15 - 14

Asian Program for Regional Capacity Enhancement for Landslide Impact Mitigation (RECLAIM)

Regional Workshop for Landslide Risk Reduction In Asia
Organized by the Asian Disaster Preparedness Center (ADPC)
13-15 September 2004, Bangkok

ANALYSIS OF RAINFALL TYPE AND LANDSLIDE RISK REDUCTION IN INDONESIA

By :

Dr. Sudibyakto

- **Lecturer of the Physical Geography and Environmental Department**
- **Director of the Research and Cooperation Bureau**

Faculty of Geography

- Former Director of the Research Center for Natural Disasters

Gadjah Mada University, Yogyakarta, INDONESIA

e-mail : tsudib@yahoo.com , sudibyakto@geo.ugm.ac.id

Abstract

Being situated geographically on tropical rain area and geologically on active volcanic belt make Indonesian landscape highly vulnerable to natural hazards. Disaster occurs when natural hazards affect human society. The total population of Indonesia has exceeding 210 million people in 1999, comprising over 36% of urban and 64% of rural, averaging density of about 101 inhabitants/km^2, the average growth rate of 1,7% annually. Due to the geological factor, geomorphology, topography, soil, landuse, and other biophysical factors may trigger a landslide during the wet seasons. A landslide usually triggered by man activities. Actually, almost every year in Indonesia a major disaster has occurred and is caused by landsliding. In many landslides death exceed a hundred of people and valuable properties. During1997 -2004 the landslides occurred very frequent up to 132 which impact on the 192 deaths, 1958 refugees, and economic losses up to Rp 15,863,017,682 ($ US 1,6 million). Mitigation Strategy for reducing the risk of hazard, many disaster management efforts have been conducted, especially before given disasters occur. This includes efforts in mapping natural hazard vulnerability, mapping the area of conflict potency, education and training for disaster handling, socializing law and regulation technical (structure) and non-technical (non-structure) mitigation

1. Introduction

Indonesia as the world largest archipelago having a total of over 17,000 islands, about 6,000 are inhabited, spread over at about 8 million km^2 of the earth's surface with the total land area of about 2 million km^2, and 3 million km2 of sea territory, with a coastline exceeding a total of 84,000 km. The total population has exceeding 210 million people in 1999, comprising over 36% of urban and 64% of rural, averaging density of about 101 inhabitants/km^2, the average growth rate of 1,7% annually (Gany, A.H. 1999).

Based on the climatic data analysis in the long term, there are two seasons, the dry season (April to September) and the wet season (October to March), the average annual rainfall is about 2,000 mm. Indonesia has three types of rainfall pattern, e.g. type A (monsoonal type), type B (equatorial type), and type C (local type), for the spatial distribution of these rainfall type as shown in Figure 1. In the region with dominated by equatorial or monsoonal rainfall are usually receive a higher rainfall with the high rainfall intensity. Due to the geological factor, geomorphology, topography, soil, landuse, and other biophysical factors may trigger a landslide during the wet seasons. A landslide usually triggered by man activities.

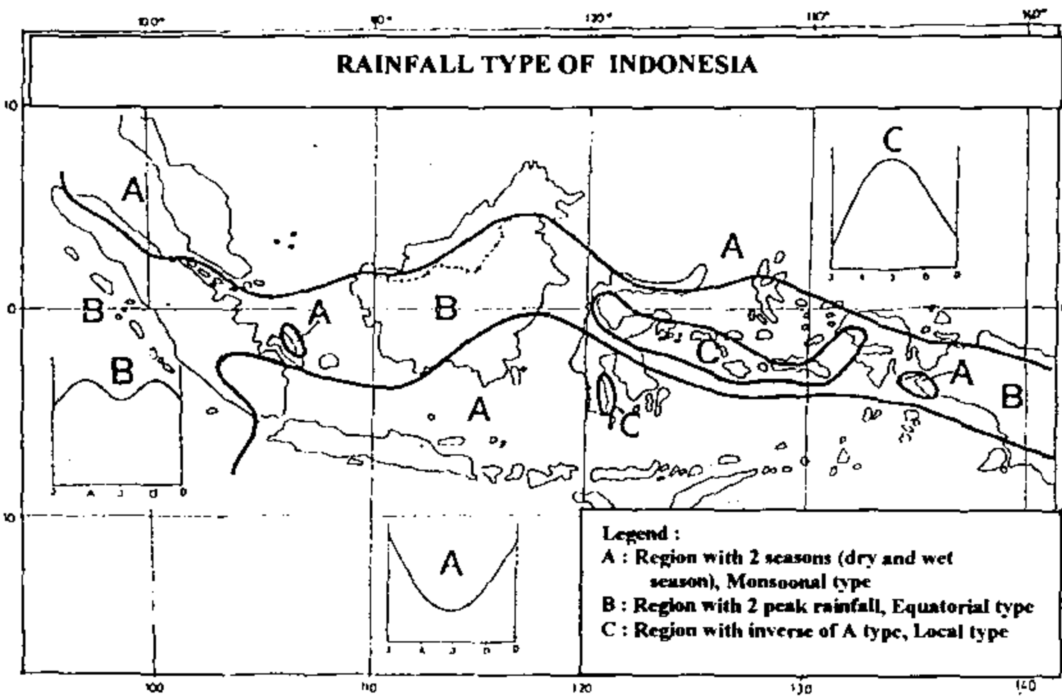

Figure 1. Rainfall type in Indonesia

Geographically, three main tectonic plates of the world meet over the Indonesian region so that region covering Sumatra, Java, Bali, Nusa Tenggara, Maluku, Sulawesi and Irian Jaya, is exposed to a deep earthquake. Shallow earthquakes may also sometimes trigger tsunami like the one occurring in Flores (1992), Banyuwangi (1994), Biak (1996), Bengkulu (1998), and Nabire (2004) which cause physically damages and thousands of life. Beside that around 129 active volcanoes exist in the Indonesian region where more than 3 million populations live in the first and second hazard zones. Indonesian seasonal rainfall also shows inter-annual variation, which sometime reaches an extreme anomaly. These anomalous conditions related closely to the well known La Nina and El Nino (ENSO) phenomena and cause hazards like drought and flood, which eventually cause serious disruption to the country's economy. The recent 1997 drought, for instance, had caused the country to loss more than US$ 600 million. Other than these natural hazards, social unrest caused by political and or undesired resources exploitations and environmental deterioration becomes frequent recently especially in the newly regional autonomy policy. Social unrest as a manifestation of many ethnic and group conflict generates not only socio-economy instability but also environmental destruction as well.

Actually, Indonesian region is vulnerable to many types of disaster including natural and anthropogenic disasters. The former could be not only landslides, but also an earthquakes, tsunamis, volcanic eruptions, floods and droughts, while the latter may be a human-induced such as forest fires, industrial/technological disasters as well as social unrest. Actually, almost every year in Indonesia a major disaster has occurred and is caused by landsliding. In many landslides death exceed a hundred of people and valuable properties. Figure 2 show the landslide susceptibility map of Indonesia. Most of the regions in Sumatera, Java, and Papua islands are very susceptible to landslide hazard.

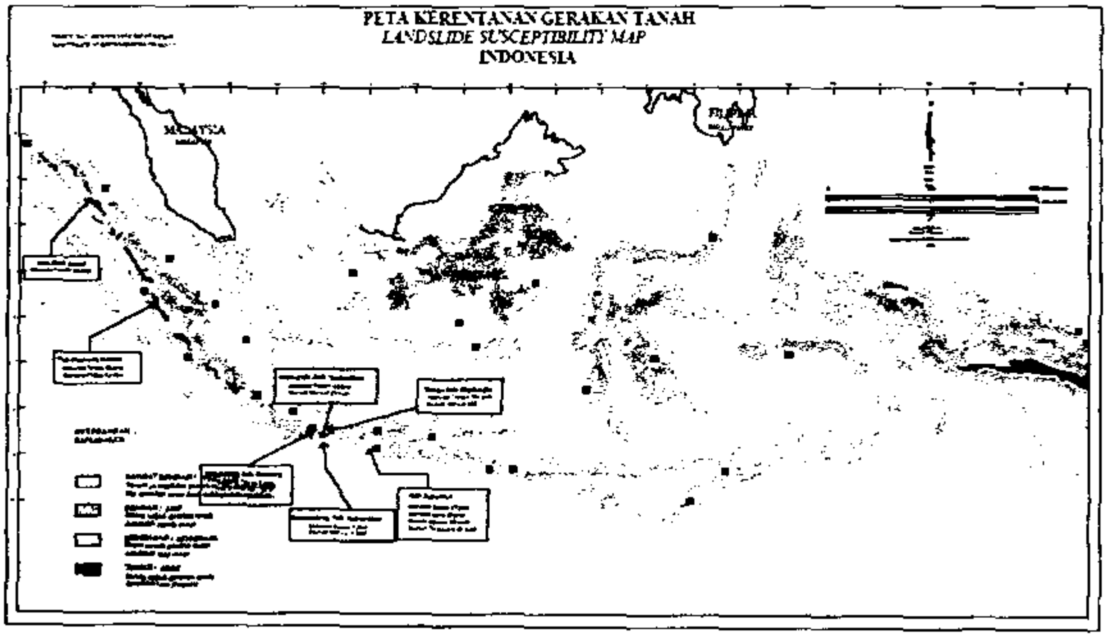

Figure 2. Landslide susceptibility map of Indonesia
(Source : Directorate of Environmental Geology and Disaster Mitigation, 2004)

During the mid rainy season many landslides frequently occurred. Landslide is referred to herein as the movement of soil, rock, and other slope materials under the influence of gravity. Its mechanism of movement is classified as **fall, topple, slide, spread and flow**. A **fall** occurs when a rock mass is detached from a very steep, nearly vertical slope, and falls in the air then collects at the break in slope. A **topple** is a rotation movement towards the direction of the slope with respect to a point or axis which is lower than the center of gravity of the moving rock mass. A **slide** is a downward movement of a mass of soil or rock along a slope which occurs on a failure surface or on fine shear zones. According to Cooke and Doornkamp (1990) a slide can be classified into rotational slides and translatio^n slides. **Rotational slides (slips)** involve a turning movement that often leaves an upper surface, on the failed mass, inclined back into the hillside. **Translational slides** involve a down-slope movement along a more or less inclined (planar) surface. Rotational slides occur with a concave-upwards curved failure plane (rupture surface) passing through a thick and relatively homogeneous bed of clay or shale. They are more deep-seated than translational slides. Movement tends to be rotational on this slip surface. Translational slides include rock slides, block-slides, and debris slides, and can be used as a universal term to cover lateral spreads as well. Finally in a certain areas a complex type of slope failures may be occurred which involve several types of movement within one event. Typical combinations include rockfalls and debris avalanches, rockfalls and rock flowslides, rotational slides, and earth (often mud) flows. Belows are example of landslides type which happened in Kulon Progo District of Yogyakarta region during the rainy season in 2001. Figure 1 show the rockfall type which characterized by the fast movement dan free fall of rock, fragmented materials, etc. Figure 2,3, and 4 also show the frequent occurrence of landslide in Indonesia, especially in the mountainous areas.

Figure 1. Example of rockfall type in Kulon Progo District of Yogyakarta Region *(Photo : Sudibyakto, 2001)*

Figure 2. Example of slump type in Kulon Progo District of Yogyakarta Region *(Photo : Sudibyakto, 2001)*

Figure 3. Example of debris flow type in Kulon Progo District of Yogyakarta Region *(Photo : Sudibyakto, 2001)*

Figure 4. Shows soil creep in Kulon Progo District of Yogyakarta Region *(Photo : Sudibyakto, 2001)*

Furthermore Cooke and Doornkamp (1990) stated that landslides can be classified into active and inactive.. It is crucial for land management or and environmental management purposes to know whether a landslides is active or inactive. Certain criteria have been identified based on the surface evidence (Table 1).

Table 1. Features which distinguish active from inactive landslides

Active	Inactive
• Scarps, terraces and crevices with sharp edges; • Crevices and depressions without secondary infilling; • Secondary mass movement on scarp faces; • Surface of rupture and marginal shear planes show fresh slickensides ; • Fresh fractured surface on blocks; • Deranged drainage system, many ponds and undrained depressions; • Pressure ridges in contact with slide margin ; • No soil development on exposed surface of rupture; • Presence of fast growing vegetation; • Distinct vegetation differences "on" and "off" slide; • Tilted trees with no new vertical growth; • No new supportive, secondary tissue on trunks.	• Scarps, terraces, and crevices with rounded edges; • Crevices and depressions infilled with secondary deposits ; • No secondary mass movement on scarp faces; • Surface of rupture and marginal shear planes show old or no slickensides ; • Weathering on fractured surface on blocks; • Integrated drainage system : • Marginal fissures and abandoned levees; • Soil development on exposed surface of rupture; • Presence of slow growing vegetation; • No distinction vegetation "on" and "off" slide; • Tilted trees with new vertical growth above inclined trunk; • New supportive, secondary tissue on trunks.

Sources : Cooke and Doornkamp (1990)

2. Extent of the Landslide Problem

During the rainy season, which is from September/October to February/March, it is common to hear news reports of landslides during the highest intensity of rainfall and sometimes the impact of tropical cyclone is the major triggering mechanism of landslides in Indonesia. Not all types of landslides have been documented, but according to the Bakornas PBP (National Coordinating Board for Disaster Management and Poverty Alleviation) of the Republic of Indonesia show that during1997 -2004 the landslides occurred very frequent up to 132 which impact on the 192 deaths, 1958 refugees, and economic losses up to Rp 15,863,017,682 ($ US 1,6 million) as shown in Table 2.

Table 2. Natural Disasters in Indonesia During 1997 - 2004

No	[illegible]	[illegible]	Victims Death	Refugee	[illegible]	[illegible]
1	Environmental pollution	0	0	0	0	0
2	Fires	150	21	9314	158,801,422,000	1894
3	Social conflict	7	3420	292,950	2,533,000,000,000	4970
4	Epidemic	20	275	0	0	0
5	Technological error	2	496	0	0	0
6	Forest fires	9	0	0	0	0
7	Volcanic eruption	3	2	13,331	0	0
8	Tsunami	5	0	500	1,033,900,000	278
9	Earthquake	15	138	6,177	797,332,000,000	13071
10	Storm	98	41	2,752	79,659,100,142	6458
11	**Landslides**	**132**	**192**	**1,958**	**15,863,017,682**	**1981**
12	Floods	150	87	191,259	692,116,901,592	33198

Source : Bakornas PBP, 2004.

3. Causative Factors

Landsliding takes place when slope materials are no longer able to resist the forces of gravity. This decrease in (shear) resistance may result either from internal or external causes. Internal causes usually involve some change in either the physical or the chemical properties of the material (rock or soil) or its water content . External factors which lead to an increase in shear stress on the slope usually involve a form of disturbance that may be either natural or induced by activities of man such as ponds, reservoir, drainage diversion across hillside, lowering of reservoir level, loading of upper valley side, and removal of vegetation.

In general terms, the stability of a slope may be defined by factor of safety F, where :

$$F = \frac{\text{the sum of forces resisting slope failure}}{\text{The sum of disturbing forces}}$$

or

$$F = \frac{\text{Shear strength}}{\text{Shear stress}}$$

If $F > 1.0$ stability is likely (but nervousness exists while $F < 1.2$), but if $F < 1.0$ instability exists (or is imminent).

Some physical factors which usually influence the landslide occurrence in Indonesia and almost in all tropical country are as follows (Cooke and Doornkamp ,1990).

a. **Relief**
The steeper a slope that more liable it is to be unstable. Steep slopes tend to predominate in areas of deep valleys, as do bedrock cliffs, which are potential rockfall sites. The slope steepness may be obtained from contour maps.

b. **Drainage system**.
High drainage densities are a sign of such things as impervious strata, high rainfall, little vegetation, and active stream incision, all of which may tend to increase the likehood of mass movement. Seepage from hill slide (e.g. along a spring line) can produce seepage erosion in fine sands and silts by a drag effect which takes with it individual soil particles, or a seepage pressure maybe generated within the ground material, so that the particles are carried outwards from the slope. Existing of high groundwater level also are critical in many slope stability

c. **Bedrock, regolith** .
For bedrock factor, joint density of other discontinuities in the rock (such as bedding planes or faults) will determine the size of falling blocks. Regolith (soils and drift materials) have an important bearing on stability conditions, the steepness of the slope being an important factor in predicting the landslides.

d. **Climate**.
In the rainy seasons water or overlandflow/surface runoff usually increase. When water arrives rapidly within a soil body (by rainstorm) there is a tendency for high pore water pressures to build up, followed by slope failure.

e. **Earthquakes.**
Landslide are more likely if the area occurs within an earth-tremor belt.

f. **Human interferences**.
A poor land management system can be a causal factor of landslides. Development of reservoir, fish ponds, drainage diversion, logging, lowering of reservoir water level and others unenvironmentally land practices also act as a causative factors of landslides.

4. Hazard Zonation

Hazard Zonation need a map. Mapping of the landslide hazard especially using the remote sensing techniques and GIS will be very useful for the spatial planning. Hazard maps outline zones that are defined in terms of the probability of occurrence of potentially damaging phenomena within a certain span of time within a specified location or an area.(Varnes,1984). After mapping the hazard zone it is possible for the reducing the impacts of disasters.

Disaster usually will impacts to the resources and its environments. Some type of losses for every natural disaster according to Montoya (2003) of the Department of Urban and Regional Planning and Geo-Information Management, ITC) are as follows.

A . Primary Effect :

a. Human – social :

- (Fatalities
- Injuries
- Loss of income or employment opportunities
- Homelessness

b. Physical :

- Ground deformation or loss of ground quality
- Structural damage or collapse to buildings and infrastructure
- Non-structural damage and damage to contents

B. Secondary Effect:

a. Human-social :

- Disease
- Permanent disability
- Psychological impact
- Loss of social cohesion due to disruption of community
- Political unrest (govt. response is perceived as inadequate)

b. Physical :

- Progressive deterioration of damaged buildings and infrastructure which are not repaired

c. Economic:

- Losses borne by the insurance industry weakening the insurance market and increasing premiums
- Loss of markets and trade opportunities through short-term business interruption
- Loss of confidence by investors, withdrawal of investment
- Capital costs of repair

5. Mitigation Strategy

Many disaster management efforts have been conducted, especially before given disasters occur. This includes efforts in mapping natural hazard vulnerability, mapping the area of conflict potency, education and training for disaster handling, socializing law and regulation technical (structure) and non-technical (non-structure) mitigation. Despite such efforts, there are still needs for improving emergency response and victims handling after the disaster happen. It is also required to improve rehabilitation and reconstruction skill so that the victims may live safely and happily.

So having identified the areas prone to slope failure and evaluated its probability of occurrence, mitigation measures should be emplaced or implemented on those areas which have a high probability of occurrence. Hazard mitigation measures may be classified as soft or hard (Arboleda, R.A., 2001). Soft mitigation measures include formulation and implementation of disaster preparedness plans, landuse planning and zonation, and information dissemination. A well-laid disaster preparedness plan should include a scheme for monitoring the slope, effective and timely warning system, and clear and easy to understand steps on what to do before, during and after the eventuality of a slope instability phenomenon. Information dissemination include educating the public on the hazards they face and that if they are within the danger zones, they should be aware of any eventualities related to slope failure and that they should listen to any announcements from the warning authorities.

Hard mitigation measures involves the construction of civil structures like retaining walls, slope works, anchors and drainage system. Retaining walls are designed to increase resisting force while anchors should interact the driving force. Slope works are designed to stabilize the gradient of the slope. Drainage system are contructed to drain the slope of excess water, reduce the water sources affecting the sliding mass and lower the groundwater level within the sliding mass.

6. Mitigation Interventions

a. stimulate and promote research and application, provide knowledge, build capabilities, convey experience and know-how transfer among countries and allocate necessary resources for reducing or preventing severe and recurrent impacts of hazards, for the most vulnerable people with particular attention given in the transfer of experience amongst those countries most exposed to risks.
b. Develop and apply risk reduction strategies and mitigation measures with supporting arrangements and resources for disaster prevention at all levels of activity including focusing multi-year risk reduction strategies on urban concentration and mega-city environments and promoting a more proactive interface between management of natural resources and risk reduction practices.
c. Build, or where existing, strengthen regional/sub-regional, national and international approaches, and collaborative organizational arrangements that can increase hazard, risk and disaster prevention capabilities and activities by establishing coordination mechanisms for greater coherence and improved effectiveness of combined hazard, risk, and disaster prevention strategies at all level of responsibility (ISDR, 2000).

Sutikno (2003) stated that the impact of disasters in Indonesia are varies and caused so many people deaths, injuries, very high lost of properties and environmental damages. Most of the vulnerability to various disasters are caused by: settlements built on hazard zones, building with weak construction and foundation, lack of understanding many types of hazard, lack awareness of many type of hazard, lack of evacuation plan and warning systems, high risk infrastructure elements, unprotected food stocks, livestock and standing crops, farming on marginal lands and subsistence farming, lack of agricultural inputs, lack of seed reserve, lack of information and communication, lack of education on earth sciences. Ideally Indonesia has database on disasters systematically, including spatial data of hazard and disaster zones in various scales. Human resources to handle the disaster in Indonesia do not sufficient yet and the existing human resources need to improve their capability and the professionalism. Understanding and awareness of the people in the dangerous zone should be improved, and if possible they want relocate in the safer area.

7. Recommendations

In spite of the facts that many disaster management efforts have been conducted, especially before given disasters occur, efforts in mapping natural hazard vulnerability, mapping the area of conflict potency, education and training for disaster handling, socializing law and regulation technical (structure) and non-technical (non-structure) mitigation are very needed. Despite such efforts, there are still needs for improving emergency response and victims handling after the disaster happen. It is also required to improve rehabilitation and reconstruction skill so that the victims may live safely and happily.

References

Arboleda,R. A. 2001. **Landslides in the Philippines**. Paper presented in the International Workshop "Learning to Expected the Unexpected : Disaster Management and Mitigation through Leadership", PHIVOLCS, Philippines.

Cooke, R.U. and J.C. Doornkamp. 1990. **Geomorphology in Environmental Management**. Oxford University Press, New York.

Gany, A.H. 19999. **The Impacts of Extreme Climate Events on Water Resources Management : Flood and Drought Mitigation, Cases in Indonesia**. Paper presented in Workshop on Extreme Climate Events (ECE) in Indonesia, and Its Impacts to Human, Society and Environment. ADPC-Bakornas PB, Bogor, Indonesia, 11-12 Febraury, 1999.

Sutikno. 2003. **The Impacts of Disaster in Indonesia**. Leture Note of the Refresher Course in Application of GeoInformation in Disaster Management. ITC, The Netherlands-Gadjah Mada University, Yogyakarta.

Terlien, M.T.J. 1996. **Modelling Spatial and Temporal Variations in Rainfall-Triggered Landslides.** Publication Number 32. International Isntitute for Aerospace Survey and Earth Sciences (ITC), The Netherlands.