Topic: "Risk Analysis of Large-scale landslides"

Mapping Geologically Complex Terrane for Landslide Susceptibility

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Abstract

Subjective and semi-quantitative approaches were employed to generate landslide susceptibility map for northwest Mindoro, an area located in an active tectonic setting. A combination of expert opinion, Analytic Hierarchy Process, and weighted overlay analysis in GIS were used to assess the relationship of landslide susceptibility with predisposing factors such as lithology, slope gradient, elevation, distance from tectonic structures and historical earthquakes, land cover, and slope aspect. The result shows lithology has the highest influence on landslide occurrence in the area. Moreover, the combination of the AHP method with factor ratings derived from expert knowledge produced a susceptibility map that is close to the actual distribution of landslide occurrences in the area.

Key words: landslide susceptibility assessment, Geographic Information System (GIS), Analytic Hierarchy Process (AHP), northwest Mindoro, Philippines

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1. Introduction

The Philippines, located in the circum-Pacific region, is naturally prone to landslides. The combined archipelagic nature, frequent exposure to precipitation, active tectonic setting, complex lithologic composition and other physical characteristics predispose the Philippines to landslide disasters. Major catastrophic weather events in the country have often resulted in the occurrence of excessive precipitation in areas characterized by densely fractured and highly weathered lithologies. Since the Philippines is located within the northwest Pacific basin, the most active basin where the majority of tropical cyclones are usually formed, an average of 20 tropical cyclones enter and/or cross the Philippine Area of Responsibility (PAR) annually (Yumul et al., 2008). Predisposing factors such as earthquakes and local geology also contribute to the occurrence of catastrophic landslides as occasionally experienced in Benguet Province (NDRRMC, 2012). Areas in an active tectonic setting are often characterized by rocks that are highly weathered, altered, and fractured, consequently promoting slope instability. Mindoro Island, which situates within an arc-continent collision boundary in west central Philippines, is deemed prone to landslide hazards due to lithologic and tectonic influences (e.g., highly weathered and heavily fractured rocks) and constant or prolonged rainfall that further weakens materials on the shallow surface.

This study looked into the geological and geomorphological parameters (e.g. lithology, slope gradient, elevation, distance to faults and lineaments, land cover, distance to historical earthquakes, and slope aspect), taking into consideration the geologically complex location of northwest Mindoro, in assessing the landslide susceptibility of the area.

2. Materials and Methods

The study uses the heuristic analysis approach wherein the Analytical Hierarchy Process (AHP; Saaty, 1980) was used to establish the most appropriate landslide susceptibility assessment and analysis for northwest Mindoro. The causative factors that were considered in the study are lithology, slope gradient, elevation, distance from faults and lineaments, land cover, distance from magnitude 5 earthquakes, and slope aspect. These causative factors correspond to geological and geomorphological data that were digitized into thematic layers, processed, and reclassified using ArcGIS. Three variations of overlay analyses were employed and compared. These are (1) field observation + non-AHP weight assignment, (2) idealized weight + AHP weight assignment, and (3) combination of field observation + AHP. Each causative factors were assigned relative weights depending on their degree of influence on landslide susceptibility (e.g. subclasses ranking from 1 to 5, with 1 having the lowest and 5 having the highest contribution to slope failure). Ground data were collected during the landslide assessment surveys conducted in the study area.

3. Results and Discussion

Landslide frequency is highest in areas characterized by other wooded land type

of land cover underlain by sedimentary rocks of the Lasala Formation. Most landslides also occur in the lowest elevation (<176 masl) which is not typical in some areas in the Philippines. For the slope-related factors, gradients with 6.5° to <45° have frequent numbers of landslide occurrences and most are in the southwest aspect. Structural data show that landslides are mostly located within a 2-km distance from thrust faults and within a 5- to 6-km distance from historical seismic centers with >5 magnitudes. The landslide frequency is mostly similar for different slope ranges. Those with steep slopes (>45°) are mostly characterized by hard rock or outcropping bedrock; some might be associated with rock fall but were found to be not associated with landslides in the study area. The frequency analysis shows that slope-related factors particularly gradient, which commonly has the highest influence among the different causative factors (Hasekiogullari and Ercanoglu, 2012), is only second in the degree of influence next to lithology. Field evidence shows that slope failures do not necessarily occur along slopes of steep gradients, nor at areas of high elevation.

Based on expert judgments and field evidence, the AHP analysis yielded highest derived weight (0.33) for lithology while aspect has the least derived weight (0.02). Three GIS-based landslide susceptibility maps were generated based on the combination of AHP and expert judgment based ranking. The landslide susceptibility zonations are categorized as low, moderate, and high using the equal interval method with minimum landslide susceptibility index (values are 1.99 to 4.79 with breaks 2.92 and 3.86). Three variations of weighted overlay analysis were carried out using subjective and semi-quantitative or numerical assignment of a factor and subfactor weights. Results show that the town centers of Mamburao, Abra de Ilog, and Paluan have low susceptibility to landslides; however, hillslopes surrounding Abra de Ilog are highly susceptible. Validation for these susceptibility maps will be carried using temporal data (i.e. recent landslide occurrences) generated through remote sensing.

4. REFERENCES

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