

# ANALYZING AND ESTIMATING THE IMPACT OF LANDSLIDE TO ROAD IN SAMIGALUH DISTRICT, KULON PROGO REGENCY

## *Analisis dan Estimasi Dampak Longsorkalahan terhadap Jaringan Jalan di Kecamatan Samigaluh, Kabupaten Kulonprogo*

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### ABSTRACT

*In this study, direct risk assessment was developed for various scenarios on the basis of hazard (e.g. spatial probability, temporal probability and magnitude class), vulnerability and estimating cost of road damage. Indirect risk assessment was derived from traffic interruption. The impact of landslide both direct and indirect impact were analyzed in the road segment 174. The research results show the highest direct impact of debris slide type of magnitude I located in the 20<sup>th</sup> mapping unit. The lowest direct impact of debris slide type of magnitude I can be founded in the 18<sup>th</sup> mapping unit. The direct impact of rock fall type of magnitude I which is located in the 6<sup>th</sup> mapping unit. Meanwhile, indirect impact which was caused by road blockage is Rp. 4,593,607.20 and Rp. 4,692,794.40 by using network analysis and community perception methods respectively. After class classification, road segment 174 is dominated by very low hazard, very low vulnerability and very low direct impact.*

**Keywords:** road segment, landslide hazard, road vulnerability, direct impact, indirect impact

### ABSTRAK

*Dalam penelitian ini, pengukuran dampak langsung (direct risk assessment) di bentuk dari beberapa skenario berdasarkan elemen penyusun bahaya (hazard)(antara lain : spatial probability, temporal probability and magnitude class), kerentanan (vulnerability) dan perkiraan biaya kerusakan jalan. Sedangkan dampak tidak langsung (Indirect risk) diperoleh dari lalu lintas yang terganggu akibat adanya longsor. Kedua dampak longsor baik langsung maupun dampak tidak langsung diukur dan dianalisa di ruas jalan no 174. Hasil penelitian menunjukkan bahwa dampak langsung dari longsor tipe debris dengan magnitude I terletak di mapping unit ke 20. Dampak langsung terendah untuk longsor tipe debris dengan magnitude I, terletak di mapping unit ke 18. Untuk dampak langsung dari longsor tipe rockfall untuk magnitude I berlokasi di mapping unit 6. Sedangkan untuk dampak tidak langsung yang diakibatkan oleh longsor adalah sebesar Rp. 4,593,607.20 jika dihitung dengan menggunakan metode network analysis dan Rp. 4,692,794.40, bila dihitung dengan metode persepsi masyarakat. Setelah dikelaskan, segmen jalan no 174 didominasi oleh tingkat bahaya sangat rendah, tingkat kerentanan sangat rendah dan tingkat dampak langsung sangat rendah.*

**Kata kunci:** segmen jalan, bahaya longsorkalahan, kerentanan jalan, dampak langsung, dampak tidak langsung

## INTRODUCTION

Actually, Samigaluh District is situated on the Menoreh limestone mountain, which is susceptible to landslide hazards. The event is initially a geomorphology process starting with erosion (Priyono, et al., 2011). This is due to several factors such as: steep slopes, humid climate, earthquakes occurrence and human activity (mining, heavy development, agriculture) (Hadmoko et.al, 2010). Based on the percentage of catastrophic events in 2009, it can be understood that landslide of 59.1%, flooding of 4.5% and hurricanes as much as 36.4%, respectively (Data obtained from the *Kesbang Linmas Office Kulon Progo*). Landslide in Samigaluh generated a large amount of damage and even loss of life. Landslides also cause damage to the road network. Based on data recorded from *Kantor Kesbang Linmas Kulon Progo Regency* (Agency for National Unity and Community Protection) in 2010, the most of landslide hit road which are 26 events (54.17%) are located in Samigaluh District.

Road network is as a vital infrastructure to support local development. Road will support transportation, economic development and ease of mobility of people, goods and services. The availability of road infrastructure has a very strong relationship with regional growth rates among others, marked by economic growth and prosperity.

In this study, the estimation of landslide impact to road considers the comprehensive estimation including the direct impact and indirect impact estimation as well. Besides that, the assessment of landslide impact used quantitative method which quantifies landslide probabilities (spatial probabilities & temporal probabilities). The assessment of landslide impact to road using this method is very limited in Indonesia, especially in Kulon Progo Regency. By using this method, the comprehensive estimations of landslide impact to road

might be assessed and predicted better. Due to this reason, it was necessary to estimate the impact of landslide risk to road in Samigaluh District, Kulon Progo Regency

Samigaluh District which lies between 110° 7' 00"E - 110° 13' 00 E and 7° 38' 40"S - 7° 43' 15" S. Samigaluh District consists of 7 villages which are Kebonharjo, Banjarsari, Pagerharjo, Ngargosari, Gerbosari, Sidoharjo and Purwoharjo village. Total area of Samigaluh District is 6,736.78 Ha. Meanwhile, road networks consist of provincial roads, district roads and village roads. Administrative map and road networks map of Samigaluh District is presented in (Figure 1).

The Slope class of > 45 % covers 29.76 % from total area. Rainfall value ranging between 248 mm - 277 mm which was categorized as almost high class. Breccia rock is the largest percentage covering 55.64 % of the total area of research. Breccia rocks in the study area have a high degree of weathering which can cause a mass movement. Meanwhile, landuse is dominated by mixed garden which cover 39.54 % from total area.

## RESEARCH METHOD

### Landslide Inventory and Landslide Density

In this study, authors collected landslide historical data by using information from people who live around the incident and key informant. (Wahono, 2010) the local community information can help to determine the landslide location and landslide boundary. The lack of historical data (especially historical data of landslide hit road) in institutional/office is caused usually people didn't report this event to office. (Budeta, 2002) stated that landslide events which didn't cause life threatening and heavy damage were usually not reported. On the other hand, village office will collect data related with big land-



tial probability can be determined by using the following equation (Nayak, 2010).

$$P(s) = AL/AM \text{ ----- (2)}$$

P(s) = spatial probability of landslide in a mapping unit

AL = area of landslide type and particular magnitude in a mapping unit

AM = area of that particular mapping unit

### Temporal Probability

Temporal probability can be approximated by using poisson model. The probability of occurring  $n$  number of slides in a time  $t$  is given by equation below (Nayak, 2010):

$$P[N(t)] = 1 - [\exp(-\lambda t)] \text{ ----- (3)}$$

N = total number of landslide occurred a time  $t$

$\lambda$  = average rate landslides occurrence

Here time  $t$  is specified, whereas rate  $\lambda$  is estimated

### Magnitude

In this research, author used the magnitude classification based on standard created by Jaiswal to determine magnitude level for different type of landslide.

### Vulnerability of road network

Road vulnerability considered the degree of loss of road network which was shown in the degree of road damage. To calculate vulnerability of road network is used the following formula:

$$V = AD/TA \text{ ----- (4)}$$

V = vulnerability of road

AD = road damaged area and or landslide mass covering road area in the road segment

TA = total area of road segment

It was assumed that between road damaged due to landslide and landslide mass covering road have the same influence of traffic interruption.

### Direct Risk Assessment

The direct risk calculation used equation below. This equation was used by (Nayak, 2010) to calculate landslide direct impact to road in India.

$$Sp(e) = H[(s \times t \times m)] \times V(d) \times A \text{ ----- (5)}$$

Sp(e) = specific risk for different kind of element at risk

H [(s x t x m)] = spatio - temporal occurrence of particular slide and magnitude

V(d) = vulnerability of different type of element at risk to specific landslide

A = amount in term of monetary value of particular element at risk

### Indirect Risk Assessment

Indirect risk assessment was derived from traffic interruption. Because of road blockage, driver or commuter will find alternative road which will result in increased costs of fuel purchases. It was used network analysis and community perception to determine the optimal road which was chosen by commuter. Indirect impact due to landslide events on the road network can be calculated by using this equation:

$$IDL = R(d) \times N(v) \times L(r) \times F(c) \times F(s) \text{ ----- (6)}$$

IDL = indirect loss

R(d) = road blockage days

N(v) = number of vehicle of a particular type

L(r) = extend distance by using road alternative

F(c) = fuel consumption per km long road

F(s) = fuel standard cost per km long road

### Data Classification

In this research, author used Equal Intervals method. This method sets the value ranges in each category equal in size. This method is the most easily computed and adequate to display data that varies linearly. It was used 5 class criteria which are very low, low, moderate, high, and very high. In order to get the same reference, the class interval used for making hazard and direct impact classification is the class interval for return period 1 yr. Interval class can be calculated by using this equation:

$$\text{Interval class} = \frac{(\text{max value} - \text{min value})}{5} \quad (7)$$

### Research Framework

There are 3 main stages which are : pre field work, field work and post field work. The research framework are represented in (Figure 2). Pre field work deals with the collecting of literature reviews including journals, reports, books, related to the data needed and the analysis methods information. In this phase, data which related with research have been collected. For example: demographic data, rainfall data, slope map, geology map, topographic map, DEM map, road network map and landuse map. In field work, it includes secondary data & primary data collection. Secondary data consists of landslides occurrence data, road network classification data, standard cost deal with road (repairs, construction and maintenance), road blockage day data, debris slide volume and so on. Primary data collection was conducted by interviewing and observing landslide occurrence to road. In order to obtain landslide historical events, author has to observe landslide and discuss with local community deal with past landslide events. Data was also collected from

discussion with community leaders and key informants. Landslide observation include identify type of landslide and measure landslide morphometry (length, width, run out and soon) by using lacer ace. In order to ensure and measure the actual road network in the field, author has to do road tracking. Slope data in term of upper and lower road which was used to create micro slope can be measured by using suunto. In this stage, primary data deal with number of vehicle of a particular type was used to calculate indirect impact to road. The primary data of community perception related with the route alternative and fuel consumption can be obtained by using quisionere. In post fieldwork, it related with the finalization of the fieldwork result. Data was analyzed according to the objective of the research such as; constructing roads hazard zone, constructing roads vulnerability level, estimating direct risk and indirect risk impact.

## RESULT AND DISCUSSION

### Landslide Analysis

In this research, landslide density was used to determine which of road segment having highest susceptibility. The impact of landslide both of direct and indirect impact will be analyzed in this road segment. Among 21 road segments in Samigaluh District, segment 174 is a segment which has the highest in both value area and number density with the values are 71.17 m<sup>2</sup>/Ha and 1.30 event/Ha respectively. It is caused by the presence of steep slope, high rainfall intensity and fully weathered volcanic breccias rocks.

Only two types of landslides occurred in segment 174 that are dominated by debris slides (94.74 %) and 5.26 % of rock falls. The landslide areas ranging from 5.66 m<sup>2</sup> to 494.11 m<sup>2</sup> with the average is 54.56 m<sup>2</sup>. The average area of landslide in seg-

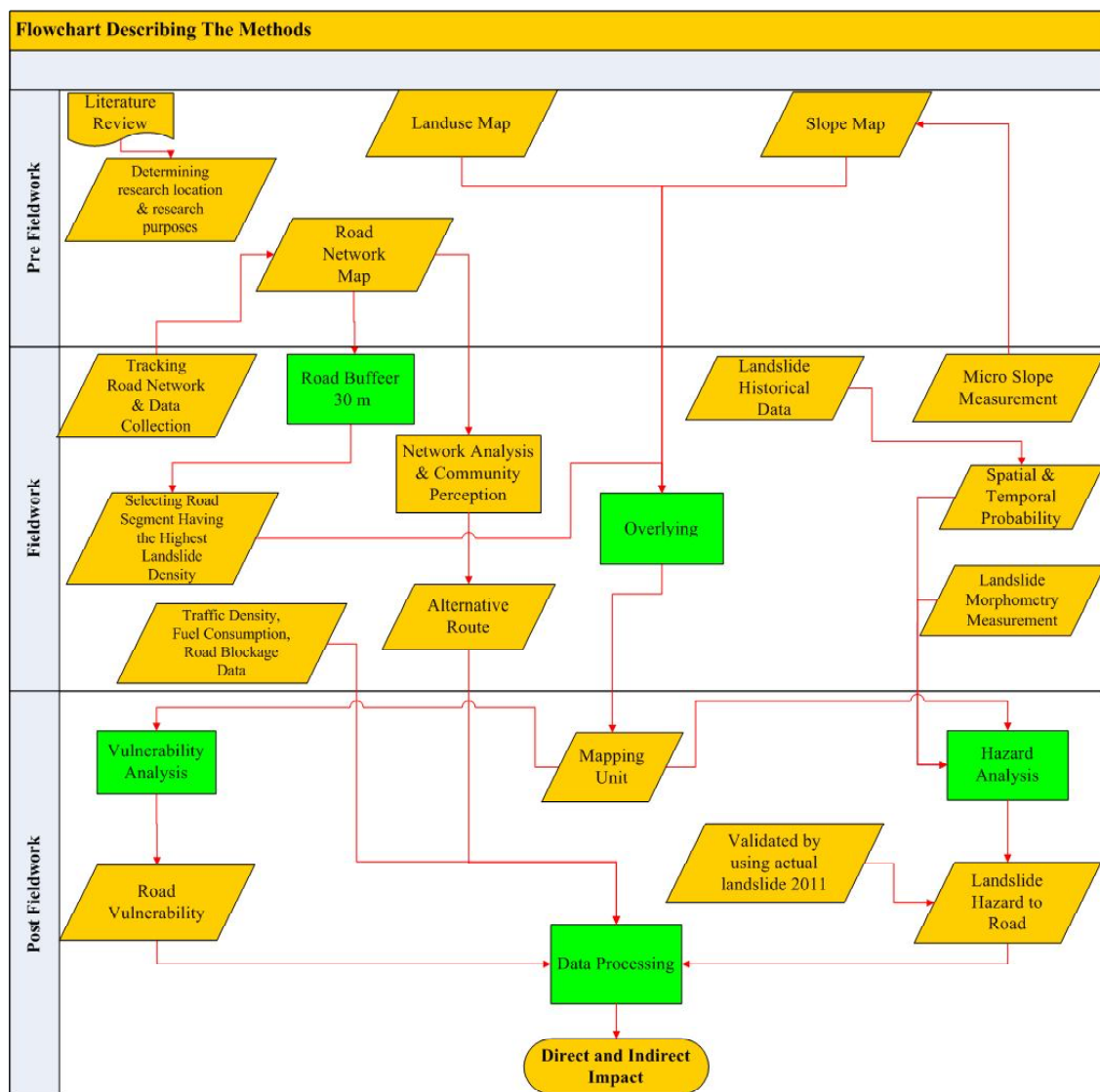
ment 174 reached the value of  $< 1000 \text{ m}^2$ . It means that based on Jaiswal's magnitude classification, the magnitude of landslide in road segment 174 is I. Temporarily, our data indicated that more than 80% of landslide events have been mostly concentrated on November, December, January, February, and March due to the maximum precipitation down pours during these periods. Meanwhile, spatially, The most of landslide events can be found in the 31<sup>st</sup>, 37<sup>th</sup>, 49<sup>th</sup>, 50<sup>th</sup>, 58<sup>th</sup>, 69<sup>th</sup> map-

ping units in which are located in steep slope ( $40^\circ$ - $50^\circ$ ) (Figure 3).

Landslide occurrences can be caused several factors which give slope failure contribution. Several factors which were determined as slope failure causing factor are slope, rainfall, lithology and landuse.

### Slope

It was used 2 slope types which are macro slope and micro slope. Macro slope was



Gambar 2. Research Framework

built from Digital Elevation Model (DEM), while micro slope can be obtained from direct measurement in the field by using suunto. The later was also used to build our mapping unit. This data indicates that the macro slope resulted from DEM (size pixel 30 x 30 m) has less detail than the micro slope result obtained from slope measurement. Actually, macro slope cannot be used to analyze the terracing system in the study area. Based on micro slope classification,. It shows that 86.88 % landslide areas are located on steep slopes (30°-50°). Landslides do not occur on gentle slope < 20°. About 2.27 % of landslides lie on slope class > 50°. which is relatively stable due to the presence of bed rock. Human interaction on this slope class is very limited due to the high degree of difficulty to access.

### Rainfall

Isohyets in the road segment 174 have a small range of values which has the minimum value 257.39 mm and maximum value 261.53 mm. That's why isohyets class was classified in one of isohyets classes which

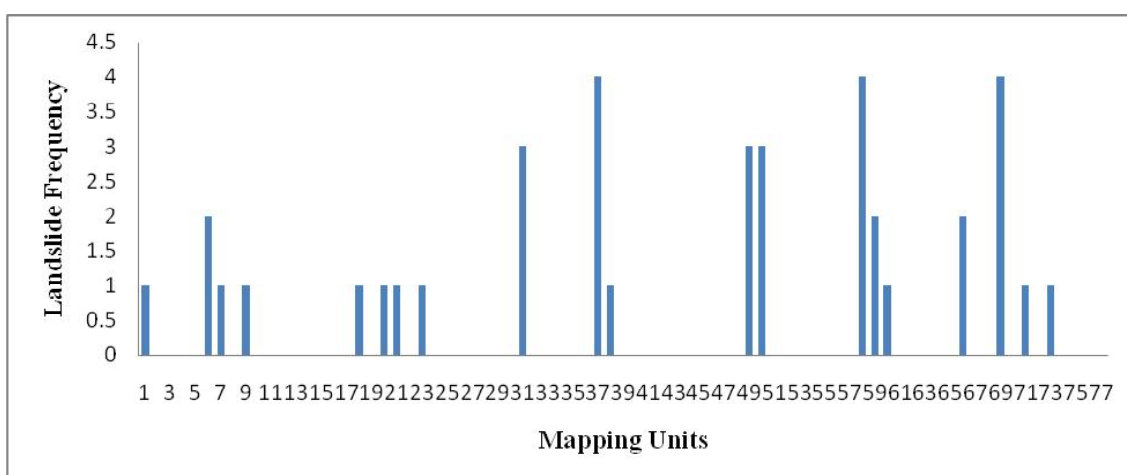
can be categorized as "Almost High Classes". Because of homogeneous rainfall value, spatially, rainfall factor is less significant than the other factors. However, temporarily, rainfall factor will influence landslide events.

### Lithology

Actually, Breccia rock types which have high degree of decomposition can be a potential factor of landslide. However, road segment 174 has one classes of lithology only which is Breccia. Because of the homogeneous of lithology class, spatially, lithology is less significant in road segment 174.

### Landuse

Landslides in the road segment 174 are widely distributed on mixed garden 49.12%, and respectively followed by rain feed paddy field 38.35%, settlements 12.53% and moor 0%. Usually, landslides occurred in mixed garden which has low vegetation density and shallow-fiber root vegetation. Bamboo and coconut trees have shallow and fiber roots in which this condition also can be found in rain feed



Source: analisis result

Figure 3. Spatial landslide distributions on Segment 174

paddy field. Thus these roots have a low ability to withstand landslides.

### Landslide Hazard

The highest hazard probability of debris slide of magnitude I is located in the 20<sup>th</sup> mapping unit for return period 1 yr, 3 yr and 5 yr which has 0.0188, 0.0512 and 0.0778 hazard probabilities respectively. This mapping unit experienced the biggest landslide which is 494.11 m<sup>2</sup> areas. Based on the information from local community, the biggest landslide lies on the bad irrigation system (situational condition in 2009), the medium vegetation density, and the steep slope 40°-50°. Because of steep slope and bad irrigation system on upper location, water flows down to the location and trigger big landslide in rainy season. It was worst by the presence of a road which is situated above the 20<sup>th</sup> mapping unit, so the vibration which is generated by vehicles can trigger landslide event. The lowest hazard probability of debris slide can be found in the 18<sup>th</sup> mapping unit which has 0.0001, 0.0002, and 0.0003 hazard probabilities respectively. The lowest hazard probability is caused by low probability in term of spatial and temporal in this mapping unit. The 18<sup>th</sup> mapping unit tends to more stable to landslide, because it is located on moderate slope 30°-40°, high vegetation density and having deep roots system. While, rock fall type which can be found in the 6<sup>th</sup> mapping unit for return period 1 yr, 3 yr and 5 yr has 0.0088, 0.0218 and 0.0305 hazard probability respectively.

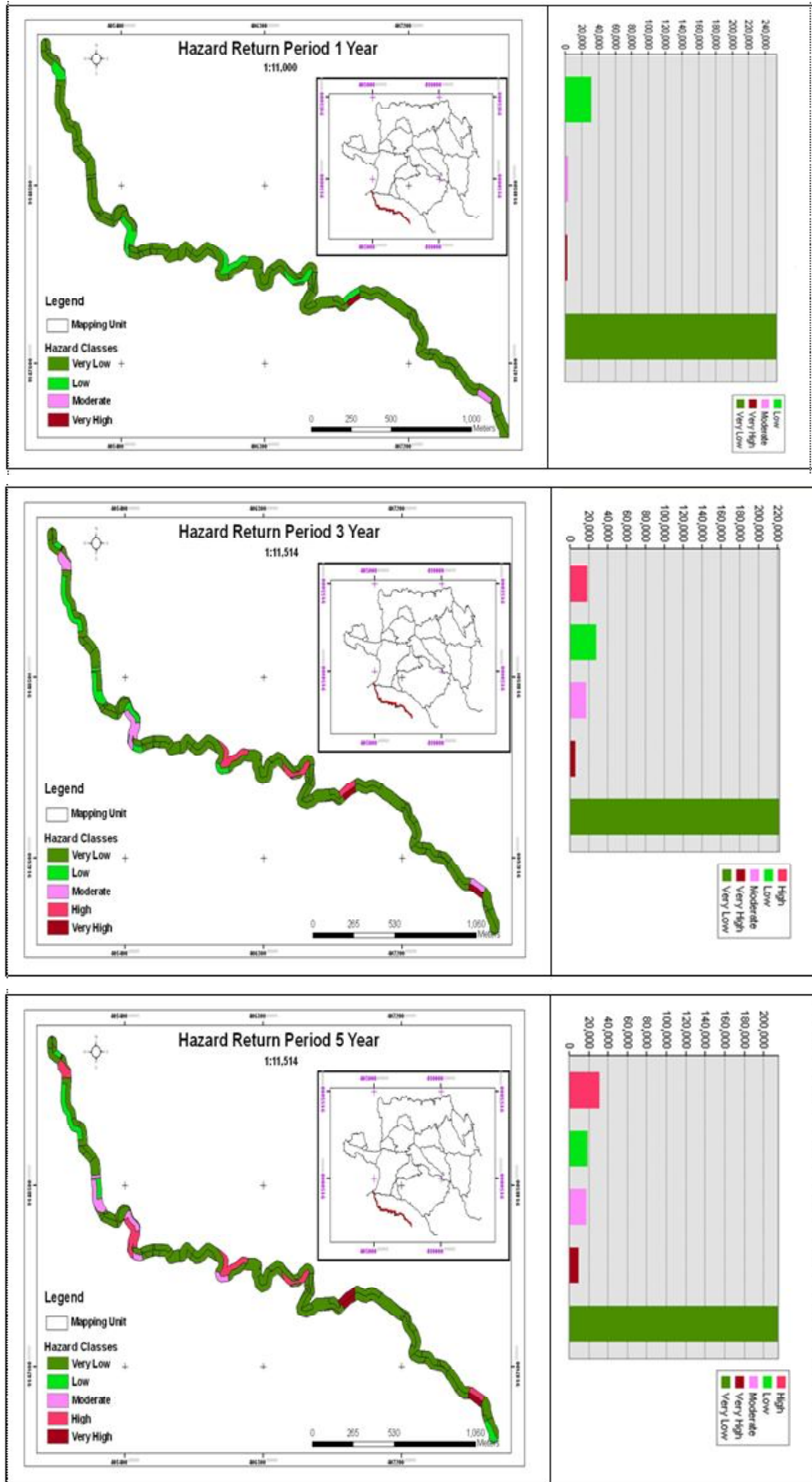
After class classification, landslides hazard return period 1 yr was distributed on the very low class 87.35 %, the low class 10.73 %, the moderate class 1.06% and the very high class 0.86% respectively followed by the high class 0%. Meanwhile, landslide hazard class for return period 3 yr are still dominated very

low class and followed by low class, high class, moderate class, and very high class which has percentage of 76.62%, 9.66%, 6.06%, 5.75%, and 1.92% respectively. The same trends still occurs in hazard return period 5 yr in which the percentage of moderate, high and very high class increase and followed by the decreasing of percentage of very low and low class compare with the hazard return period 1 yr and 3 yr. It means that the higher return period will result the higher hazard classes. It shows that the study area are still dominated by very low class and followed by high class, low class, moderate class, and very high class which have 74.06%, 10.56%, 6.39%, 5.83%, and 3.16% of total area respectively for the hazard return period 5 yr. It can be seen in Figure 4.

Based on these figure, although the higher return period will result the higher hazard classes but the most of hazard class for return period 1 yr, 3 yr and 5 yr is still dominated by the very low class. This condition compatible with the Jaiswal's Landslide Magnitude Classification that magnitude I have little landslide area or less spatial probability occurrence. As explained before, segment 174 has landslide magnitude which was categorized magnitude I. That's why, segment 174 has the very low hazard class.

Before calculating the risk impact, hazard must be validated by using the actual data of landslide occurrences in 2011 which have 20 landslide events. The distribution of landslides events (2011) in term of very low, low and very high class are almost equal which are more less 20% for the validation of the hazard return period 1 yr. For hazard return period 3 yr validation, the most of landslide events in 2011 are located in the high and very high classes which have percentage of 15.82% and 51.44% respectively. Meanwhile, hazard return period 5 yr validation in which the most of landslide occurrences can be found





Source: classification result

Figure 4. Landslide Hazard Map Return Period 1 Yr, 3 Yr and 5 Yr and Their Histogram After Classification

in the high (29.16%) and very high class (51.44%). Based on these data, the most of landslide events in 2011 are distributed in the high class and the very high class. It means that the hazard model can be used.

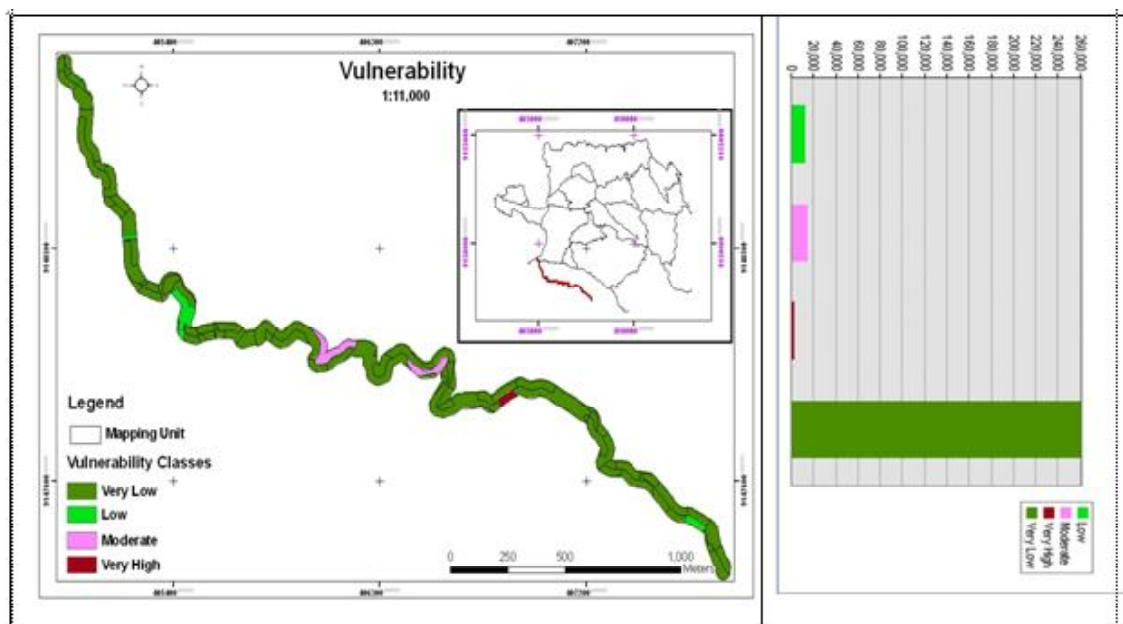
### Road Vulnerability

The highest road vulnerability lies on the 20<sup>th</sup> mapping unit which is 0.7133 road vulnerability. While, the lowest road vulnerability located in the 18<sup>th</sup> mapping unit which has 0.0018 road vulnerability. After classifying, road vulnerability segment 174 has 4 vulnerability classes only which are very low, low, moderate, and very high class and followed by the absence of high class. The very low class dominates road vulnerability class on segment 174 which can be found in almost of mapping unit. The low class can be found 4 times on segment 174 which are the 6<sup>th</sup>, 50<sup>th</sup>, 60<sup>th</sup> and 71<sup>th</sup> mapping units. The very high class located in the 20<sup>th</sup> mapping unit which has the highest of road vulnerability (Figure 5). Based on the Jaiswal's Landslide Magnitude Clas-

sification that magnitude I cause minor damage only. That's why the vulnerability class is dominated by very/low class.

### Direct Impact

The highest of direct impact of debris slide of magnitude I located in the 20<sup>th</sup> mapping unit which is Rp. 89,586.69, Rp. 243,995.46 and Rp. 370,414.67 for return period 1 yr, 3 yr and 5 yr respectively. It is caused the 20<sup>th</sup> mapping unit has the highest of hazard probability and road vulnerability among the other mapping units. The lowest of debris slide direct impact can be founded in the 18<sup>th</sup> mapping unit which has Rp. 0.04, Rp. 0.11 and Rp. 0.17 for return period 1 yr, 3 yr and 5 yr respectively. As explained before, the 18<sup>th</sup> mapping unit has the lowest hazard probability and road vulnerability among the others. Direct impact which was caused by rock fall type of magnitude I can be found in the 6<sup>th</sup> mapping unit only. The value of rock fall direct impact is Rp. 3,976.34, Rp. 9,897.32 and Rp. 13,866.27 for return period 1 yr, 3 yr and 5 yr respectively.



Source: classification result

Figure 5. Road Vulnerability and Its Histogram After Classification

After classifying, direct impact has 2 classes only which are very low and very high. Spatially, after classification, direct impact class for return period 1 yr, 3 yr and 5 yr and their histogram can be depicted in (Figure 6).

The most of mapping unit for return period 1 yr, 3 yr and 5 yr were categorized as the very low direct impact class which is 99.14% of total areas and 0.86% can be categorized as the very high direct impact class. It is caused by the low of road vulnerability and hazard probability for return period 1 yr, 3 yr and 5 yr.

### **Indirect Impact**

In this research, indirect impact was determined by road blockage which was caused by landslide. Because of road blockage, driver or commuter will find alternative road which has longer distance to reach public facility. This condition will cause the increasing of fuel purchases cost. Landslide indirect impact can be calculated by using equation 6 in (section 3.1.6.). This formula has several variables which are road blockage days, the number of vehicle of a particular type (traffic density), extend road alternative distance and fuel consumption. Road blockage data can be obtained from local community information. Based on community information, the biggest landslide for 10 years (2001-2010) which caused road blockage for 14 days located in the 20<sup>th</sup> mapping unit. Traffic density data were got by measuring at 6 measurement points simultaneously for 7 days. Alternative routes can be determined by using network analysis and community perception. Fuel consumption and community perception data can be obtained by community interviewing (questionnaire).

In this study, author used 2 scenarios of indirect impact by considering 2 methods which are network analysis and community perception methods. We can know that in-

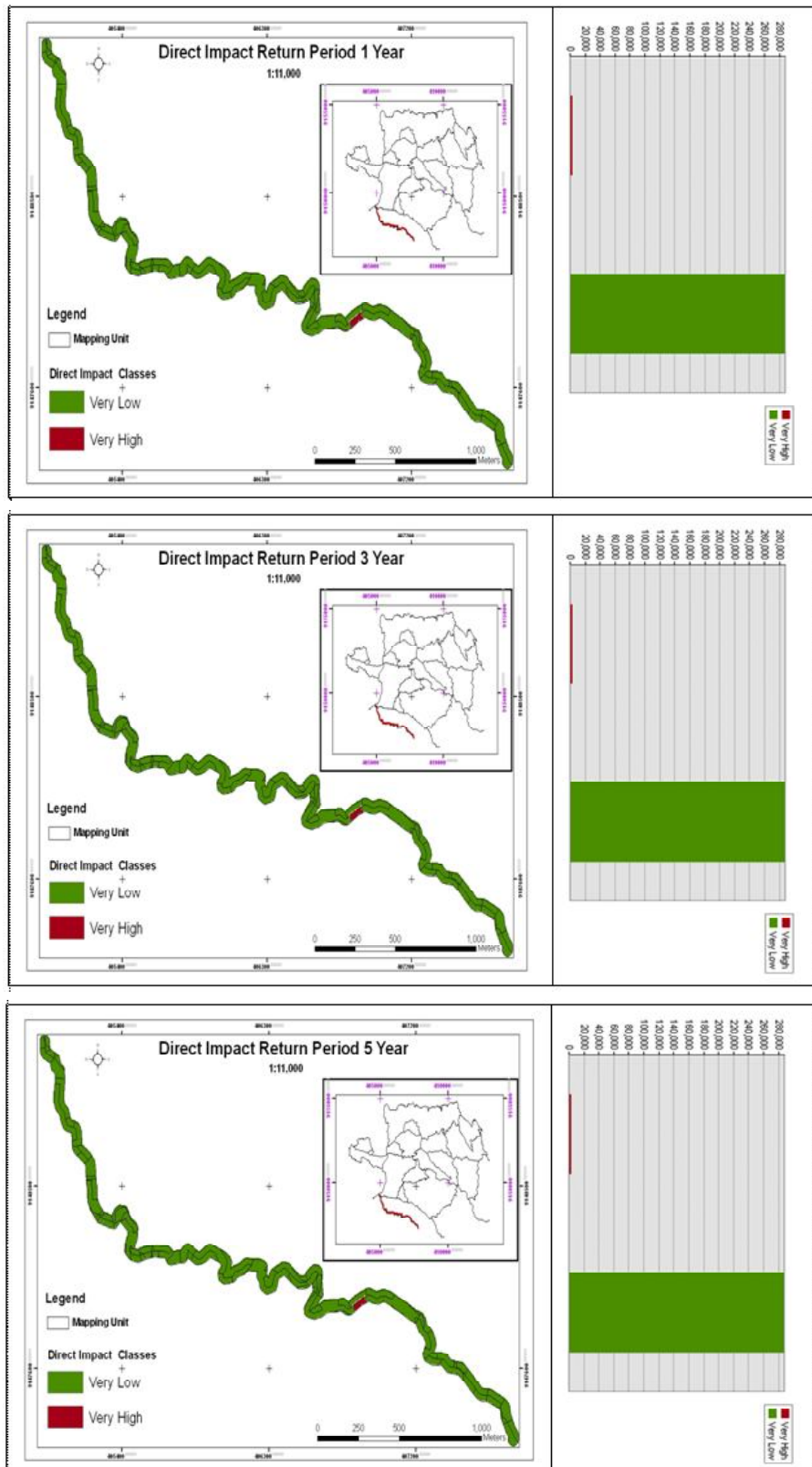
direct impact based on network analysis is Rp. 4,593,607.20. Meanwhile, total of indirect impact based on community perception is Rp. 4,692,794.40. Based on network analysis and community perception methods, the contribution of indirect impact is dominated by motor cycle and followed by truck and car which has percentage of 53.66%, 24.39%, and 21.95% respectively. This is caused by the highest traffic density of motor cycle among the other vehicle types. Because of many load, truck spends much fuel consumption than car. That's why, truck gives higher contribution than car.

There are the differences of indirect impact calculation which are Rp. 4,593,607.20 and Rp. 4,692,794.40 by using network analysis and community perception methods respectively. It is caused by the differences of alternative route determination. In the determination of alternative route (optimum route), network analysis considers the shortest of route distance only. While, community perception consider both of route condition and route distance.

## **CONCLUSIONS AND RECOMMENDATIONS**

### **Conclusions**

In this research, conclusions were made based on the research result and discussion in which the research objectives and research question will be answered. Several conclusions can be presented below by following the detail research objectives (in italic letter). (1) The first research objective is to assess level of landslide hazard to road. Road segment 174 is a segment which has the highest density of landslides in terms of landslide number and landslide area. This due to several condition such as; steep slopes in which 86.88% landslide occurred, the dominance of shallow-fiber root vegetation



Source: classification result

Figure 6. Direct Impact for Return Period 1 Yr, 3 Yr & 5 Yr and Their Histogram After Classification

and low vegetation density in mixed garden and rain fed paddy field type. Because of low ability to withstand landslides, 49.12% and 38.35% of landslide occurred in mixed garden and rain fed paddy field type, respectively. Breccia rocks which have high degree of decomposition can be a potential factor of landslide. Besides that, temporarily, rainfall factor will influence landslide events. Actually, debris slide type of magnitude I has the highest spatial probability of 0.1976 located in the 20<sup>th</sup> mapping unit and the highest temporal probability of 0.3297, 0.6988, and 0.8647 for return period 1 yr, 3 yr and 5 yr respectively situated in 3 mapping unit (i.e. 37<sup>th</sup>, 58<sup>th</sup> and 69<sup>th</sup>). Meanwhile, the rock fall type of magnitude I can be found in 6<sup>th</sup> mapping unit only which has the spatial probability of 0.0483 and the temporal probability of 0.1813, 0.4512 and 0.6321 for return period 1 yr, 3 yr and 5 yr respectively. The highest hazard probability of debris slide of magnitude I is located in the 20<sup>th</sup> mapping unit for return period 1 yr, 3 yr and 5 yr which has 0.0188, 0.0512 and 0.0778 hazard probabilities respectively. While rock fall type of magnitude I for return period 1 yr, 3 yr and 5 yr has 0.0088, 0.0218 and 0.0305 hazard probability respectively. Both debris slide and rock fall type have a tendency that the higher return period the higher hazard probability. After the hazard probabilities were classified, the most of hazard class is the very low hazard class. This condition compatible with the Jaiswal's Landslide Magnitude Classification that magnitude I have less spatial probability occurrence. That's why the hazard class is dominated by very low class. (2) The second research objective is to assess landslide vulnerability of road. The highest road vulnerability lies on the 20<sup>th</sup> mapping unit which is 0.7133 road vulnerability. Spatially, road vulnerability has 4 classes which are very low, low, moderate very high classes and followed by the absence of high class. The

very low class dominates road vulnerability class on segment 174 which can be found in almost of mapping unit. The very high class located in the 20<sup>th</sup> mapping unit only. Based on the Jaiswal's Landslide Magnitude Classification that magnitude I caused minor damage only. That's why the vulnerability class is dominated by very/low class. (3) The third research objective is to estimate the landslide direct impact to road. The highest of direct impact of debris slide of magnitude I located in the 20<sup>th</sup> mapping unit which is Rp. 89,586.69, Rp. 243,995.46 and Rp. 370,414.67 for return period 1 yr, 3 yr and 5 yr respectively. Meanwhile direct impact which is caused by rock fall type of magnitude I is Rp. 3,976.34, Rp. 9,897.32 and Rp. 13,866.27 for return period 1 yr, 3 yr and 5 yr respectively. After the direct impact was classified, the most of direct impact class is the very low class. It is caused by the low of road vulnerability and hazard probability for return period 1 yr, 3 yr and 5 yr. (4) The fourth research objective is to estimate the landslide indirect impact to road. Indirect impact was caused by road blockage in which driver or commuter will find alternative road to reach public facility (Balai Desa Kebonharjo and SDN Kebonharjo). Traffic density was measured by considering vehicles type which were dominated by motor cycle and followed by car and truck. In this research, author used network analysis and community perception to determine route optimum as alternative route. Due to the differences of alternative route determination, there are the differences of indirect impact calculation which are Rp. 4,593,607.20 and Rp. 4,692,794.40 by using network analysis and community perception methods respectively. The contribution of indirect impact cost is still dominated by motor cycle and followed by truck and car which has the contribution percentage of 53.66 %, 24.39% and 21.95% of indirect impact total respectively.

## Recommendations

(1) Local government must record continuously landslide data related with road damage and traffic density data. Those data can be used to determine the landslide risk zones and calculate the landslide impact to road. (2) For the next research, the indirect impact which relate with the disruption of economic activity, social, educational, delay in travel time can be considered in the indirect impact estimation. (3) In order to reduce landslide susceptibility, authorities have to conduct tree planting with the deep root vegetation.

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