Tidak disarankan sebagai daerah pemukiman yang padat penduduknya. Apabila telah ada pemukiman sebaiknya dilakukan perbaikan dan kontrol terhadap kekuatan lereng, serta pemahaman resiko dan antisipasi longsor bagi penduduk setempat. Perlu pengaturan terhadap jenis vegetasi, pola tanam, pemanfaatan lahan, dan sistem drainase.
Rendah	Kemiringan lereng < 10 ° , ketebalan tanah > 1 meter, pemanfaatan lahan sebagai ladang, persawahan, pemukiman, dan perkebunan tebu. Belum ada gerakan tanah meski ada pemicu.	Dapat digunakan sebagai daerah pemukiman. Perlu manajemen sistem pananaman dan pemanfaatan lahan. Pengaturan sistem drainase.
Sangat Rendah	Topografi daerah hampir datar atau datar, ketebalan tanah > 1 meter, kondisi batuan tidak menunjukkan kondisi yang rawan gerakan tanah, lahan sebagian besar dimanfaatkan sebagai area pemukiman, persawahan, dan perkebunan tebu. Tidak ditemui adanya gerakan tanah di daerah ini.	Aman sebagai daerah pemukiman. Perlu dihindari kegiatan penggalian yang dapat memicu gerakan tanah. Perlu panataan tebing-tebing sungai agar aman dari erosi airyang dapat memicu terjadinya gerakn tanah.

(a)

Data Desa Kerentanan Tinggi

Show 10 entries Search:

No	Nama Kecamatan	Nama Desa	Curah Hujan	Kelerengan	Jenis Tanah	Penggunaan Lahan	Status Kerentanan
1	Ngrayun	Mrayan	190.1111111	16-25%	Endapan Pliosin	Hutan	Tinggi
2	Ngrayun	Temon	190.1111111	9-15%	Endapan Pliosin	Hutan	Tinggi
3	Ngrayun	Selur	190.1111111	16-25%	Endapan Pliosin	Pertanian Non Sawah	Tinggi
4	Sawoo	Tumpuk	143.6666667	16-25%	Endapan Pliosin	Pertanian Non Sawah	Tinggi
5	Sawoo	Pangkal	143.6666667	16-25%	Endapan Pliosin	Hutan	Tinggi
6	Sawoo	Tumpakpelem	143.6666667	9-15%	Endapan Pliosin	Pertanian Non Sawah	Tinggi
7	Sawoo	Temon	143.6666667	9-15%	Endapan Pliosin	Hutan	Tinggi
8	Sawoo	Sriti	143.6666667	16-25%	Endapan Pliosin	Pertanian Non Sawah	Tinggi
9	Slahung	Wates	144.8888889	16-25%	Endapan Pliosin	Hutan	Tinggi
10	Slahung	Tugurejo	144.8888889	16-25%	Endapan Pliosin	Pertanian Non Sawah	Tinggi
No	Nama Kecamatan	Nama Desa	Curah Hujan	Kelerengan	Jenis Tanah	Penggunaan Lahan	Status Kerentanan

Showing 1 to 10 of 37 entries Previous 1 2 3 4 Next

(b)

Fig. 5 (a) Mitigation information and recommendations display; (b) Output of villages with high vulnerability class

Figure 5(a) displays mitigation information in four lines table of landslide vulnerability classes, namely high (red), medium (orange), low (yellow) and very low (green). The second column provides information on the general condition of the area from the landslide vulnerability class, the third column provides information on mitigation recommendations for each vulnerability class. In each vulnerability class there is a link to see the list of villages included in each class of vulnerabilities. If the user chooses a high vulnerability class, an information link will appear in Figure 5(b). Figure 5(b) shows a list of villages that have high landslide susceptibility, which consists of information about sub-district names, village names, rainfall in millimeters, slope of land in percent, and land use. The table display is responsive and there is a search feature so that users can search for desired village data easily and quickly.

C. Evacuation Information

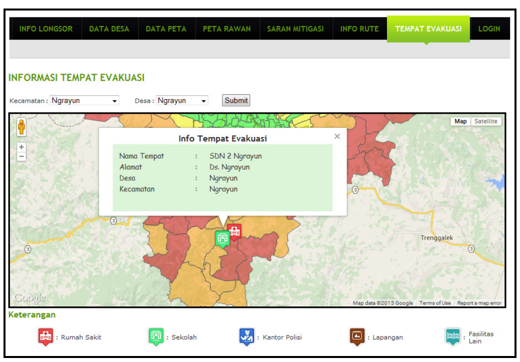
The evacuation area is divided into five types, namely hospitals, fields, police stations, schools and other public facilities that are safe from landslide points. Each type of evacuation area is displayed with a different marker.

TABLE 5

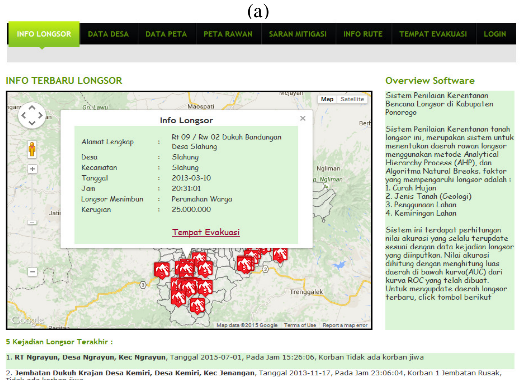
CHI-SQUARE VALUE FOR NATURAL BREAKS

Susceptibility area	Class				Total’
	Very low	*Low*	*Medium*	*High*	
Observed number cell (Oi)					
Without landslide	172	39	47	4	262
With landslide	0	1	20	33	54
Total	172	40	67	37	316
Expected number cell (Ei)					
Without landslide	142.6076	33.1646	55.5506	30.6772	262
With landslide	29.3924	6.8354	11.4494	6.3228	54
Total	172	40	67	37	316
Chi-Squared value					
Without landslide	6.0580	1.0268	1.3162	23.1988	31.5997
With landslide	29.3924	4.9817	6.3858	112.5570	153.3170
Total	35.4504	6.0085	7.7020	135.7558	184.9166

Figure 6(a) is an example of evacuation location markers complete with detailed information, information about the evacuation sites provided including the name of the place, address, village name and sub-district name. The system also displays the location marker that is in the landslide that is included by the government as Figure 6(b). There is detailed information about the marker in the form of landslide events, hours and dates of landslides, accommodation that is buried by landslides, the number of losses and landslide status for the area whether the area is still buried by landslides or not. In addition, there are also links to find alternative routes and links to find the nearest evacuation site from the area.



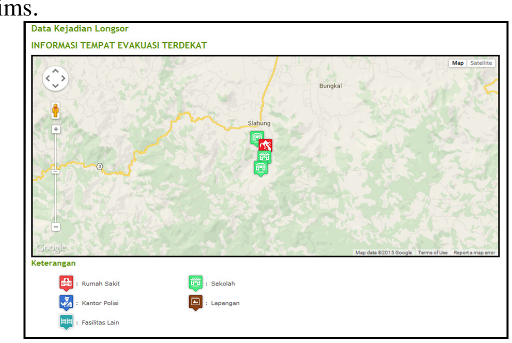
(a)



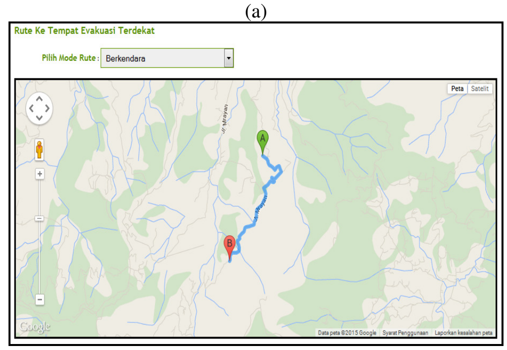
(b)

Fig. 6 (a) Information of nearest evacuation point marker; (b) Route to the nearest evacuation point

Figure 7(a) display the nearest evacuation site from the location of the landslide that is shown by the red marker. The evacuation site shown in this page is just an evacuation site that is less than two km away from the landslide location. If there is another evacuation area in the area with a distance of more than two km, the evacuation site will not be displayed. The information consists of the name and location of the point. In addition, the marker has a Route Info link to see the route from the landslide scene to the nearest evacuation site. If the user clicks the Route Info link, a route map will appear as shown in Figure 7(b). The route to the nearest evacuation site can be chose in the route mode. There are driving and pedestrian route modes. Figure 7(b) is an example of a route display from a landslide point to the nearest evacuation site using driving mode. With the availability of information on the route to the nearest evacuation site, it can facilitate the evacuation of landslides victims.



(a)



(b)

Fig. 7 (a) Information of nearest evacuation point marker; (b) Route to the nearest evacuation point

D. Alternate Route Information

This experiment was conducted with two scenarios, the first scenario for users who were in a secure area and the second scenario for users who were in the affected area. The first scenario is that the user chooses a secure destination from landslide points and from the village which is not included in the level of high and moderate landslide susceptibility. In Figure 8 the user chooses Babadan village, as the original village and Surodikraman village as the destination village. Surodikraman Village is a village that is declared to have a very low vulnerability level. The output map displays two markers, marker A as the souce village and marker B as the destination village, and directions to the two points. This shows that there was no detention to the village of, because the road to this village has not yet happened landslides and this village is included in a very low vulnerability class. At the bottom of the map there is detailed information, such as the recommended route complete with travel time and estimated distance to be traveled.

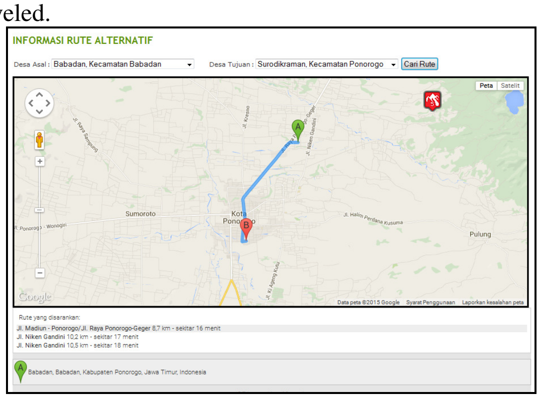


Fig. 8 Information of secure route from landslide prone

The second scenario, the user inputs villages that are in the high or medium level of vulnerability as the destination. The resulting output consists of three markers, the source, destination and alternative route locations suggested to avoid landslide-prone locations. The system displays a warning because the user chooses the location of the high or medium level of vulnerability as the destination. Then there is information on the diversion of the traffic lane to a safe place from the landslide location, System adds the location of the alternative point, Snepo village as shown in Figure 9(a). The location of this alternative path is taken from the database, according to the input from the user. There are three markers namely marker A, B and C. marker A is the source, B is the recommended alternative point and C is the destination point. The system also displays detailed information about the distance from the starting point to the destination point which consists of several road instructions, estimation of distance and estimated time to the destination as shown in Figure 9(b).

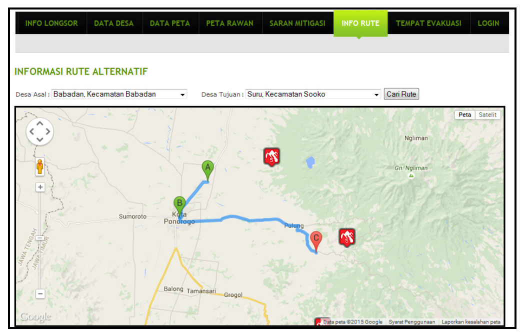
V. Conclusions

This application determines landslide prone villages by using AHP method, where the calculated criteria include soil type, land use, slope and rainfall. By using natural breaks classification algorithm, AHP weighting results are classified into four classes of vulnerability levels areas with high, medium, low and very low landslide susceptibility.

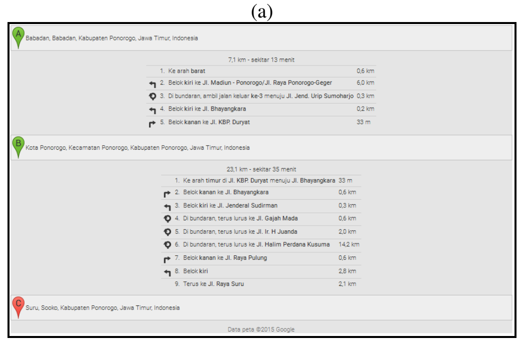
The calculation of landslide susceptibility areas using AHP-Natural breaks is validated using the landslide point from the public work service of Ponorogo district obtain 75.8% accuracy rate and Pearson's Chi-squared test showed the classification class of vulnerability was declared very significant result. Based on the results of trials from the regional disaster management agency (Badan Penanggulangan Bencana Daerah) of Ponorogo district, the classification of landslide-prone villages and landslide-prone maps declared accurate.

Landslide disaster mitigation in this system also provides information and recommendations for steps to deal with areas with very low, low, medium and high vulnerability classes.

The emergency system provided by the system consists of information on evacuation sites and alternative routes. Evacuation information consists of information on evacuation points and directions to the nearest evacuation point from the landslide point. Alternative route information provides alternative route information if it passes through landslide points and directions from origin to destination.



(a)



(b)

Fig. 8 (a) Alternate route; (b) Detail information of alternate route, distance and time estimation.

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