LANDSLIDE HAZARD ASSESMENT ON JAVA ISLAND
Case Study: Landslides In Warungkiara, Bogor, Majalengka, Banjarnegara And Jember

KAJIAN BENCANA TANAH LONGSOR DI PULAU JAWA
Studi Kasus: Tanah Longsor Di Warungkiara, Bogor, Majalengka, Banjarnegara Dan Jember

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Abstract

All of landslides recorded in Indonesia between 2003 – 2006, 90% of the events occurred on Java Island, Indonesia. Due to lack of long term statistical data, their characteristics are not well known. Based on the analysis of climate, geology, topography and landslide statistical data, the landslide characteristics on Java Island can be ascertained. It can be concluded that the frequency of occurrences of landslides are highest in the southern part of the West Java Province, followed by the Central Java Province and the East Java Province.

Landslides on Java island can be classified based on their triggering factors, which comprise: rainfall, morphology, earthquakes, lithology, and the occurrence of active faults. As far as types of landslides are concerned, rockslides and toppling are rather rare, while most landslides are of the sliding (translation, rotation, block failure), creeping and debris flow types. The materials involved in landslides comprise weathered volcanic breccia, sedimentary material mixed with clay, mudstone, sandstone, limestone, marl and pyroclastic (deposits of volcanic ash and tuffaceous sand) and loam.

Landslide events significantly occur in the rainy season, especially from December to April. Dead and missing victims by landslides increase when annual rainfall is in excess of 2100 mm. In this paper, with reference to the above mentioned factors and conditions, type of landslide prone areas and countermeasures will be discussed.

Keywords: Landslide hazard, Java Island, classification, statistical data analysis.

Abstrak

Sebagian besar data tanah longsor di Indonesia antara tahun 2003-2006 yang tercatat , hampir 90% terjadi di P.Jawa. Kekurangan data tanah longsor dalam perioda yang panjang, menyebabkan karakteristik tanah longsor tidak dapat diketahui dengan baik. Akan tetapi berdasarkan integrasi analisis iklim, geologi, topografi dan data statistik tanah longsor, maka karakteristik tanah longsor di P.Jawa dapat diketahui. Selanjutnya dapat disimpulkan bahwa frekuensi kejadian tanah longsor yang paling tinggi ada di bagian selatan Propinsi Jawa Barat, kemudian diikuti di Propinsi Jawa Tengah dan Propinsi Jawa Timur.

Tanah longsor di P.Jawa dapat diklasifikasikan berdasarkan faktor pemicunya, yaitu curah hujan, morfologi, gempabumi, litologi, dan adanya patahan aktif. Sejauh ini tipe tanah longsor yang terjadi sebagian besar berupa gelinciran material rombakan (translasi, rotasi dan block failure), rayapan serta aliran massa. Sementara itu gelinciran batuan (rocksliding) dan toppling agak jarang ditemui.

Material longsoran umumnya terdiri dari breksi volkanik lapuk, material sedimen yang bercampur dengan lempung, lumpur, batupasir, batugamping, napal dan piroklastik (endapan abu volkanik dan pasir tufaan) dan loam. Tanah longsor secara signifikan terjadi pada musim hujan terutama dari Desember sampai April. Korban meninggal dan hilang karena bencana tanah longsor semakin bertambah bilamana curah hujan tahunan melebihi 2100 mm. Makalah ini menguraikan daerah rawan tanah longsor dan cara penanggulangannya berdasarkan kondisi dan faktor-faktor yang diuraikan tersebut diatas.

Kata kunci: bencana tanah longsor, Pulau Jawa, klasifikasi, analisis data statistik.

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Introduction

Over the past centuries many natural disasters, especially landslides, have affected the islands of Indonesia, particularly on Java island. These disasters occurred due to the specific geological and weather conditions. However, the lack of long period disaster records and the minimal amount of systematic research effort, combined with the lack of financial resources, have led to a limited capability to prevent and mitigate these disasters. The occurrence of many recent landslides and their resulting material and human losses reflect this limited response capability. Although general descriptions and reports of landslides are available, no systematic landslide research efforts for Java using long period records have been conducted up to date.

For a better understanding of landslide hazard phenomena and their mechanism, as well as for the purpose of adequate hazard prevention and mitigation, such detailed investigations are a necessary. As an entry point for gaining an understanding of landslide problems affecting Indonesia, this study is focused on Java. There is a rapid increase of population and land use development on this island. About 60% of the Indonesian population is living on this island (BPS, 2000), which has caused environmental problems, such as land use changes and uncontrolled development of hilly areas. Furthermore, 70% of the dead and missing in Indonesia are caused by landslides which have occurred on this island (Surono, 2006).

Surono (2006) has described the landslides which have occurred in some provinces of Indonesia during 2003 – 2006 and the resulting victims. Karnawati (2003) has elaborated on rain-induced landslides on Java Island. Rain-induced landslides in several locations in the vicinity of the Yogyakarta area on Java island have also been discussed by Long and Karnawati (2006) and Tu *et al*. (2006). Distribution of landslide sites which occurred on this island has been extended in the technical report of Geotechnology-LIPI (2005), Subowo *et al*. (2001) and Djamal and Sukatja (2001). Utomo *et al*. (2006) has attempted to investigate the landslides on Java island based on the observation of landslide data occurred in several places in the island. A study on seismic hazard assessment relevant to landslide has been explained by Yeats *et al*. (1999).

The objective of this study is to gain a better understanding of landslides affecting the whole of Java island, and for this purpose analyses of the geological landslide characteristics, climatic conditions, geomorphology, land use and time series of data analysis of landslide events have been integrated.

A Brief Overview of Studys Area

This research mainly carried out in Java Island, especially in the area prone to landslide hazard with significant toll such as in Warungkiara-Sukabumi, West Java, in Majalengka, West Java, in Babakan Madang-Bogor, West Java, Bajarnegara, Central Java, and Jember, East Java.

Landslide at Warungkiara in 1998 causing the closing of the main road of economically vital in Sukabumi and Southern West Java in general. About 700 to 1000 vehicles carrying goods every day during the working days and 1000 to 1500 vehicles during the weekend or holidays can not use this road for about one to two weeks (Transportation Service of Sukabumi Regency, 1998).

In Majalengka and Babakan Madang area-Bogor, West Java and Banjarnegara in Central Java landslides frequently occurring causing life toll. The landslide prone in those areas covering wide areas and lot of inhabitant should be evacuated when landslide occur. In Jember - East Java, landslide rarely occurring but during the continuously heavy rainfall of 5 days with total 536 mm rain in the end of December 2005 till 1 January 2006 huge landslide occurred followed by flooding. In this big disaster many life lost and also wealth.

Methodology

This research was carried out by analyzing the climate, geology, topography, earthquake, statistical data of landslide frequency, landuse and lost of life and goods related to landslide disaster in general in Java island, and representative analysis were made to the landslides of Warungkira, Majalengka, Babakan Madang (West Java), Banjarnegara, Central Java and Jember, East Java.

Results and Discussion

Climatic conditions

Java Island experiences heavy rainfall mainly from November to April during which period of many geological hazards, particularly landslides, occur over the whole island. However, the lack of long

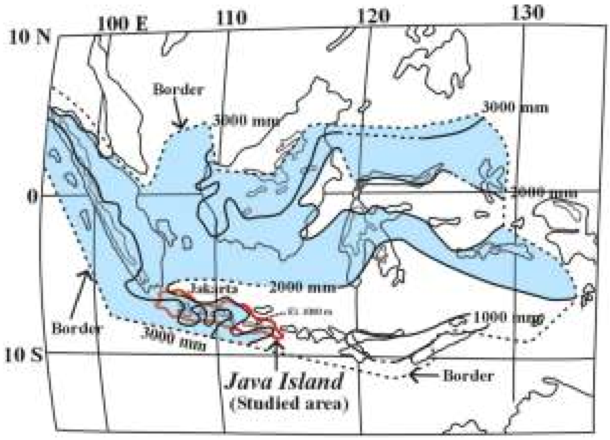

Figure. 1 Mean annual rainfall distribution in mm (millimeter) whole over the Indonesia. (Eguchi, 1983). Shaded area: more than 2,000 mm precipitation. Contour line shows 1,000 mm high

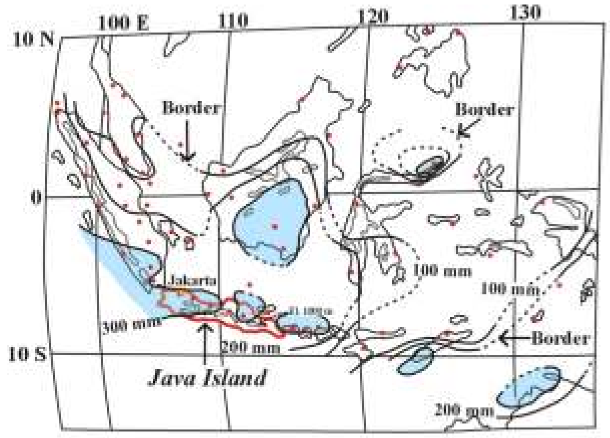

Figure. 2 Monthly rainfall distribution in January 1979 (Eguchi, 1983). . (Unit: mm., Dot : station, Shaded area: more than 300 mm precipitation)

period weather records, a dense network of weather stations, and the diverse topographic conditions, makes it difficult to present a coherent and detailed picture of the weather conditions.

Java Island is located in the area affected by the western wind which originates in the Indian Ocean. Figure 1 shows the mean annual rainfall (in mm) for the whole of Indonesia. This figure. shows that Java is located within the 2,000 to 3,000 mm contour of annual precipitation. On the islands to the East of Java, annual precipitation is less than 2,000 mm. This kind of phenomenon is basically dependent on the seasons and the geographical location of the areas.

According to a sample record of monthly precipitation for the rainy season as shown in figure 2, the areas receiving more than 300 mm precipitation in January cover the whole of West Java and the higher altitude areas of Central Java. On the other hand, in the dry season, as shown in figure 3, areas with a monthly precipitation of more than 100 mm only occur in the higher mountainous area of West Java. Figure 1 to 3 have been quoted and redrawn from Eguchi (1983). As this observation covers temporal and wide area phenomena, they are quite useful for a better understanding of the whole of Indonesia.

For the preparation of a more detailed rainfall map of Java Island, data covering the recent decade have been collected and figure 4 shows the mean annual rainfall for the period between 1993 and 2002. In this figure, it can be seen that the monthly precipitation record for Jakarta in West Java and Semarang in Central Java shows heavy rainfall

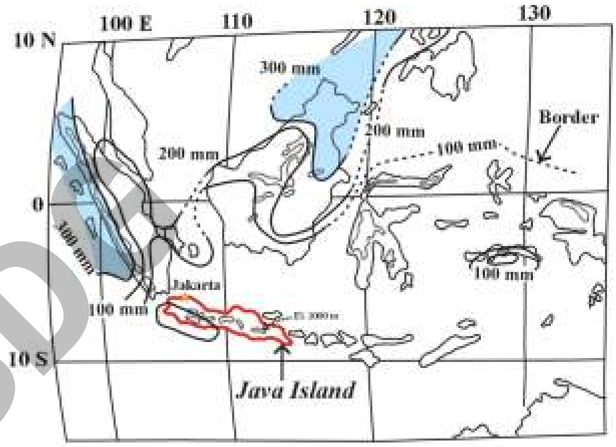

Figure. 3 Monthly rainfall distribution in July 1979 (Eguchi, 1983).

generally starting in November and ending in April. From the viewpoint of landslide hazards, precipitation represents the main trigger agent, besides geology, earthquake and topography. Hence we might expect that landslides might occur frequently in West Java and the areas where annual rainfall exceeds 2000 mm, due to above mentioned factors.

Figure 5 provides useful information of the potential landslide sites on Java Island, and represents a useful map for the planning for prevention and mitigation of such kind of natural disasters. Apparently, locations of potential landslide coincide with areas within the annual rainfall contour of more than 2000 mm. In this figure, several sites of landslide area (designated by arrow) will be discussed.

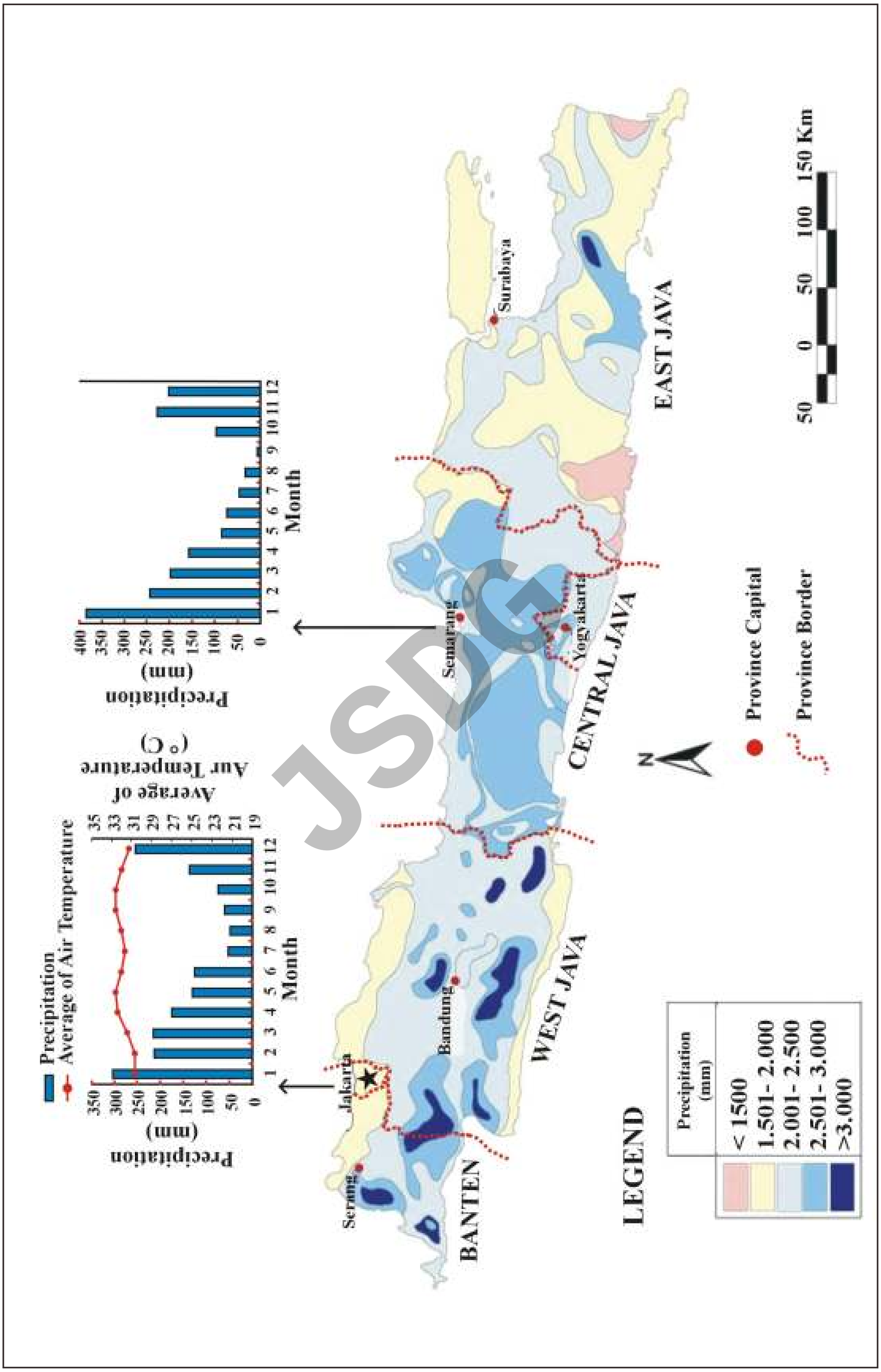

Figure 4. Mean annual rainfall map of Java island, period of 1993 – 2002 (Source : Indonesian Agricultural Research Agency, 2002)

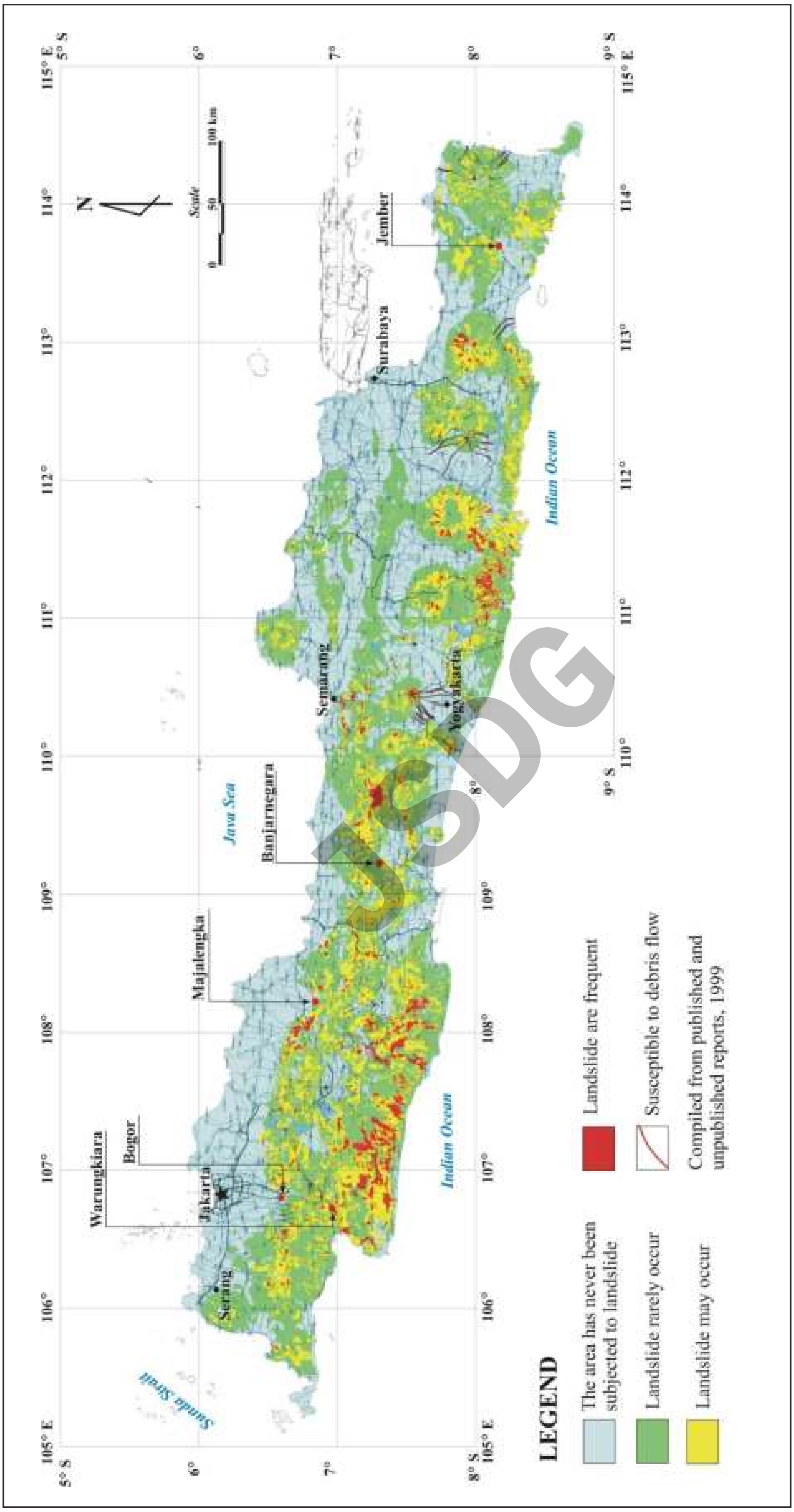

Figure 5. Location of study areas and landslide potential map of Java island (Source : DVMGH, Ministry of Energy & Mineral Resources)

Geological setting.

Figure 6a and 6b show the locations of landslides (6a) and faults (6b) on the simplified geologic map of Java. Depending on the nature of the bedrock, six different geological units have been identified, as shown on the legend on figure 6b, respectively: Alluvial Deposits, Young Volcanic Deposits, Tertiary Marine Sediments (intensely deformed), Tertiary Marine Sediments (dominantly volcaniclastics), Tertiary Marine Sediments (dominantly limestone), Pre-Tertiary Rocks.

On figure 6a shows that landslides mainly occur in the southern part of West Java, the central part of Central Java, while the occurrence in East Java is distributed over the central and the southern part of the area. Most landslides are located in the West Java and Central Java Provinces. In the West Java Province, the landslides mainly occur in areas underlain by marine volcaniclastic sediments. In Central Java, the landslides mostly occur in those areas where the bedrock has undergone intensive folding and faulting. In the East Java Province, the dominant landslide prone areas are those underlain by strongly weathered limestone and young volcanic products, with some sparsely distributed landslides occurring in other areas of the southern part of the province.

In West Java landslides occur in areas with a steep-sloped topography and are usually not of large scale. The triggering factors comprise heavy rainfall and frequently also earthquakes. In Central Java, heavy rainfall represents the main triggering mechanism for landslides, the occurrence of which is dominantly in areas of which the geology is characterized by intense folding and faulting. The controlling factor for the generation of landslides in East Java is rainfall, the landslides frequently being of a relative huge scale.

Figure 7 shows the landslide events in Java island during 2003 – 2006 (until March). The types of landslides which can be recognized include landslides due to bed rock characteristics, landslide due to slope, and/or located within the susceptibility zone; which mainly comprise sliding, creeping and a mixture between sliding and debris flow (Fig. 7a). Material components of these landslides consist dominantly volcanic breccia, clay, sandstone and tuffaceous soil s (Fig.7c). These materials are weathered and permeable and laid in many slopes of soils in Java island where landslide occur. The infiltrated rain water can penetrate these materials but it cannot penetrate further down through more impermeable rocks. As a consequence, the accumulation of infiltrated rain water in the weathered of slopes causes the water table rise and reduces shear strength in the contact between the weathered layer and the underlain more impermeable rocks. From the topographic point of view, landslides mainly occur in areas with a slope in excess of 300 covering 65% of the events (Fig. 7b). The occurrence of debris flow can be considered to be triggered by these factors. The low susceptibility zone of landslides covers only 2% of the island (Fig. 7d).

Statistical data of landslide disaster

Landslide hazards often occurred on Java island. However, statistical investigations are quite few (Surono, 2006), and no systematical landslide research work through long period record have been conducted up to date.

Table 1 shows landslide hazard events which have occurred in each province of Indonesia during 2003 to 2006. As it has been discussed earlier, damages due to landslides are most prominent on Java.

Figure 8 shows a time-series of (a) landslide events, (b) number of damaged buildings, and (c) number of deaths and missing persons for the period 1980 to 2006. In figure 8a over time a gradual increase in number of landslides have been observed. It is also shown that an extreme number of landslide events occurred in 1998. This correlates also with the highest number of damaged buildings in 1998 as shown in figure 8b. These facts can be correlated with the high number of earthquakes at the end of 1997 (Fig.11). Damaged houses frequently appear with landslide after earthquakes.

Furthermore, there is a significant record of death and missing persons, representing the victims of landslides in 2006 as shown in Figure 8c. This might be considered to be due to a combination of extreme number of earthquakes since 1973, landslide events and a twenty yearly heavy rainfall at the end of 2006. Detailed relationship between death and missing (DM) and landslide events (E) is shown in figure 9. From this figure. it could be concluded that there is no special relationship between DM and E before DM reaches 50, but as a whole the relationship is relatively non-linear.

Earthquake frequency.

As mentioned above, the number of dead and missing can be correlated with high earthquake frequency.

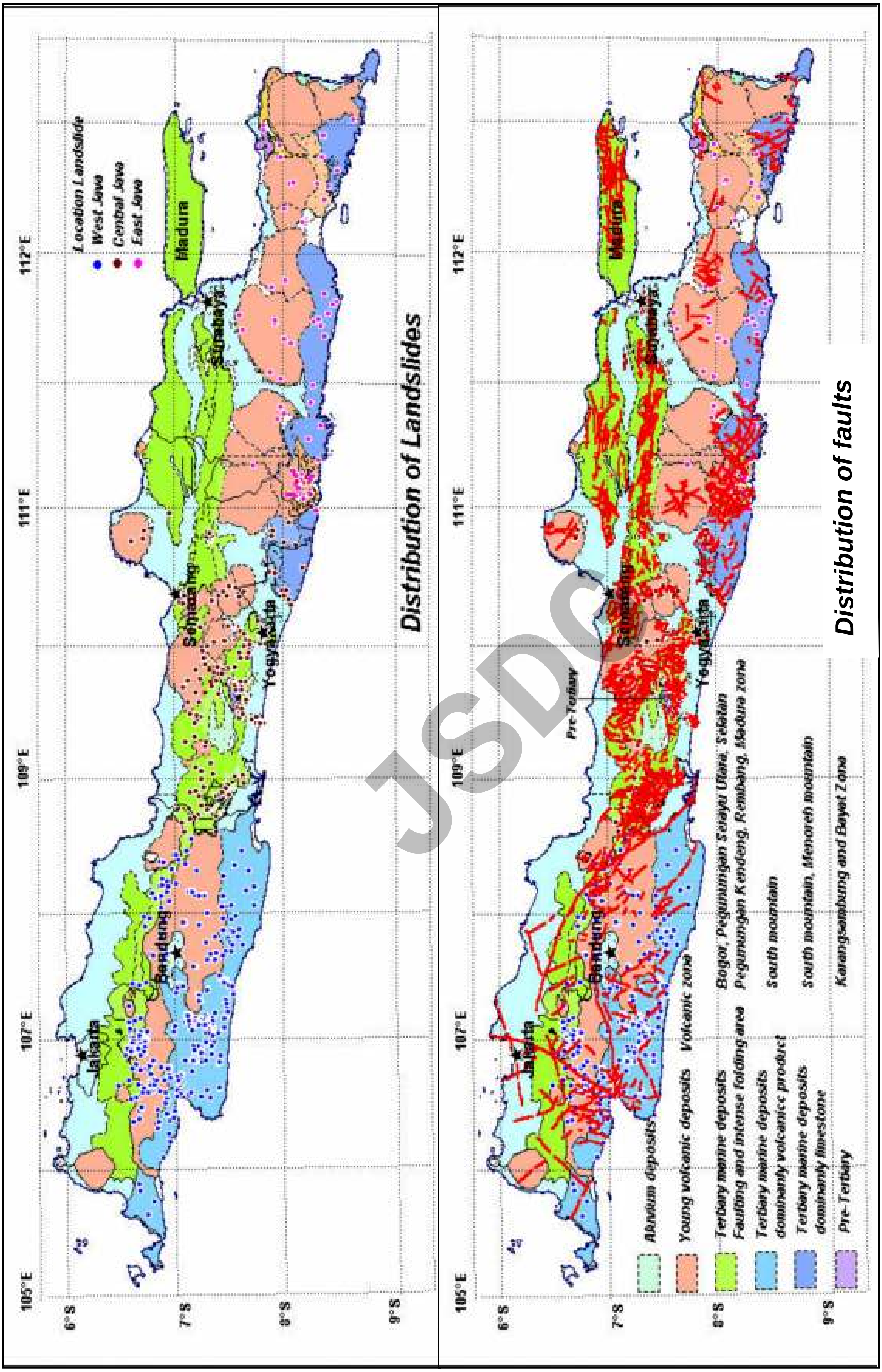

Figure 6. Geological setting of Java Island (Source : Geotechnology – LIPI 2005)

Table 1. Landslide hazard events, Indonesia 2003 – 2006 (Surono, 2006)

Province	Dead	Inj	Hd	Htd	Ht	Afd (ha)	Rd (m)	Event
West Java	292	129	2024	215	2759	208	1645	107
Central Java	172	118	30	27	494	3	95	30
East Java	103	1	129	148	2	147	0	8
West Sumatera	64	29	34	28	175	96	70	5
North Sumatera	126	0	40	1	8	10	80	2
Aceh	8	0	0	151	0	0	0	1
South Sulawesi	33	2	0	10	0	10	0	1
North Sulawesi	18	4	637	150	0	15	130	5
West Nusa Tenggara	3	95	785	7	25	0	20	3
East Nusa Tenggara	4	8	0	0	0	0	0	1
Papua	3	5	0	0	0	0	0	1
Total	826	391	3679	737	3463	489	2040	164
Dead : Dead people	Inj : Injured people		Hd : Damaged houses			Htd : Totally damaged houses		
Ht : Threatened houses	Afd : Damaged agricultural field		Rd : Damaged roadway					

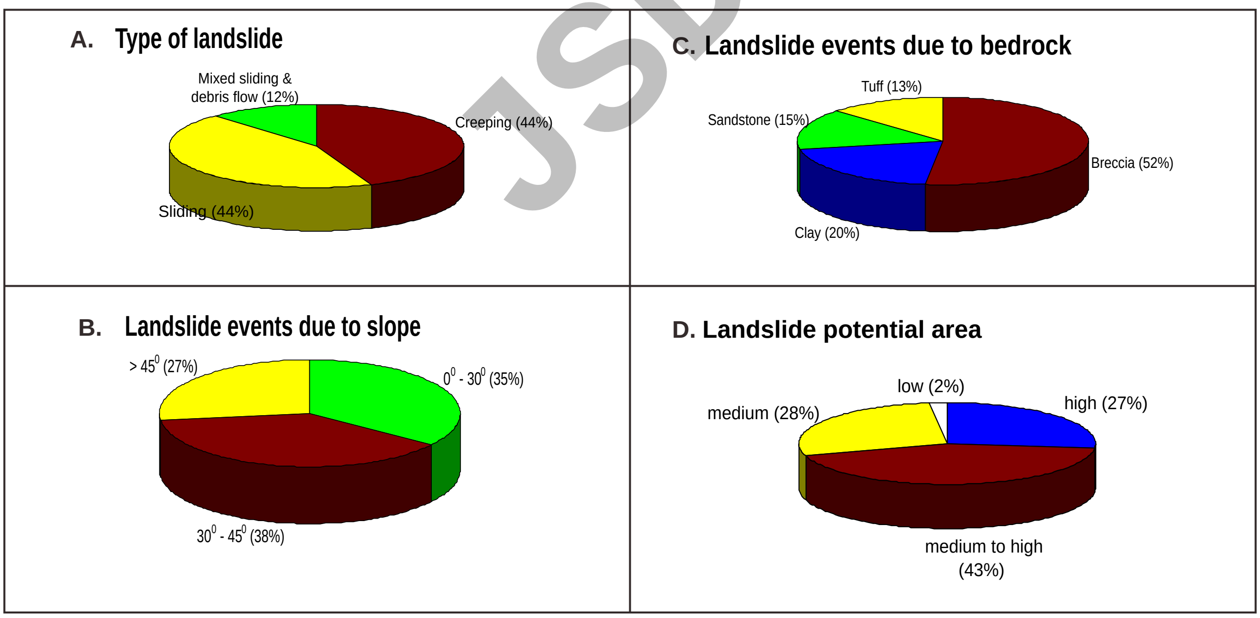

Figure. 7 Characteristics of landslide events (145 events) on Java Island in the period of 2003 to 2006 March. (Modified from Surono, 2006)

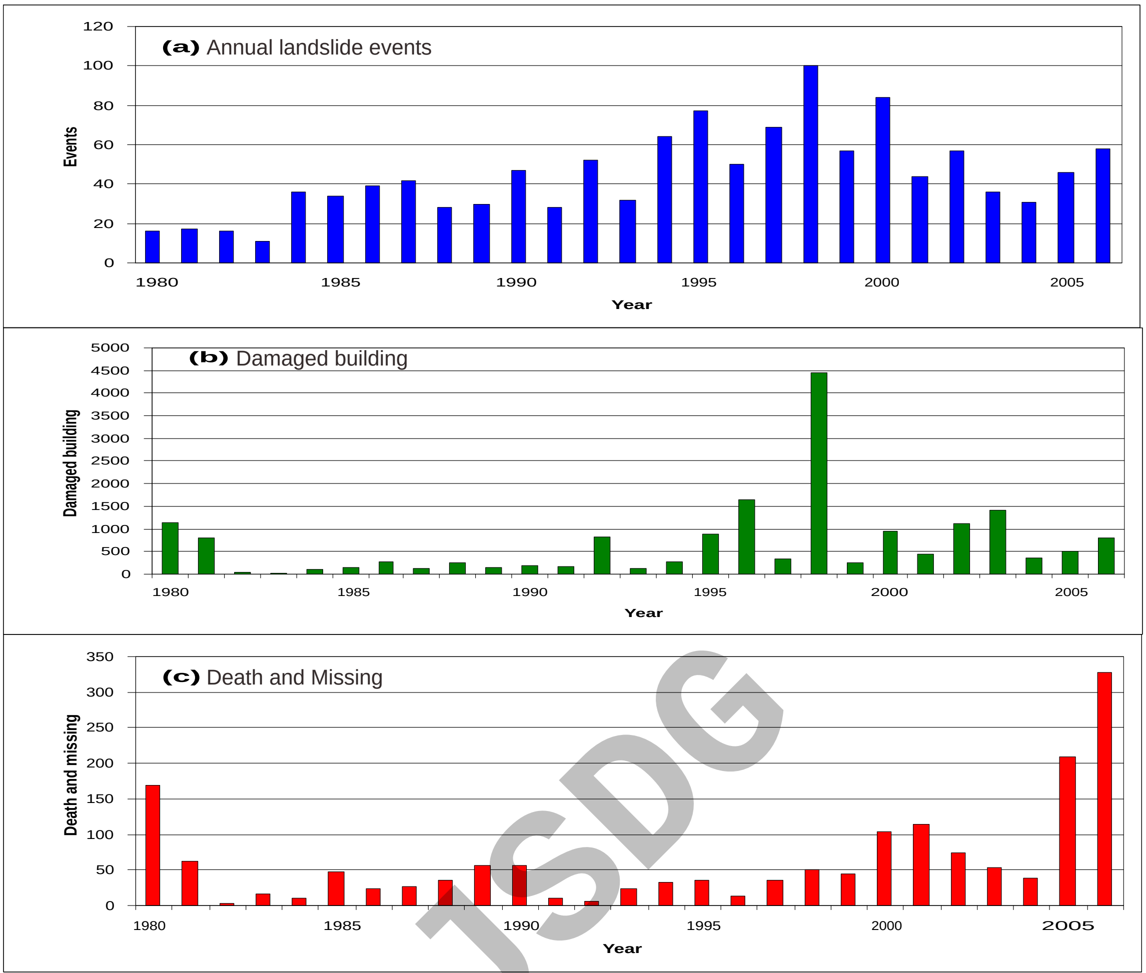

Figure 8. Statistical reflection of landslide disaster on Java Island, Indonesia 1980 – 2006. (Modified from Surono, 2006).

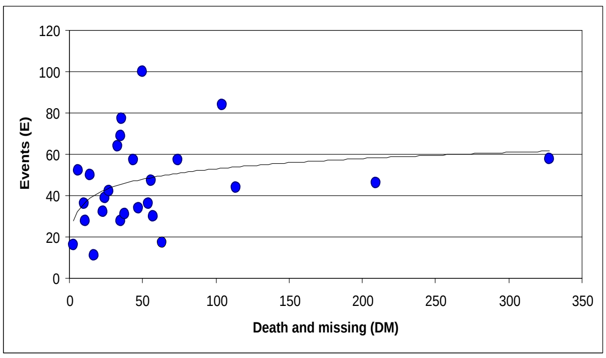

Figure 9. Correlation between E and DM

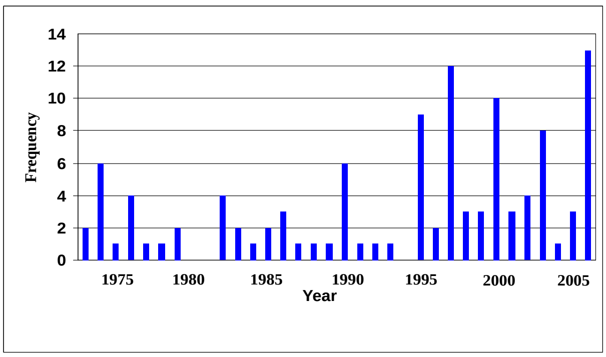

Figure 10. Earthquake frequency in south part of Western Java, Indonesia (Magnitude > 4 Richter, Source USGS)

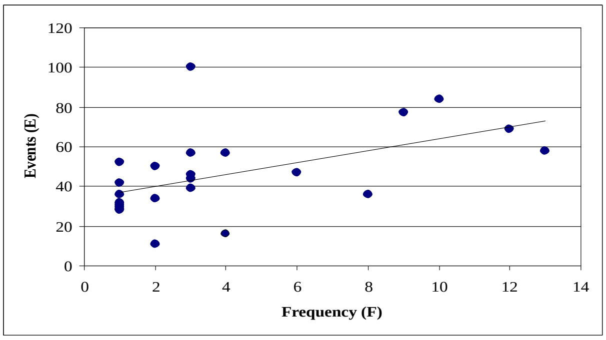

Figure 11. Correlation between frequency of earthquakes (F) and landslide events (E) on Java island, Indonesia

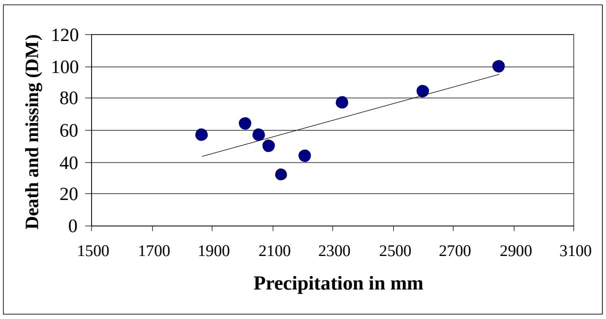

Figure 13. Correlation between annual precipitation and number of human victims at Yogyakarta area

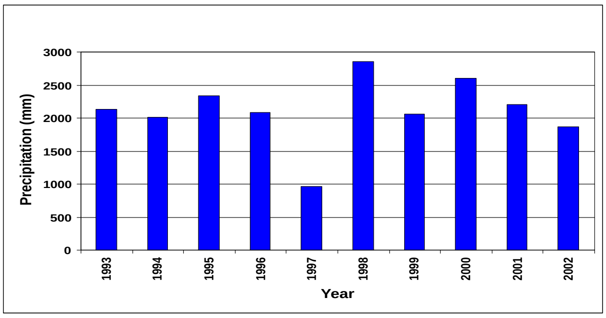

Figure 12. Annual rainfall in mm at Yogyakarta area during period of 10 years from 1993 to 2002 (Source: Indonesian Geophysical & Meteorological Agency (BMG), 2002)

Figure 10 shows the time series of earthquake frequencies with has a magnitude of larger than 4 Richter scale during the period between 1973 to 2006 for the West Java Province. It shows that in 1997 and 2006 the frequency of earthquakes were the highest for the recorded period. On figure 8c and 10, we can find an extreme value of DM and earthquake frequency in 2006. We can also observe that a large number of landslide events were recorded in this year, see figure 8a. Hence it can be deduced that a good correlation exists between these two factors. Therefore, we can make an estimate of a good correlation between earthquake frequency and landslide events as shown in figure 11. These results also suggest that the relationship between both phenomena shows an increasing tendency.

Relationship between rainfall and human victims.

Figure12 depicts the annual precipitation at Yogyakarta and surrounding areas for the period of 1993 to 2002. In this figure it can be noted that the year 1998, which stands out as far as the frequency and number of landslide related facts are concerned, is characterized by its large annual precipitation. There seems to be a relationship between the number of human victims death and missing (DM), and annual precipitation in mm as is shown in the figure 13. It shows that there is a tendency of an increasing number of victims with increasing precipitation, suggesting that if annual precipitation exceeds 2100 mm, the number of victims will increase linearly. With a different precipitation quantity, this figure is probably suggestive of representing one of the patterns of landslides which have occurred on Java in recent years.

Examples of typical landslides

CVMGH (Centre of Volcanology and Mitigation of Geological Hazard) 2005 has classified landslides on Java island into the following main types:

a. Translation
b. Rotation
c. Block failure
d Creeping
e. Debris flow
f. Toppling

Of these types, a to c comprise the sliding type as shown in figure 7a. We will discuss several examples of above listed types which have occurred on Java (see fig. 5).

(1). Earthquake triggered landslide at Warungkiara

It is well known that many landslides occur in the southern part of West Java area. This area has the highest landslide potential on the Java Island. The reason behind this is the existence of steep slopes, strongly weathered volcanic products (volcanic breccias, tuffaceous sand, tuff) and frequent heavy rainfall. Furthermore, this area is strongly influenced by complicated active faults (Utomo *et al*. 2005). Most of landslides in this area are of the creeping type and are triggered by earthquakes. The Warungkiara landslide near Sukabumi occurred early in November 1998

(Fig.14a, designated by dark star) and caused damage to forested areas, paddy fields, houses and the provincial road (CVMGH, 1999). In this area, an accumulated earthquake frequency of greater than 4 Richter scale from 1995 to 1998 was recorded 26 times (USGS, 2006) Lithologically, the area consist of alluvium, residual material, andesitic breccia, clay, marl, sand and their strongly weathered counterparts. Fortunately no deaths occur, however, the provincial road was seriously damaged which caused a disturbance of the local economic activity. The landslide crown-width was 750 m and the length of the emergent area reached up to 700 m. This landslide is located along the active Cimandiri fault (Fig.15a). This figure also shows the complicated fault pattern which makes this a high potential area for landslides. This area is well known as an area frequently affected by earthquakes. Figure 14b shows the distribution of earthquake epicenters with a magnitude of more than 4 Richter scale within the period of 1973 to 2006 in the area of the southern part of West Java with latitude 6°30' to 7°30' S and longitude 106°15' to 107° E.

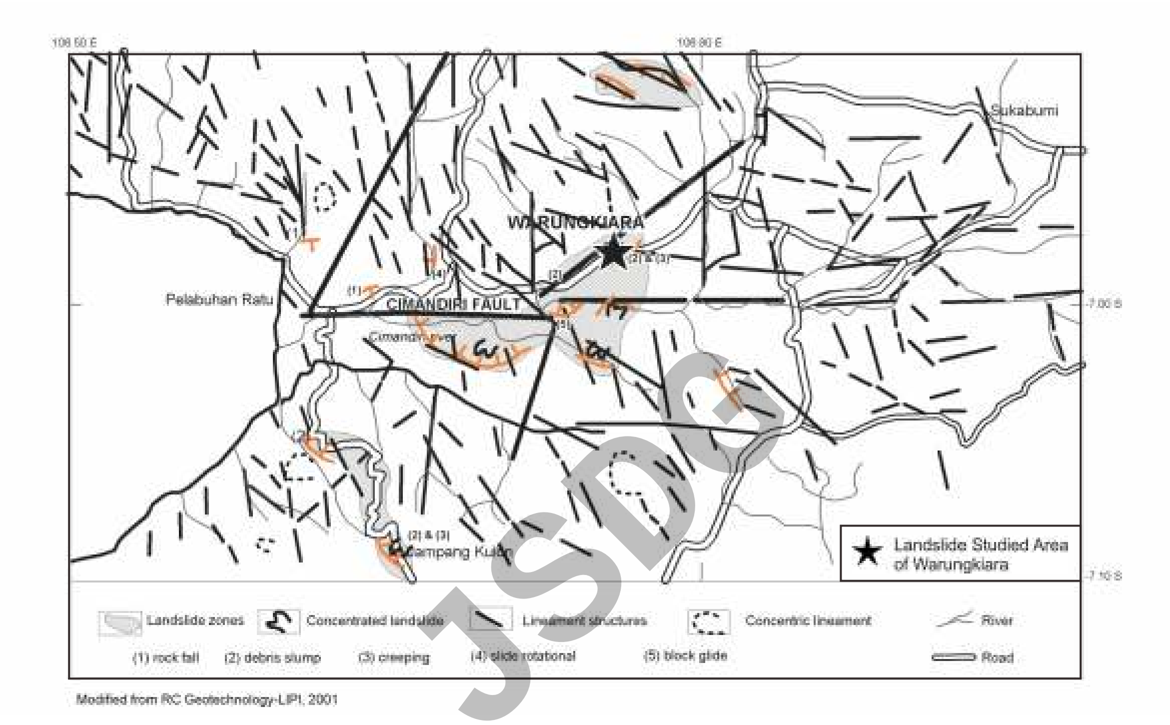

Figure 14a. Fault lineaments at the surrounding Warungkiara and the active Cimandiri faults, West Java, Indonesia (Geotechnology-LIPI, 2001)

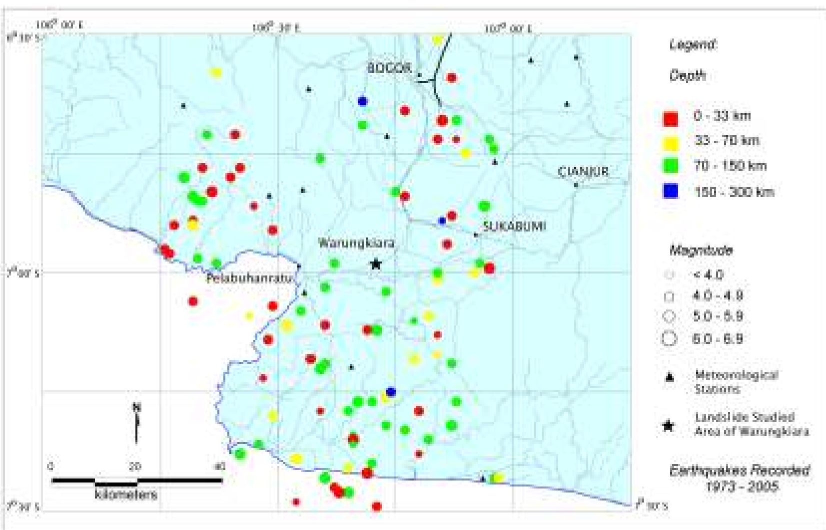

Figure 14b. Earthquake distribution at the surrounding Warungkiara, West Java, Indonesia (Source: USGS, 2006)

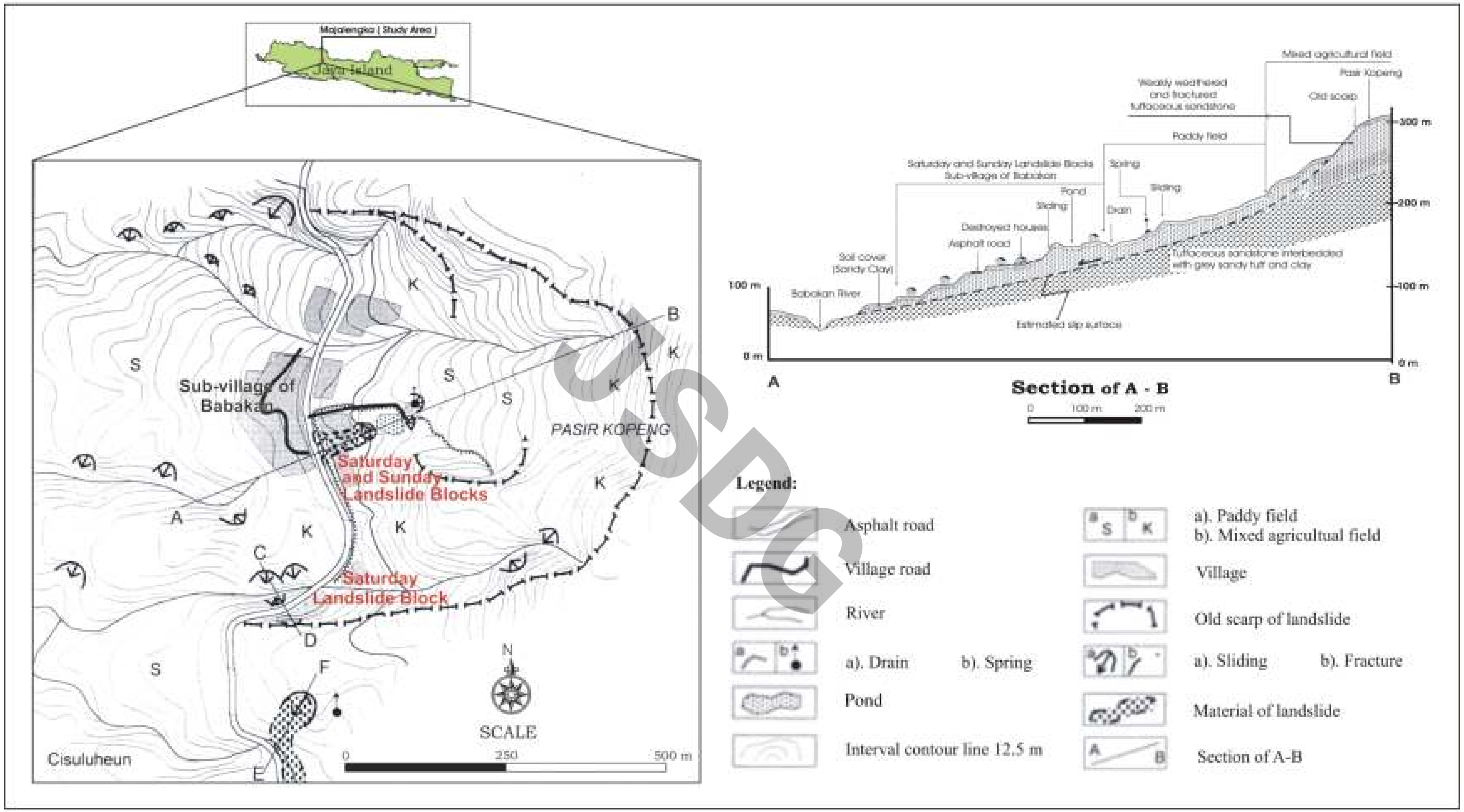

Figure 16a. Situation map of landslide area in sub village of Babakan, Wanahayu and Cihaur, Regency of Majalengka, West Java, Java Island

Figure 15. Geyser at the active Cimandiri fault, West Java

Figure 16b. Destroyed house by Majalengka landslide, West Java, January 3-4, 2004

These figures we clearly show that many earthquakes occurred during a period of 33 years. In the active Cimandiri fault zone, we can also encounter several steam geysers (Fig.15).

It implies that this area is geologically complex. Several aspects of this landslides include: the estimated traverse of the active fault crosses the provincial road, this landslide is of the creeping type and triggered mainly by active fault movement. It is recommended to make another provincial road to prevent loss to the local economy of this region. It is also recommend as a mitigation measure for this landslide to drive piles at the center of the landslide (at the boundary of the deflection zone and the accumulation zone) and construct a gravel gabion at the tail-end of the landslide.

(2) Landslide - Debris Flow at Majalengka

On 3-4 January 2004, at least sixteen landslides occurred in the western slope of the Pasir Kopen Hill area (Fig.16a). Large landslides occurred in three locations (Utomo *et al*., 2004) and they occurred on a Sunday evening. Four people died, seven houses were destroyed, fifty seven houses were heavily damaged, and one fish-pond was lost. The main asphalt road was heavily damaged. About 150 people had to be evacuated (BNPB, 2004). The landslide occurrence coincided with heavy rainfall. A couple days before this event, the average rainfall ranged from 70 to 80 mm/day. Rainfall declined to less than 60 mm after this event (BMG, 2004). A hill side collapsed in the area, destroying approximately half a hectare of paddy and mixed agricultural fields. The landslide was 50 m long, 25 m width, and formed a 10 m high scarp as shown in figure 17a. The relief of western slope of Pasir Kopeng Hill has a steepness of more than 300 and a height of 600 to 750 m above sea level.

Figure 17. Creeping at village of Wangun 3, Bogor landslide area. There is a road surface displacement of 0.5 m from existing level position to a lower position

The water from the heavy rain infiltrated through the soil and along fractures but hardly penetrated into the underlying unweathered and weak rocks. Consequently, the soil and weathered rocks became saturated with water which led to landsliding – debris flow. Figure 17b shows destroyed houses by the Majalengka landslide. It is recommended that setting up of extensometer with alarm system is useful for avoiding a casualty toll in this landslide prone area.

(3) Creeping type landslide at Bogor

The landslide occurred on Friday, February 2, 2007 at the district of Babakan Madang, in the vicinity of Bogor. This area is located at longitude of 106° 56' 19" E and latitude 6° 35' 45" S. The landslide was in the form of cracks, slump, sliding and creeping.

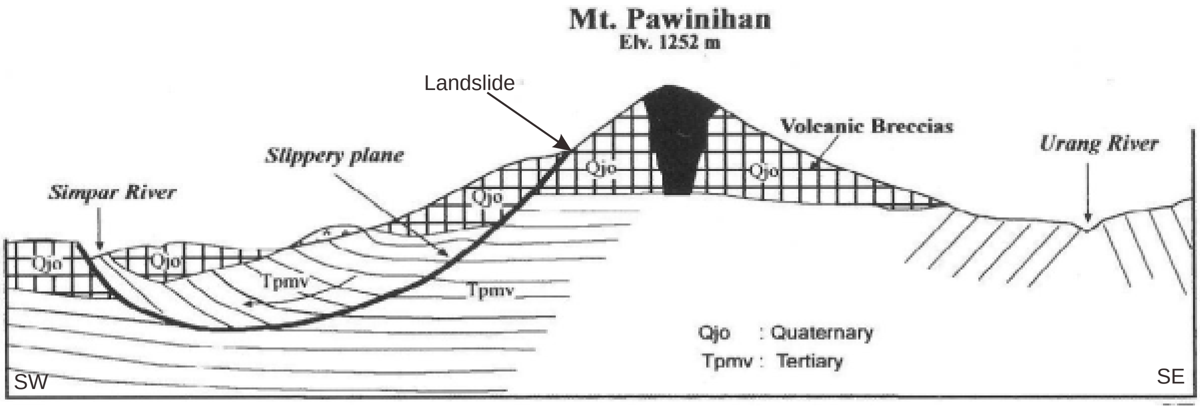

Figure 18a. Schematic section of an active gravitational fault triggering landslide at Sijeruk, Banjarnegara, Java Island (Modified from Bemmelen, 1949)

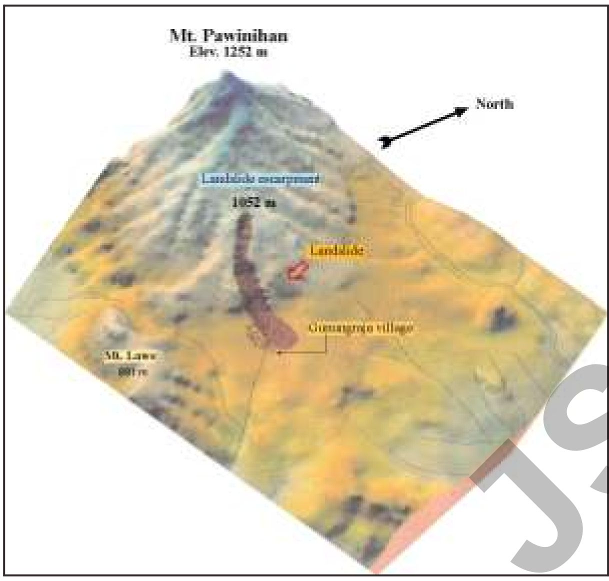

Figure 18b. Landslide and debris flows at Banjarnegara, Java island

Up till the end of February, 2007 the landslide creep was still going on. Three villages of the landslide area were seriously destroyed. This area extended over residential area, agricultural land, forestry land and a local country road. This area is a typical creeping landslide area. Many sites were displaced from their previous level to a lower position (Fig.18).

Many cracks were encountered at the surface with a width of about 5 to 15 cm, a length of 40 – 70 meter and a depth of 60 – 200 cm. The slope-angle of the deflection zone was more than 350, but the angle of the slip-line was approximately less than 100. This landslide resulted in 168 heavyly damaged houses. Another 178 houses were slightly damaged and several hectares of agricultural land were damaged. High intensity rainfall occurred in this area and led to the occurrence of the landslide (Soedradjat *et al*., 2007). As a whole, this area might be classified as a high potential area prone to the creeping type landslide.

Lithologically the area is composed of volcanic breccia, tuffaceous breccia, layered tuff sand with intercalation of black clay at the upper part; while the lower part consists of a layered clay. This layered clay acted as a basement sediment in the landslide area and as a slippery bed. The crown of the escarpment is about 20 m in height with a length from this point to the toe of approximately 1 km. The dewatering until deeper than slippery bed is needed to mitigate the landslide occurrence.

(4) Gravitational sliding at Banjarnegara, Central Java

The landslide occurred on January 4, 2006. Regionally, the Banjarnegara area is a gravitational fault zone (Bemmelen, 1949). Topographically it conmprises a hilly terrain. In this area creeping occurs from higher elevations triggered by gravitational fault movement (Utomo *et al*. 2006). Mt. Pawinihan 1,252 m (Fig. 18a) represents the highest peak in the area. Annual rainfall of 3000 mm with precipitation concentrated between December to March. The composition of landslide material comprises surface soil (Quarternary volcanic breccia and in the lower part composed of Tertiary sediments composed of mixed material with/including shale, marl, limestone and sandstone). Thickness of this layer is about 300 m. Creep phenomena was observed and many gully traces occur at the slope surface of the mountain. Sabo disasters have occurred similar to those which have occurred at higher elevation of the Himalaya area (Ito *et al*. 2001).

Figures 19 (A) & (B) View of debris flow disaster triggered by landslide at Banjarnegara

However, geologically the lithology of the Banjarnegara sediment is quite different. In the Himalaya areas every time landslide and flood occur together with rock avalanche and flood disaster.

The landslides start from an elevation of 1052 m and stopped at 850 m, with a slip-length of up to 284 m. After the landslide a continuous heavy rain fell. Due to the landslide, a dam was formed inside the landslide mass and due to gradually progressing soil failure, 5 hours later a rapid landslide occurred. The landslide caused a toll of 142 death and missing victims, 102 damaged houses and the loss of much agricultural field area (BNPB, 2006). Figure 18b depicts a three dimensional sketch of the Banjarnegara landslide area.

Many cracks occurred in the hilly area. Owing to this matter, we proposed some recommendation for mitigation of the landslide which include the following measures: there still remain 80 threatened houses (approximately 400 people) which have to be immediately moved to other places. Control of land use is very important to manage and a check-dam should be constructed. Finally more detail information on the prevention and mitigation in the framework of disaster education should be provided to the local people, as instant information is frequently ignored by the local people. Figure 19a & 19b are views of the debris flow disaster triggered by the landslide.

(5) Sliding and debris flow at Jember

The landslide occurred on January 2, 2006. Many traces marking old landslides in the form of a fan sedimentation occur in this area. This case is similar to the Sumikawa hot spa landslide area in the Akita Prefecture in Japan (Ito, 1999). Moreover, a lot of

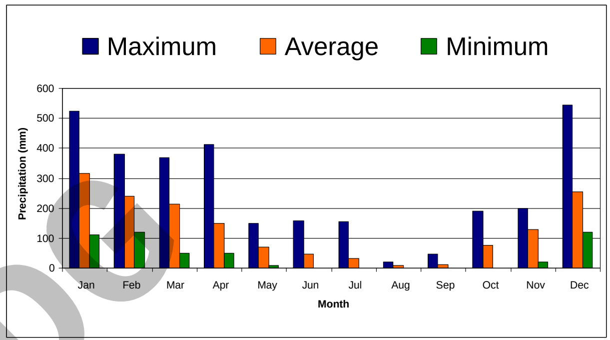

Figure 20. Rainfall records by month at Jember, East Java during 1985 – 2005 (Source: Indonesian Geophysical & Meteorological Agency (BMG), 2005)

ponds exist in many places upstream of the landslide area. These represent a typical indicator of repetitive landslide occurrence from ancient to recent times. These ponds can be considered one of the trigger factors of landslide occurrence. This pattern is quite similar to the huge landslides in the snowy region in Japan (Ito, 1998). Additionally, quite heavy rainfall continued for 5 days from December 28, 2005 to January 1, 2006 with 536 mm precipitation during this period. The rainfall was recorded 178 mm on January 1, 2006 just one day before the landslide occurred. Figure 21 shows rainfall records by month at Jember for the recent twenty years period between 1985 to 2005 (BMG, 2005). This is considered the main factors contributing to the occurrence of the landslide. This landslide caused the death of at least 98 people, numerous injured people, hundreds of hectare paddy field and houses totally damaged, the collapse of 6 bridges and 9 check dams and damage to the local public road (BNPB, 2006). Figure 21 is a bird's eye view of the huge landslide area in Jember.

Figure 21. Huge landslide at Gunung Pasang, Jember, East Java, January 2, 2006.

Setting up of early warning system for landslide and debris flow in the form of rainfall-gauge completed with alarm system is recommended to avoid or mitigate a lot of casualties.

Conclusions

- The presented statistics indicate possible correlation between landslide events, the cause of the interdependency of the various factors mainly comprising changes in land use, the environment, and population increase.
- The largest number of landslides on Java Island occurred in the West Java Province, followed by the Central Java Province, while the least number of landslides occurred in the East Java Province
- Generally landslides occur in the southern part of Java Island.
- The amount of precipitation represents the main trigger factor for the occurrence of landslides occurring on the whole island of Java. Landslides in West Java mostly occur in areas with a steep sloped topography and they are of relatively small scale, while landslides associated with fault movements are quite frequent. In Central Java most landslides occur in areas underlain by intensive folded and faulted bedrock. In East Java many landslides occur in areas underlain by intensely weathered limestone and young volcanic products, the landslides being of a relatively huge scale.
- The change of land use, the environment and an increasing population, earthquake frequency and rainfall intensity represent triggering factors for the generation of landslides on Java.
- The statistical relationship between dead and missing human victims and intensity of precipitation in Yogyakarta and surrounding area suggest that if annual precipitation exceeds 2100 mm a linear increase in the number of victims can be expected. The similar pattern is probably same on the Java area with the different precipitation quantity.

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