Landslide Susceptibility Analysis of Clicap, Indonesia

I. J. Kim, S. Lee, J. W. Choi
Geology and Geoinformation Division, Korea Institute of Geology & Mineral Resources (KIGAM)
30, Gajung-dong, Yusung-gu, Daejeon, 305-350, Korea
ijkim@kigam.re.kr

Gatot Moch Soedradjat
Directorate of Volcanology and Geological Hazard Mitigation
E-mail:gatot@vsi.esdm.go.id

Abstract: The aim of this study is to evaluate the susceptibility of landslides at Clicap area, Indonesia, using a Geographic Information System (GIS). Landslide locations were identified from field surveys. The topographic and geological map were collected and constructed into a spatial database using GIS. The factors that influence landslide occurrence, such as slope, aspect and curvature of topography, were calculated from the topographic database and lihology and fault was extracted from the geological database. Then landslide susceptibility was analyzed using the landslide-occurrence factors by likelihood methods. The results of the analysis were verified using the landslide location data. The GIS was used to analyze the vast amount of data efficiently. The results can be used to reduce associated hazards, and to plan land use and construction.
Keywords: Landslide; susceptibility; frequency ratio, GIS; Remote Sensing; Indonesia

1. Introduction

Landslides are major natural geological hazards and each year are responsible for enormous property damage and both direct and indirect costs. Indonesia experiences frequent landslides. They often result in significant damage to people and property. In Pemalang and Clicap, much damage was caused by the landslides, which were due to the heavy rainfall, and, because there was little effort to assess or predict the event, damage was extensive. Through scientific analysis of landslides, we can assess and predict landslide-susceptible areas and, by allowing proper preparation, decrease landslide damage. In order to achieve this, landslide-hazard analysis techniques were validated using a frequency ratio model.

There have been many studies of landslide hazard evaluation using GIS. Guzzetti et al. (1999) summarized many landslide hazard evaluation studies. Also, recently, there are studies for landslide hazard evaluation using GIS and many of their studies that have applied probabilistic method (Rowbotham and Dudycha, 1998; Parise and Jibson, 2000;Baeza and Corominas, 2001;Wu et al., 2001;Clerici et al. 2002; Donati and Turrini, 2002;Zhou et al., 2002), logistic regression method (Atkinson and Massari, 1998;Dai et al., 2001, Dai and Lee, 2002; Ohlmacher and Davis, 2003) and safety factor method (Luzi and Pergalani, 1996; Gokceoglu et al, 2000;Luzi et al., 2000; Romeo, 2000;Refice and Capolongo, 2002;Carro et al., 2003;Shou and Wang, 2003;Zhou et al., 2003) to landslide hazard mapping. Especially, in Korea, there are some studies of landslide hazard evaluation with GIS (Lee and Min, 2001, Lee et al., 2002a, Lee et al. 2002b).
2002b).

For the landslide-hazard analysis, we have collected data, made spatial database, extracted landslide related factors, calculated frequency ratio, overlaid the factors, made landslide susceptibility map and verified the map. A key assumption using probability, frequency ratio, approach is that the potential (occurrence possibility) of landslides will be comparable to the actual frequency of landslides. Landslide occurrence areas were detected in the Clicap area, Indonesia by interpretation of aerial photographs and field surveys. A map of landslides was developed from aerial photographs, in combination with the GIS, and this were used to evaluate the frequency and distribution of shallow landslides in the area. Topography and lithology databases were constructed. Maps relevant to landslide occurrence were constructed to a vector type spatial database using the GIS software ARC/INFO. Using the database, landslide related factors were extracted. First, using the topographic database, the digital elevation model (DEM) was created and using the DEM, slope, aspect and curvature. For this, the calculated and extracted factors were converted to a 10m × 10m grid (ARC/INFO GRID type). Then, using univariant probability analysis, frequency ratio method, the spatial relationships between the landslide location and each landslide-related factor, were analyzed. The relationship was used as each factor's rating in the overlay analysis. So, the factor's ratings were summed to landslide hazard index and hazard mapping. Finally, the hazard map was verified using existing landslide location.

2. Application of probabilistic method and its interpretation

The relationship between landslide occurred area and landslide related factors can be distinguish from the relationship between landslide not occurred area and landslide related factors. To represent the distinction quantitatively, the frequency ratio was used for this study. The frequency ratio is ratio of probability that is occurrence probability to not-occurrence probability in certain attribute. In the case of landslide, if we set the landslide occurrence event to B and certain factors' attribute to D, the frequency ratio in D is ratio of conditional probability. Therefore, the ratio is higher than 1, the higher relationship between landslide and the certain factors' attribute and the ratio is lower than 1, the lower relationship between landslide and the certain factors' attribute. For calculating of the frequency ratio, the table was made for each landslide related factors. Then area ratio for landslide occurrence and not occurrence was calculated for range or type of each factor, and area ratio for range or type of each factor to total area was calculated. Finally, frequency ratios for range or type of each factor was calculated by divide the landslide occurrence ratio by the area ratio.

3. Landslide susceptibility mapping

Using the probability method, the spatial relationship between landslide-occurrence location and each landslide-related factor was derived. The used factors that influence landslide occurrence are topographic slope, topographic aspect and topographic curvature from topographic database, geology from the geologic database. The factors were converted to a 10 m × 10 m grid for calculate the landslide hazard index.
The correlation ratings are calculated from relation analysis between landslides and the relevant factors. Therefore, the rating of each factor's type or range was assigned as the relationship between landslide and each factor's type or range, that is, ratio of the number of cells where landslides not occurred to the number of cells where landslides occurred as shown in Table 2 to Table 9. The landslide hazard index (LHI) is calculated by summation of each factor's ratio value.

LHI = ΣFr (Fr: Rating of each factors' type or range) (1)

Using the frequency ratio and Eq. (1), the LSI values were computed for the four cases. If no ratio was available for a certain class, the average value (i.e., unity) was used. The computed LSI values were mapped to allow interpretation such as that illustrated in Fig. 1. The values were classified into equal areas and grouped into five classes for visual interpretation. If the LSI value is high, there is a higher susceptibility to landslides; a lower value indicates a lower susceptibility to landslides.

4. Discussion and conclusion

Landslides are among the most hazardous of natural disasters. Government and research institutions worldwide have attempted for years to assess landslide hazard and risk and to predict their spatial distribution. In this study, a verification of a probabilistic approach to estimating the susceptible areas is presented using GIS.

In this study, only the susceptibility analysis was performed because the small area studied did not allow us to determine the distribution of rainfall. However, if data on factors causing the landslides (such as rainfall, earthquakes or slope cutting) exist, then a possibility analysis could also be done. In particular, if the data could be combined with a hydrological model, a more accurate analysis would be possible. If the factors relevant to the vulnerability of buildings and other property were available, a risk analysis could also be done. Landslide susceptibility maps are of great help to planners and engineers choosing suitable locations for development. These results can be used as basic data to assist slope management and land-use planning.

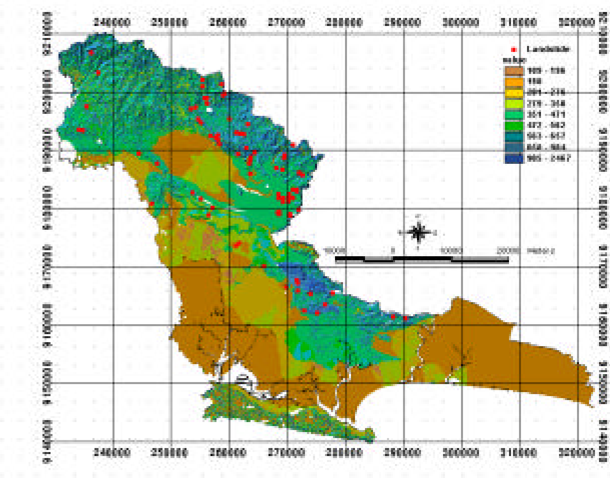

Fig. 1. Landslide susceptibility map.

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