GIS-based Landslide Susceptibility Mapping at Pasir Open Pit Coal Mine, Indonesia

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1. INTRODUCTION

In open pit mines, the ultimate slopes of pits are generally excavated to the steepest possible angle to minimize the amount of waste rock which has to be removed in the recovery of an ore-body. Unfortunately, the economic benefits gained can be negated by major slope failure (Bye and Bell, 2001). Therefore, continual evaluation of the stability of the ultimate slopes is a vital part of open pit planning, and controlling of landslides safely and economically is a great challenge to mine operators.

Although the evolution of both slope designs and controlling measures has led to improvements in slope stability and safety, landslides are still major geological problems in open-pit mines (Wei et al., 2008). There have been many studies to analyze the stability of open pit slopes using numerical simulation codes (e.g., FLAC) (Chung et al., 2000; Wang et al., 2000). Since these approaches express the stability of slopes in terms of the safety factor (absolute hazard), they have been widely used as practical tools for the slope designs in the open pit mining sites. However, for large scale open pit mines, the variations in parameters included in the analysis of the safety factor are too large to accurately quantify (Jibson and Keefer, 1989). Therefore, the stability analysis using numerical simulation codes has been usually applied not to a whole open pit area but to several vertical cross-sections of open pit slopes.

This study considers the landslide susceptibility at the Pasir open pit coal mine located in a humid region in Indonesia. The basic concept of landslide susceptibility includes the spatial distribution of factors related to the instability processes in order to determine zones of landslide-prone areas without any temporal implication (Chacon et al., 2006). Consequently, the landslide susceptibility mapping is useful for open pit mines where it is difficult to secure enough information concerning the historical record of landslide events, meteorological records of rainfall are lacking or scarce, and the magnitude/intensity of earthquakes that have triggered landslide is unknown. The result of landslide susceptibility mapping can depict pit walls likely to have landslides in the future by correlating some

of the past distribution of slope failures (Brabb, 1984).

This study presents a raster-based Geographic Information Systems (GIS) model to assess the landslide susceptibility in large scale open-pit mines using multi-criteria evaluation technique. The reliability of landslide susceptibility mapping mostly depends on the amount and quality of available data, the working scale and especially the selection of the appropriate method of analysis and modeling (Yalcin, 2008). The model developed in this study uses a semi-qualitative method, which incorporates the concept of ranking and weighting into the knowledge of experts, to identify sites of similar geological and geomorphological properties that are susceptible to slope failures. This paper describes the concept and details of the model and its application to the Roto South region at the Pasir open pit coal mine, Indonesia.

2. MODEL DEVELOPMENT

The model for geo-processing in the conventional GIS software was developed in this study to assess the landslide susceptibility of open pit slopes from several thematic maps of an open-pit mine. It considers 7 criteria as follows:

- Overall slope gradient of the pit wall
- Height of the pit wall
- Gulley erosion due to the concentrated drainage flows
- Distance from water-bodies at upper parts of the pit
- Distance from structural elements such as fault
- Density of tension cracks
- Monthly mean volume of excavation

Fig. 1 shows the model developed in this study. The model consists of three data processing steps: (1) rating by fuzzy membership functions to normalize the susceptibility score at each criterion within the range of 0 and 1; (2) weighing the each criterion using Saaty's pairwise comparisons; and (3) combining the information from 7 criteria to form a single index of landslide susceptibility.

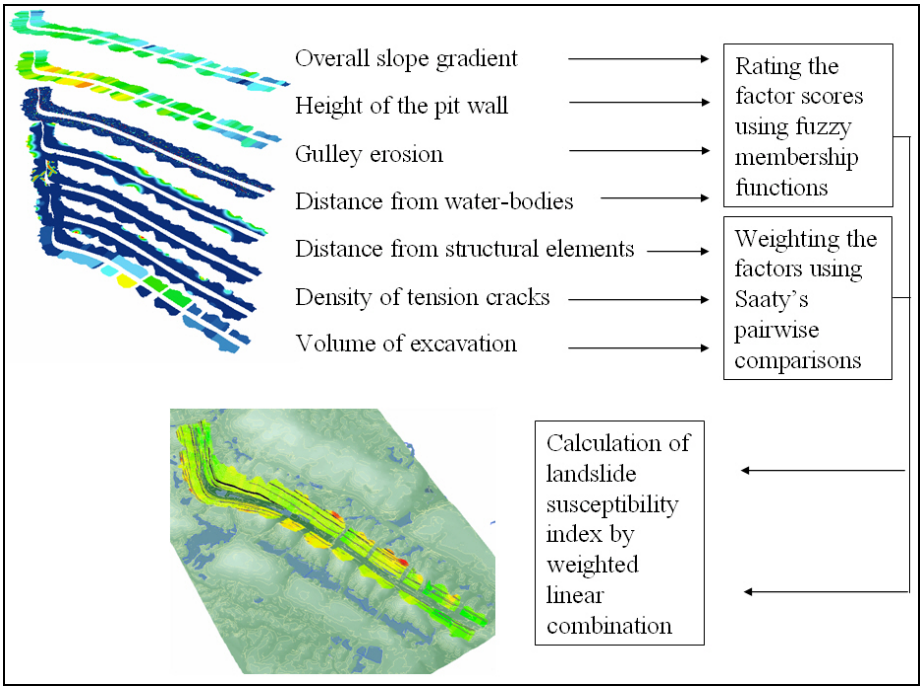

Fig. 1 Geo-processing model for the assessment of landslide susceptibility in open-pit mines

3. APPLICATION

The Pasir open pit coal mine is located in the east side of Kalimantan, Indonesia (115°53´E longitude and 1°51´S latitude). A region of the Roto South pit was selected as a study area (Fig. 2). The highest elevation in the study area is 196 ML (i.e., 196 m above sea level), and the lowest is currently – 60 ML. The lowest elevation will be – 230 ML according to the final pit plan. The current height of opened walls varies from 150 m to 220 m. The average height of benches is 20 m and average gradient of bench slopes is 40 degrees.

The DEM which has 5m grid spacing was used to generate the grade of terrains and several thematic maps such as water-bodies, coal seams, haul road networks, etc. were digitized from the mine area map for geo-processing. Fig. 3 shows the landslide susceptibility index derived from the developed model through the three steps of geo-processing. As seen in Fig. 3, field survey showed that the highly rated location at the landslide susceptibility map is unstable.

Fig. 2 View of the study area

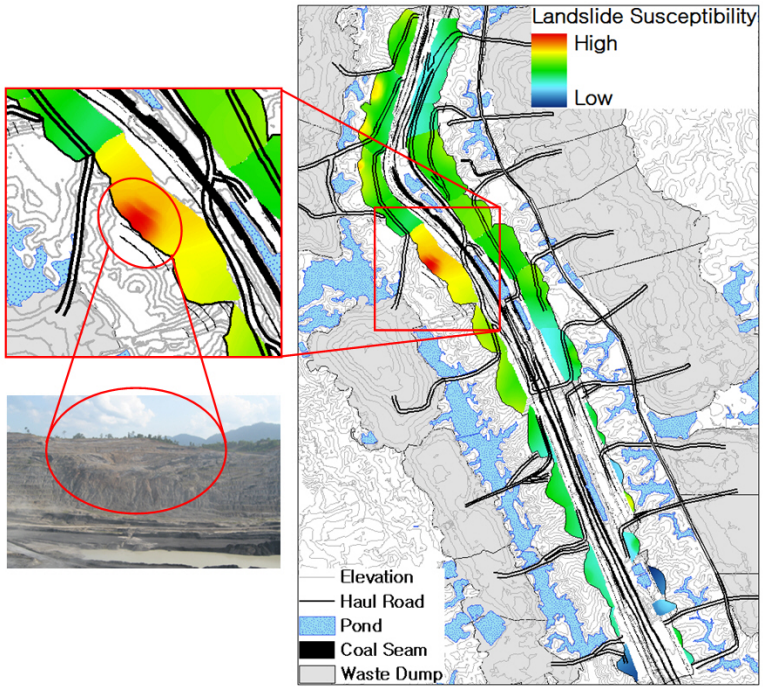

Fig. 3 Landslide susceptibility at the Roto South region, Pasir open pit coal mine, Indonesia (May 2007)

4. CONCLUSIONS

In this study, a novel methodology that combines the knowledge of experts and the concept of ranking and weighting based on multi-criteria evaluation technique was proposed to assess the landslide susceptibility in large scale open-pit mines. The model logic for landslide susceptibility mapping considers 7 criteria which can significantly influence the instability processes of open pit slopes. Using fuzzy membership functions, the normalized factor scores that represent adverse affects of slope stability can be assigned and the weight of each criterion can be determined through the Saaty's pair-wise comparisons. The application at the Roto South in the Pasir open-pit coal mine, Indonesia showed that the proposed methodology could make rational solutions to evaluate the stability of the ultimate slopes approximately and to make a decision for controlling of landslides safely and economically.

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