Landslide susceptibility using Analytic Hierarchical Process in northern Thailand

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ABSTRACT

Landslides are one of the most common natural disasters. It causes a lot of damage to both people and property. This is triggered by a physical factor and the amount of rainfall is considered as the most important factor. The purpose of this research is to study susceptible zones to landslides in northern Thailand. This study used Analytic Hierarchy Process (AHP) integrated with Geographic Information Systems (GIS). Ten factors were considered namely, slope, slope aspect, slope angle, lithology, distance to lineament, distance to drainage, soil texture, rainfall, land use, and normalized difference vegetation index (NDVI). The study revealed areas that very high susceptible levels found in Lampang, Phrae, and Nan provinces. The Area Under Curve (AUC) method used to validate the map, showed the success rate accuracy of 59.67% and the prediction was correct 62.56%. Furthermore, these results will guide planning to deal with and prevent landslides in northern Thailand effectively.
Keywords : Landslides, Analytical Hierarchy Process(AHP), Geographic Information Systems (GIS), northern Thailand, Area Under Curve (AUC)

1. INTRODUCTION

Landslides are one of the most common natural disasters in the world. It causes a great deal of harm to both people and property. It also has an impact on the global and national economies. In the last 41 years, more than 150 landslides have occurred in Thailand, with the northern area bearing the brunt of the damage. According to data collected, the landslide caused total damage of 2,575.5 million baht and impacted the lives of approximately 286 people. (Soralump *et al.*, 2010). There have been numerous studies and assessments of landslide areas by considering many factors, including: geology, lithology, soil texture, land use, rainfall, and human activity (Guzzetti *et al.*, 2000; Intarawichian., 2008; Boroumandi *et al.*, 2015).

The analytical process is currently presented as a map qualitatively as well as quantitatively by integrating Geographic Information Technology (GIS) with Analytic Hierarchy Process (AHP). As extensively used in previous studies, GIS can be used to manage, process, and analyze landslide surveys due to its powerful tools. Therefore, this paper aims to; Landslide susceptibility zoning can substantially assist future risk mitigation and sustainability planning in areas. The Analytic Hierarchy Process (AHP) was a powerful tool for landslide susceptibility zoning. This technique is well-known applicability in multi-criteria decision making and the analytical capabilities of Geographic Information Systems (GIS).

2. DATA AND METHOD

2.1 Study area

In this study, we are focusing on Northern Thailand as the study area that covers an area is approximately 93,691 km^2. The study area consists of nine provinces: Chiang Rai, Mae Hong Son, Chiang Mai, Lamphun, Lampang, Phayao, Nan, Phrae, and Uttaradit. Data collection on previous landslide events revealed that the majority of the events occurred in the north of Thailand and takes place between May and August. The data used in an analysis for this study rainging from 2002 to 2012. As shown in Figure 1, a total of 64 locations were discovered, which were divided into 45 locations for modeling success rate analysis accounted for 70 percent of success rate, while 19 locations used for model prediction rate accounted for 30 percent of success rate.

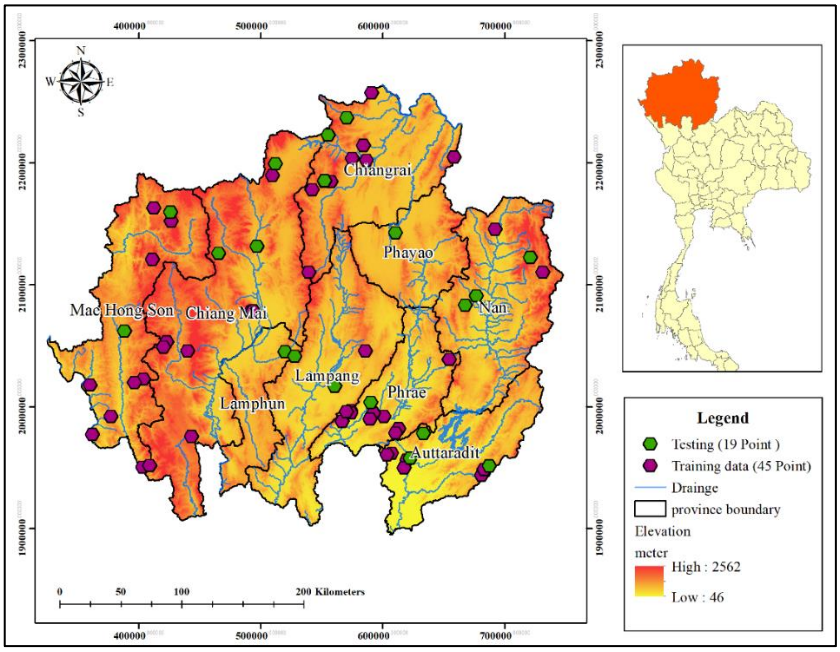

Figure 1. Study area with locations of landslides

2.2 Conditioning factors for landslide

Total ten causative factors were chosen for the susceptibility analysis of landslide based on the study by Intarawichian et al. (2008). A variety of data sources were used to collect landslide causative factors. These maps were prepared in GIS software by classifying and then reclassifying to create a landslide susceptibility map. In this study, the locations of landslide occurrences between 2002 to 2011 were derived from Geotechnical Engineering Research and Development Center (GERD). Rainfall: The annual rainfall average over the ten year was computed from daily rainfall extracted from TRMM 3B42 V.7 (https://pmm.nasa.gov/data-access/downloads/trmm). Elevation and slope angle were derived from Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) and then generate slope aspect for the study area. Distance from drainage/Lineament was calculated from GIS data from the Department of Mineral Resources by creating a buffer at distance of 500 m for each interval. Soil texture was created by grouping soil types from the Land Development Department (LDD). NDVI was used as monthly vegetation indices L3 Global 0.05Deg CMG product (MYD13C2). Finally, Lithology was obtained from the Department of Mineral Resources as shown in Figure 2.

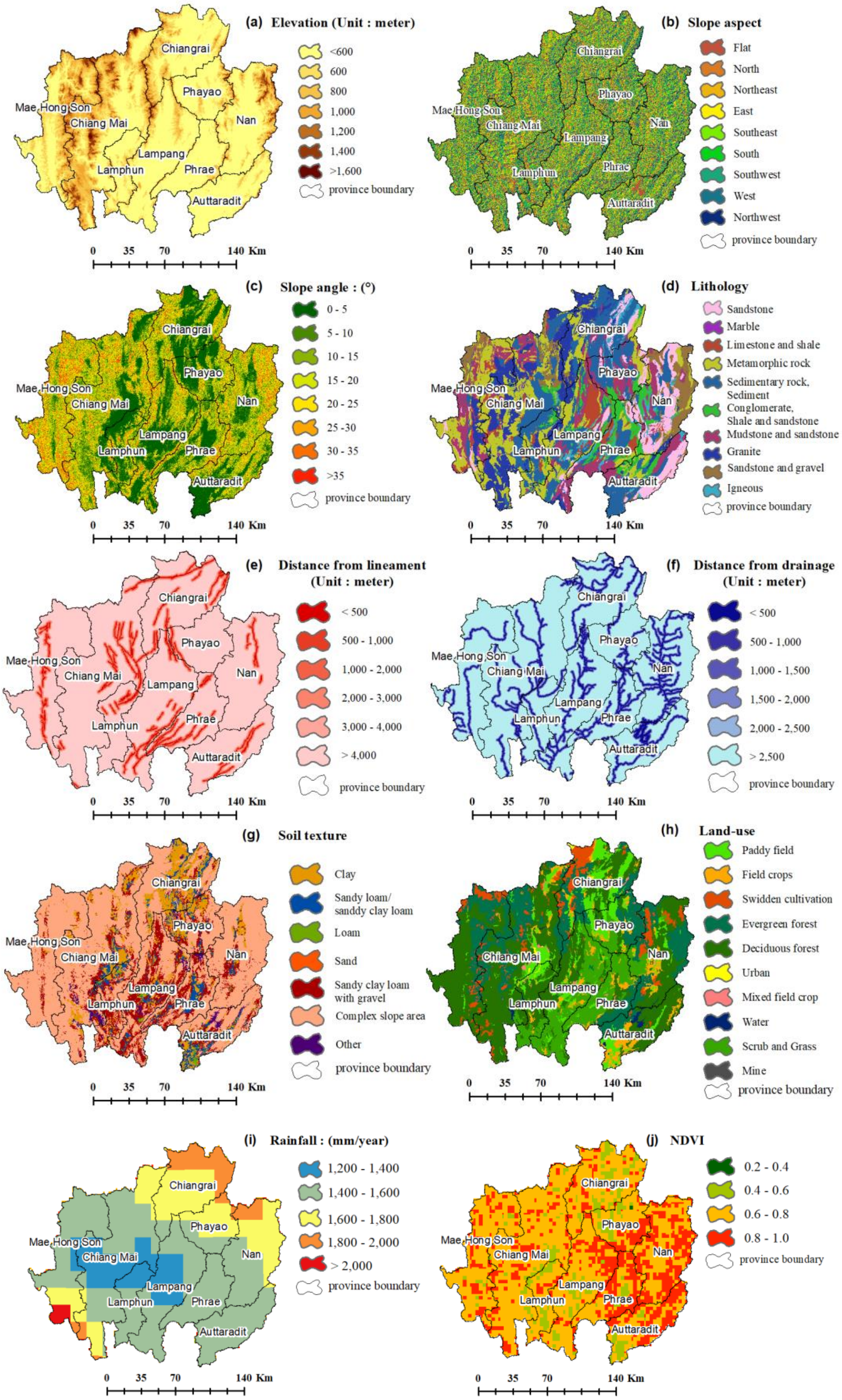

Figure 2. Map of physical parameters

2.3 METHODOLOGY

The present study is based on the AHP method for synthesizing weights of the factors/classes. AHP concept developed by Saaty (1980), we adopted to create the landslide susceptibility map. The computational steps to find criterion weights of a reciprocal matrix are as following operations (equation 1):

$$\text{Consistency Index (C.I.)} = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Where λ_{max} is the the most significant positive eigenvalue of the matrix and n is order of matrix. Finally, the Consistency ratio (C.R.) is calculated using the following (equation 2):

$$\text{Consistency Ratio (C.R.)} = \frac{CI}{RI} \quad (2)$$

Where R.I. is called Random Index and depends on the order of the matrix (n). The standard value of R.I. is represented (In this paper use R.I.= 1.49). If the threshold of Consistency ratio (C.R.) is achieved (C.R.<0.1), the weights of each row of the matrices are calculated.

Table 1. gives a comparison matrix for different classes of the thematic factors viz., elevation, slope aspect, slope angle, a distance from drainage, lithology, distance from lineament, soil texture, rainfall, land use and NDVI. Figure 3 presents the thematic maps generated for this study.

Table 1. Weight assignment of all factors based on AHP concept

Factor	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	Weight
[1] Elevation	1.00	1.00	0.20	0.50	0.20	0.33	0.50	0.20	0.25	0.33	0.03
[2] Slope aspect	1.00	1.00	0.25	2.00	0.20	0.20	0.33	0.17	0.25	0.33	0.03
[3] Slope angle	5.00	4.00	1.00	5.00	0.50	2.00	5.00	0.50	3.00	5.00	0.16
[4] Distance from drainage	2.00	0.50	0.20	1.00	0.33	0.25	0.33	0.20	0.33	0.50	0.03
[5] Lithology	5.00	5.00	2.00	3.00	1.00	2.00	2.00	0.33	4.00	5.00	0.17
[6] Distance from lineament	3.00	5.00	0.50	4.00	0.50	1.00	3.00	0.33	3.00	4.00	0.12
[7] Soil texture	2.00	3.00	0.20	3.00	0.50	0.33	1.00	0.20	0.33	0.50	0.06
[8] Rainfall	5.00	6.00	2.00	5.00	3.00	3.00	5.00	1.00	5.00	5.00	0.26
[9] Land-use	4.00	4.00	0.33	3.00	0.25	0.33	3.00	0.20	1.00	2.00	0.08
[10] NDVI	3.00	3.00	0.20	2.00	0.20	0.25	2.00	0.20	0.50	1.00	0.06
CR : 0.07											

The weights of classes of each of the 10 factors derived using AHP were assigned in the attribute Table to create weighted raster maps of the thematic layers. The weighted raster maps were loaded in the ArcGIS software. Then, the Landslide Susceptibility Index is applied in the raster calculator tool of Spatial Analyst Extension to produce the landslide susceptibility map of the study area, as (equation 3) :

$$\text{Landslide Susceptibility Index (LSI)} = \sum_{i=1}^{n} W_i \times R_i \qquad (3)$$

Where Wi = Factor weight
Ri = Class weight/rating for factor i

Then, the resulting map is reclassified into five susceptibility classes. The final landslide susceptibility map is produced as shown in Figure 3.

3. RESULT AND DISCUSSION

3.1 Landslide susceptibility map

Landslide Susceptibility Map (LSM) was created using the AHP method. AHP was used to weight factors and their classes (Table 1) by overlaying the layers in the GIS environment and using relative weights. Accordingly, the LSI map is classified into the following five categories: Very low susceptibility, low susceptibility, moderate susceptibility, high susceptibility and very high susceptibility as shown in Figure 3. As shown in Table 2, we found that 11% of the entire area is accounts for very low susceptibility class, 13% in low susceptibility class, 30% in moderate susceptibility class, 33% in high susceptibility class and 13% in very high susceptibility. The results show that most of areas in Phrae, Lampang, and Nan provinces are in the very high susceptibility classes.

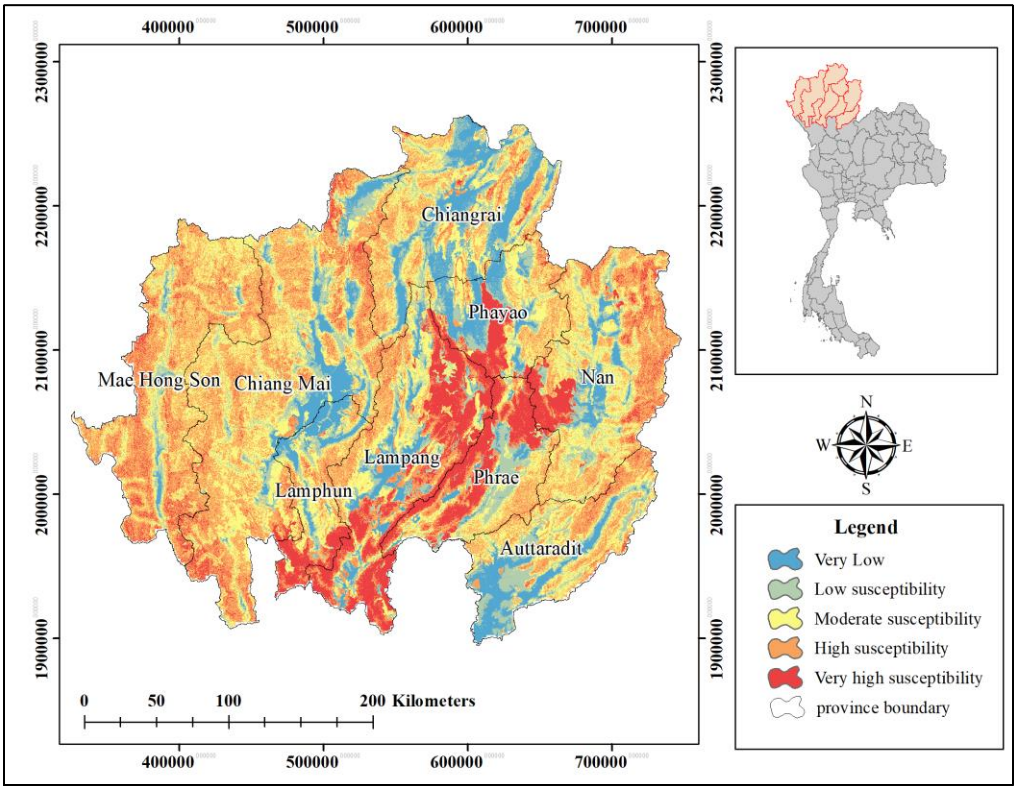

Figure 3. Landslide susceptibility map

Table 2. Landslide susceptibility classes, area and coverage percentage of the study area based on AHP

Landslide susceptibility classes	Number of landslide points (out of 64)	Area (km^2)	% of area
Very low susceptibility (VLS)	2	10,479.57	11.00
Low susceptibility (LS)	6	12,118.71	13.00
Moderate susceptibility (MS)	22	28,256.45	30.00
High susceptibility (HS)	21	31,620.76	33.00
Very high susceptibility (VHS)	12	12,185.14	13.00

3.2 AUC (Area Under the Curve) Validation

In this study, accuracy assessment results from Area Under the Curve. It was found that the hierarchical analysis process found that the accuracy of the success rate value was 59.67% and the prediction rate was 62.56%. A map that is susceptible to landslides can be prepared.

4. CONCLUSION

Demarcation of landslide zones in Northern Thailand, by using influencing analytical hierarchy process models in GIS. The goal of this paper was to use AHP to create a landslide susceptibility map. The results show that Phrae, Lampang, and Nan provinces are in the very high susceptibility classes. However, the most vulnerable areas to landslides were discovered. It was 31,620.76 Km^2 at the high susceptibility level, accounting for 33% of the total area. Finally, the susceptibility mapping method was found to be reliable with a success rate of 59.67 % and a prediction rate of 62.56%. In present days remote sensing and GIS tools are the most cost and time effective tools for landslide investigation.

5. ACKNOWLEDGEMENTS

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