GIS ANALYSIS FOR DETERMINING OF POTENTIAL LANDSLIDE AREA DISTRIBUTION PATTERN

A CASE STUDY IN SUMEDANG REGENCY WEST JAVA INDONESIA

Yosef Dwi Sigit Purnomo*, Ferrari Pinem

National Coordinating Agency for Surveys and Mapping (Bakosurtanal)

Jl. Jakarta Bogor KM 46 Cibinong INDONESIA

sigitpurnomo@bakosurtanal.go.id

ferrari@bakosurtanal.go.id

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ABSTRACT:

Landslide is one of disasters that occur frequently in Indonesia. It shows the natural reaction form of slope instability. Such unbalance is caused by natural factors as well as human factors. The natural factors include slope, lithology, rainfall, landuse, geology and the like consisting of slope cut, development over the slope, and also slope mining. The human factors are those that change stress condition and material strength. Landslide is usually made by the combined two factors. Conveying accurate information on the potential landslide areas will help to minimize their effects. One of efforts in identifying and determining the distribution, width, and characteristics of lindslide is research using geographic information system (GIS) technology, using quantitative and qualitative methods. Overlaying slope, lithology, landuse, and rainfall maps and their weigth will result a map of potential landslide areas. Consequently, overlaying the map of potential landslide area with geomorphological map will produce a geomorphology map of potential landslide areas. The general prediction of mass movement events is based on the principles that the number of landslides, which have occurred in the past within a terrain unit are good indication of what can be expected to occur in the future. Therefore, the map of distribution pattern of sensitive landslide areas is very important. This paper presents a reaserch works done in Sumedang Regency of West Java. The result shows that the potential landslides of the area are 2.83% very high, 19.23% high, 54.17% low, and the rest 23.77% are very low. The very high and high areas are located in structural hilly morphology, denudation, and volcano, in which the plantation, mixed garden, rice field and settlement dominate the landuse.

1. BACKGROUND

Factors that cause landslides can be grouped into two: natural factors such as geomorphology, lithology, slope, rainfall and landuse of a landscape and human activities such as agriculture, slope stress, slope cut, mining, etc.

The estimated number of landslide hazard areas in West Java are 276 locations in some places like Bogor, Puncak, Sukabumi, Cianjur, majalengka, and Sumedang. Sumedang Regency is one of regions that experiences landslide. Between 1987 and 2002 or more than 15 years, there have been 87 events of landslide recorded, distributed in districts and sub-districts in Sumedang Regency. Some areas in Sumedang that experince landslide often are the Districts of: Cimalaka, Cadasngampar, Darmaraja, Rancakalong, Sumedang Selatan, Sumedang Utara, Situraja, Tanjungsari, Tomo and Wado.

2. OBJECTIVE

The objectives of this research are

1. to study the spatial distribution of Landslide areas in Sumedang
2. to determine the area of landslide
3. to study the characteristics of the landslide areas

3. METHOD

The landslide areas in this reseach were determined from the total scores of four parameters within a unit area. Parameters of landslide can be seen in Table 1. The score of each parameter slope, lithology, rainfall and landuse was determined from the computation of weight according to van Westen (1993). The weight computation of a parameter that was developed by van Westen uses bivariate statistical analysis based on the frequency of event variable or the number of events in an area that is called the event density. The event density (D_{number}) is the ratio between the landslide events per kilometer square with the area of parameter where the landslide occurs (Westen, 1993:12).

$$D_{number} = \frac{1\times10^{6}}{Area(X_1)} \times Event(X_1)$$

where: Area (X_1) : Area of parameter class

The weight of parameter class (*Wnumber)* is the difference between,

$$W_{number} = \frac{1\times10^{6}}{Area(X_1)} \times Event(X_1) - \frac{1\times10^{6}}{\sum Area(X_1)} \times \sum Event(X_1)$$

One of the advantages of using GIS in determining the landslide area distribution is the ease to conduct spatial analysis. The spatial analysis is done to answer where and why the phenomena occurred. Hence the spatial analysis of landslide hazard answers the questions of where and why the distribution pattern of landslide area in Sumedang Regency. The validation of the result with the field condition is conducted by plotting the landslide events during 15 years period on a map that displays the distribution of landslide. Theoretically in areas that have very high – high results will have more points that indicate

* Corresponding author. sigitpurnomo@bakosurtanal.go.id

the landslide events than areas of low – very low results. All of the reseacrh steps can be illustrated in the following research diagram (Figure 1):

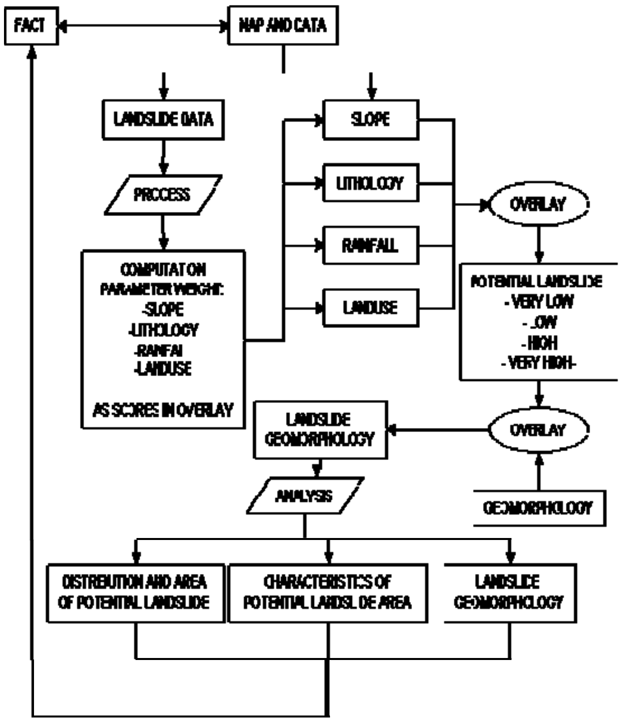

Figure 1. Research steps.

4. RESULT

4.1 Weight of Parameters

The weights of parameters of slope, lithology, rainfall, and landuse using the Event Density formula can be seen in Table 2.

No	(slope)	(rainfall)	(lithology)	(Landuse)
1	-28.71	-28.71	39.56	84.09
2	-20.84	-24.88	-10.44	63.00
3	-20.08	-11.18	51.47	-13.37
4	37.83	31.26	-22.47	5.65
5	41.01	61.29	8.12	8.12

Table 2. Parameter weight, event density method

4.2 Results of Parameter Class Interval Computation

Based on the highest and the lowest scores from the four parameters as well as the number of classes, the class interval can be defined as:

Class interval with event density method
Very low potential landslide : -110.63 to -23.50
Low potential landslide : - 23.51 to 63.15
Highly potential landslide : 63.16 to 150.74
Very Highly potential landslide : 150.75 to 237.86

4.3 Classification and Overlay Result Area

The overlay result of the four parameters using the event density weight method as seen in map 1 produce four classes of landslide areas (Table 3).

Table 3 shows that the area of very highly potential landslide following the overlay using the event density method is the smallest area compared to other three. The high landslide area is the second and the low potential landslide area is the largest.

No	SLOPE	RAINFALL (mm/year)	LITHOLOGY	LANDUSE
1	0°-3°	<1500	volcanic breccia, undecomposed volcanic rocks, silt rocks, subang rock formation, cinambo formation	Garden/ Mixed garden
2	3°-8°	1500 - 2000	tufa, tufa lapili, tufa breccia, volcanic breccia, silt rocks with sand stones, kaliwungu formation sand stones, volcanic breccia, holosenvolcanic rocks, tufa sand stones, lava breccia, volcanic breccia	Settlement
3	8° - 15°	2000 –2500	tufa and tufa sand stones, tufa sand stones and lava, volcanic breccia, andesite lava, lava breccia, ancient volcanic deposits, volcanic breccia, volcanic rocks, silt rocks and tufa sand stones.	Bushes
4	15° - 30°	2500 - 3000	Volcanic breccia	Dry Agricultural Field
5	>30°	>3000	Tufa breccia, tufa sand stones, tufa	Paddy Field

Table 1. Parameters of landslide

No	Classification	Area (Ha) Event Density Method	Percentage (%) Event Density Method
1	Very Highly potential landslide	4442	2.83
2	Highly potential landslide	30143	19.23
3	Low potential landslide	84910	54.17
4	Very low potential landslide	37257	23.77

Table 3. Area of each class of landslide potential area

4.4 Landslide distribution

The distribution of potential landslide area resulting from the overlay of slope, lithology, rainfall and landuse can be seen in map 1 (Fig. 2). The landslide distribution is not bounded by the administrative data, so that one administrative area of district may have two or more than landslide classes. The complete data can be seen in Table 4.

No	Classification	Location (Event Density Method)
1	Very Highly potential landslide	Jatigede, Jatinunggal, Tomo, Cimalaka, Buahdua, Surian, Cisarua, Sumedang Utara
2	Highly potential landslide	Cibugel, Sumedang Selatan, Jatinunggal, Tomo, Conggeang, Buahdua, Surian, Cimalaka, Cimanggung, Jatinangor, Situraja,Cisitu
3	Low potential landslide	Jatinunggal, Ujungjaya, Paseh, Tanjungkerta, Tanjungmedar, Pamulihan, Rancakalong, Sukasari, Tanjungsari, Jatinangor, Sumedang Selatan
4	Very low potential landslide	Wado, Darmaraja, Jatinangor, Ujungjaya, Tanjungkerta

Table 4. Distribution of Landslide Areas

5. DISCUSSION

The plotting result of 45 events for the landslide area can be seen in Table 5 and figure 3.

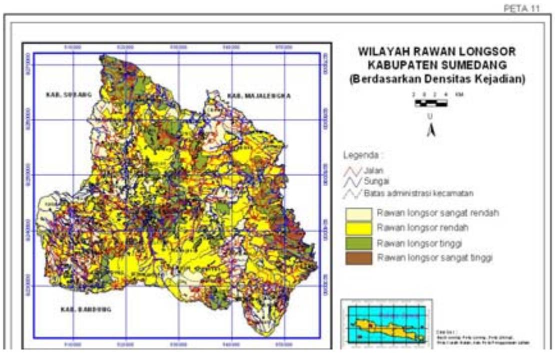

Figure 2. Distribution of Landslide Areas

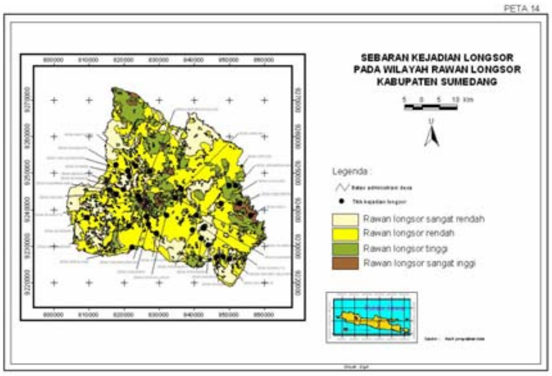

Figure 3. Plotting of 45 Landslide Events

The plotting result of 45 event data on the map of potential landslide is used assess the difference between field data and overlay result. It shows that there are similarity between the field data and the landslide potential distribution from overlay. Landslide occurs in most of the region using each class as follows: there are 9 events in very highly potentail landslide, 20 for high, 9 for low and 6 for very low. Note that there are some locations that have more than one landslide events.

There was difference between field data and analysis result. Some of Cibugel, Surian, and Buah Dua District are highly potential landslide areas but there was no data about landslide events. This may be because Cibugel and Buah Dua are two areas that are located in the middle slope and under a volcano; and Surian is located in structural hilly area (anticline and fault). Geomorphologically the two areas have slope, lithology and rainfall that give potential for landslide. The fact that there was no record of landslide events in those areas may be caused by the slope of the landuse and/or the water system are still in good condition and managed well by the local society so that the slope is still stable. In thoses cases Cibugel, Buah Dua, and Surian can be classified as potential landslide areas.

NO	SUBDISTRICT	DISTRICT	SLOPE	LITHOLOGY	LANDUSE	RAINFALL	NUMBER OF EVENTS	AREA (Ha)
1	CIKAREO SELATAN	WADO	>30	As(cs)	MIXED GARDEN	<1500	1.00	137440.500
2	MULYAJAYA	WADO	>30	As(cs)	BUSHES	<1500	1.00	418585.200
3	SUKAMELANG	WADO	0-3	BX,LH/B	SETTLEMENT	<1500	1.00	4676602.000
4	MARUYUNG	TANJUNGSARI	0-3	R(mc)(cm)	SETTLEMENT	<1500	1.00	154556.000
5	SUKASARI	TANJUNGSARI	0-3	R(mc)(cm)	SETTLEMENT	<1500	1.00	154556.000
6	CITENGAH	SUMEDANG SELATAN	15-30	BX,LH/B	GARBEN	>3000	1.00	14062140.000
7	GUNASARI	SUMEDANG SELATAN	15-30	BX,LH/B	CANAL AREA	>3000	2.00	65120.000

8	PASANGGRAHAN	SUMEDANG SELATAN	>30	R(mc)(cm)	SETTLEMENT	>3000	2.00	246199.000
9	MARGAMEKAR	SUMEDANG SELATAN	15-30	R(mc)(cm)	GARDEN	>3000	4.00	1044598.000
10	SINDULANG	CIMANGGUNG	15-30	An/Lv.An	DRY AGRI. FIELD	1500-2000	1.00	862455.600
11	CIJEUNGJING	CADASNGAMPAR	0-3	As(cs)	SETTLEMENT	2000 -2500	2.00	9834209.000
12	PAJAGAN	SITURAJA	15-30	AN/Lv.AN	MIXED GARDEN	2000-2500	1.00	344789.100
13	CISALAK	CIMALAKA	8_15	AN/Lv.AN	PADDY FIELD	2000-2500	1.00	115303.800
14	KADU	CADASNGAMPAR	>30	Bp	PADDY FIELD	2000-2500	2.00	215450.100
15	CIMANINTIN	CADASNGAMPAR	15-30	Bp	GARBEN	2000-2500	2.00	3410477.000
16	CIPELES	TOMO	15-30	CS/BI	SETTLEMENT	2000-2500	1.00	2167623.000
17	CISAMPIH, CIJEUNJING	JATIGEDE	15-30	As(cs)	MIXED GARDEN	2000-2500	1.00	65140.000
18	CISOKA (PRKBN TEH MARGA WINDU)	RANCAKALONG	>30	R(mc)(cm)	PLANTATION	2000-2500	1.00	215475.100
19	SUKAMAJU	RANCAKALONG	15-30	R(mc)(cm)	RAIN COAT	2000-2500	3.00	2385567.000
20	NEGARAWANGI	RANCAKALONG	15-30	R(mc)(cm)	BUSHES	2000-2500	1.00	373127.000
21	CIKURAY	RANCAKALONG	15-30	R(mc)(cm)	BUSHES	2000-2500	1.00	3257016.000
22	JEMBARWANGI	TOMO	15-30	S,LP/Ps (Lp)	SETTLEMENT	2000-2500	1.00	9572448.000
23	CIBEUREUM KULON	CIMALAKA	8_15	SS,LP	GARBEN	2000-2500	1.00	2215687.000
24	NEGLASARI	DARMARAJA	>30	BX,LH/B	FOREST	2500 -3000	1.00	10022630.000
25	TANJUNGMEKAR	TANJUNGKERTA	0-3	BX,LH/B	BUSHES	2500-3000	1.00	44874.250
26	PASIR MUKTI	DARMARAJA	15-30	BX,LH/B	FOREST	2500-3000	1.00	19737340.000
27	DAYEUH LUHUR	SUMEDANG UTARA	15-30	BX,LH/B	MIXED GARDEN	2500-3000	1.00	429811.100
28	MEKARJAYA	SUMEDANG UTARA	15-30	BX,LH/B	PADDY FIELD	2500-3000	1.00	320575.400
29	KUBANG	TANJUNGKERTA	8_15	BX,LH/B	BUSHES	2500-3000	1.00	249133.000
30	SUKAMUKTI	TANJUNGKERTA	>30	R(mc)(cm)	RAIN PADDY FIELD	2500-3000	1.00	316409.500
31	SUKALUYU	SUMEDANG UTARA	15-30	R(mc)(cm)	RAIN PADDY FIELD	2500-3000	4.00	1107410.000
32	BANYUASIH	TANJUNGKERTA	8_15	R(mc)(cm)	BUSHES	2500-3000	1.00	669395.600

Table 5 Distribution of Landslide Events.

6. CONCLUSION

Based on this reseach, the study and discusion of potential landslide area in Sumedang Regency, some conclusion can be drawn:

1. The very highly and highly potential landslide have the least (22%) area compared to the low and very low potential landslide area. The areas are well distributed in the eastern, northern, souther and central parts of Sumedang Regency.
2. The high and very high categories of potential landslides tend to occur in area with structural hill characteristics (fault and anticline), eroded hills and middle slope volcano.
3. The landslide events during more 15 years were always started with rain, however this can not be interpreted that when it rains then landslide will happen.
4. Human intervention on slopes which are steeper tends to increase the events of landslides.

The interesting matter that can be done for further research is about the chance of an area for landslide to occur when there is rainfall in Sumedang Regency.

REFERENCES

Aronoff, S. 1989. *Geographic Information System*: A Management Perspective, WDL Publication, Ottawa.

Djamaluddin Ridwan. 1993. *Terrain Mapping And Mass Movement Hazard Zonation Using Remote Sensing And Geographic Information Systems In Cimahi-Padalarang Area, West Java, Indonesia*, Thesis, International Institute for Aerospace and Earth Sciences (ITC), Enschede, The Netherlands

Dikau Richard, Denys Brundsden Lothar Schfott and Maia – Laura Ibsen.1996. *Landslide Recognition, Identification, Movement and Causes*. John Wiley & Sons.

Eckel, Eb (Ed) ed .1958. *Landslide and Engineering Pratice*, Highway Research Board Special.

Nitihardjo Sugiharto, Suranta, Sugalan. 2000. *Peta Zona Kerentanan Gerakan Tanah Lembar Kebumen dan Sekitarnya Jawa Tengah*, Direktorat Tata Lingkungan Geologi dan Kawasan Pertambangan. Indonesia.

Van Westen,.1993. *Aplication of Geographic Information System to Landslide Hazard Zonation*, ITC Publication No 15, Enschede.