INTEGRATED REMOTE SENSING AND GIS FOR LANDSLIDE RESEARCH IN BAC KAN PROVINCE BY COMBINING ANALYTIC HIERACHY PROCESS AND BIVARIATE STATISTICAL ANALYSIS APPROACH

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ABSTRACT

Bac Kan is a province located in the northeast, Vietnam, where landslides occur frequently and seriously affect human life and the natural environment. To reduce these effects, there should be scientific assessment of region landslide risk. In particular, the establishment of landslide hazard maps have proven to be an effective approach. In this paper, we used analytic hierachy process and bivariate statistical analysis method for landslide susceptibility mapping. In the first stage, a landslide inventory map was prepared using high resolution satellite images (IKONOS, SPOT-5) and field survey. In the second stage, causative factor such as slope, weathering, landcover, geomorphology, fault density, geology, surface roughness, land cover, distance from road, precipitation, were used as thematic layers in the analysis. The final map were diviede into 5 zones: very low, low, moderate, high, and very high susceptibility for landsliding, according to the map, approximately 20% of the study area was identified as very high and high-susceptibility and concentrated in the north of study area, where the forest cover was severely reduced.

INTRODUCTION

Landslide is a form of geological disasters, often occurs in areas of steep terrain. Cause serious consequences to life and property in areas where landslides occurred. Bac Kan is a province located in the northeast, Vietnam. This region exhibits mountainous topographical features, and is frequently subjected to heavy precipitation. Due to these adverse effects, them region is prone to extensive and severe landslides. However, the warning, early detection landslides in this area have not been interested. The landslide susceptibility maps is a necessary and the first step approach in the prevention and mitigation damage due to landslide disasters as well as for other purposes such as landuse planning.

Many landslides research methods were introduced in recent years (Gorsevski et al., 2006; Yalcin, 2008; Yilmaz, 2009) According to Aleotti and Chowdhury (1999) can be divided into 2 groups, qualitative methods and quantitative methods. With the development of remote sensing and geographic information systems, quantitative methods have been used by many scientists than other method. However, the methods of statistical analysis, many reseaches have focused on analysis of the frequency of landslide on each classs factor without evaluating the correlation between the parameters. This study was carried out to establish the landslide susceptibility maps for study area using a comnination of two methods combined AHP (Analytic Hierachy Process)and BSA (Bivariate Statistical Analysis) method.

METHODS

Study area

The study is located in the northeast region of Vietnam. This area has a monsoon climate, with an average humidity of 84%. There are two distinct seasons: the rainy season, rainfall accounted for 80% of average annual rainfall (1,900 millimetres, about 150 rainy days per year), usually begins in May and ends in September; the dry season lasts from October to April. The average temperature is 21^{o}C.

Procedures

Susceptibility is estimated by correlating some of the principal factors that have contributed to past landslides, and can be used to predict the location of future landslide events. In evaluating landslide susceptibility, the selection of the cause factors involved in the model depends on data availability and scale of the reseach area. In this study, eight factors will be selected for the evaluation model of landslide susceptibility include: Slope, rainfall, weathering, land cover, geomorphology, river density, geology, vertical density divided. The research process consists of 5 steps (based on Soeters and van Western, 1996): i) landsliding inventory map; ii) selection of the landslide causative factor; iii) Calculate the rank of each class using BSA method; iv) Assigning the weight of each parameter using AHP method; v) Landslide susceptibility index maps (LSI) were calculated using tools in ArcGIS 9.3, then based on LSI map, Landslide zonation maps were established with 5 susceptible zones.

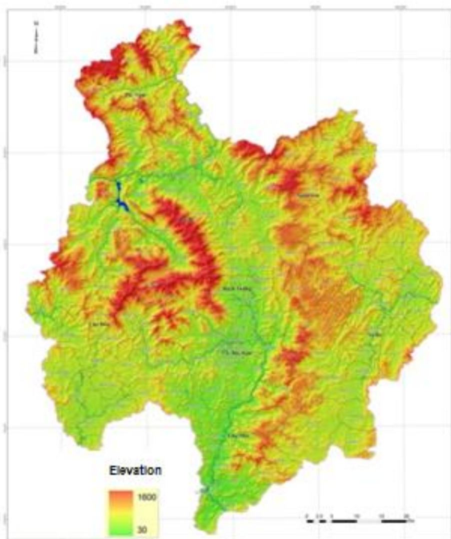

Fig 1. DEM in the study area

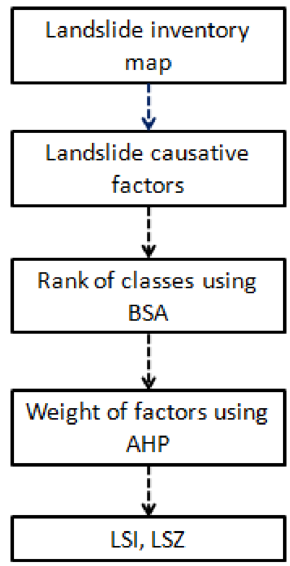

Fig 2. Flow of chart

Landslide inventory mapping

In this study, SPOT 5 and IKONOS images were used to interprete landslides by using ERDAS 9.2. Then site of landslides was checked by field. With multi-temporal satellite data and fieldwork was carried out in 3 years, we have detected a total of 534 landslides occurred in the study area. Most of the landslides concentrated in the roads, while others area occurred in the northern part of the study area.

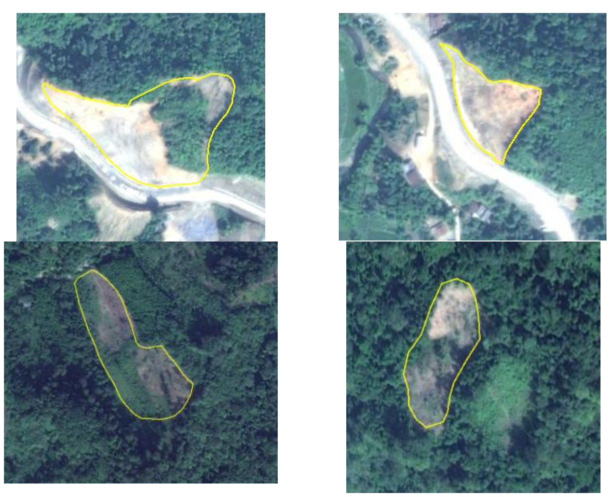

Fig 3. Site of lanslides on IKONOS image

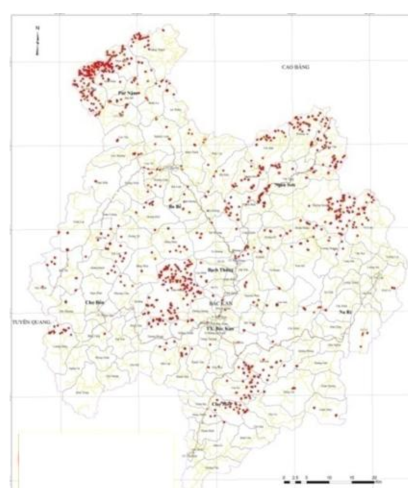

Fig 4. Landslide inventory map in the study area

Landslide causative factors

Based on the availability of data and the scale of reseach, eight landslide causative facors were selected for the model of landslide susceptibility evaluation are slope, rainfall, weathering, land cover, geomorphology, river density, geology, vertical density divided. In particular, the slope map and vertical density divided were extracted from the DEM and the slope map was classified into 5 classes 0 – 8^o; 8^o – 15^o; 15^o – 25; 25^o – 35^o; > 35^o. All maps were converted to raster format with 30pixel x 30pixel.

Rank of class using BSA method

To do so, the landslide inventory map was combined with thematic layers to compute the number of landslide pixel lying on each class of the 8 parameters. The form of BSA used in the information value methods of Yin and Yan (1988). Class weights are computed for all factors.

$$\text{Ri} = \ln \frac{S_i/N_i}{S/N}$$

Where: Si = the pixep of landslides in class i, Ni = the pixel of class i, S = the total pixel of landslides , N = the total pixel of study area.

The weight of each parameter using AHP method

AHP is a method of choosing the alternatives satisfies the given criteria, based on the comparative importance of the pair of factors (Saaty, 1980). The landslide causative factors play an important role for the occurrence of landslides, but they affected on landslides process is not the same. In other words, weight of factors is different in landslide sussceptibility evaluation model. To calculate weight of factors by the method of AHP, we used ExpertChoice software. The slope is defined as the most important factors for landsliding.

Table 1. Comparison matrix for all factors

All factors	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	Eigen-vector
[1] Slope	1	2	3	4	5	6	7	8	0.323
[2] Rainfall		1	2	3	5	7	6	8	0.246
[3] Weathering			1	2	3	5	4	6	0.154
[4] Landcover				1	2	3	4	6	0.106
[5] Geomorphology					1	3	2	5	0.072
[6] River density						1	2	3	0.043
[7] Geology							1	1/2	0.030
[8] Vertial density divided								1	0.027

LSI and LSZ

Landslide susceptibility index map were calculated according to the following formula:

LSI=0.323*[1] + 0.246*[2] + 0.154*[3] + 0.106*[4] + 0.072*[5] + 0.043*[6] + 0.030*[7] + 0.027*[8]

Based on LSI value, we divide the study area into 5 landslide susceptibility. In other words, landslide susceptibility zonation map includes five susceptible region.

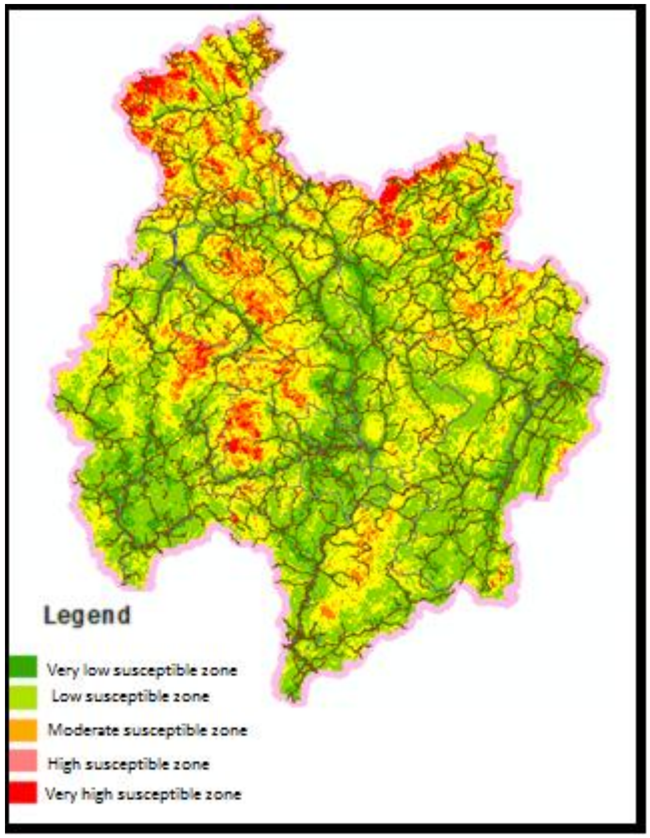

Fig 5. Landslide susceptibility zonation in the study area

RESULTS

There are more than 60% occurrence of landslide and over 20% of the study area is located in high and very high susceptible zone. By comparison with landcover, bare hills area is most prone landslides occur and this is located in very high susceptible zone.

Table 2. The distribution of five susceptibility zones in the study area

Susceptibility class	LSI value	% area covered	% Landslide number
Very low	0-0.21	38,4	5.4
Low	0.22-0.33	25,5	10.1
Medium	0.34-055	15,6	19.3
High	0.56-0.77	14,3	26.5
Very high	0.78-0.99	6,2	38.7

Validation

For accuracy assessment of landslide susceptibility zonation, the area under the curve (AUC) obtained from the ROC (receiver operating characteristics) plot is the most common used accuracy statistics for the prediction models in natural hazard assessment (Begueria, 2006). The AUC is a good indicator to check the prediction performance of the model and the largest AUC, varying from 0.5 to 1.0, is the most ideal model. For the study, by use of the 100 subdivisions of LSI values of all cells in the study area and cumulative percentage of landslide occurrence in the classes, curves were drawn to calculate AUC (Fig.3). The AUC value was found to be 0.82 means the accuracy of the contructed model was 82%.

Susceptibility maps were validated by means of landslide affected area corresponding to susceptibility classes. It was obtained that the smaller degree of fit was distributed in the low and very low susceptibility classes, and the higher values of degree of fit were scattered in the high and very high susceptibility classes of the landslide susceptibility maps produced by model used.

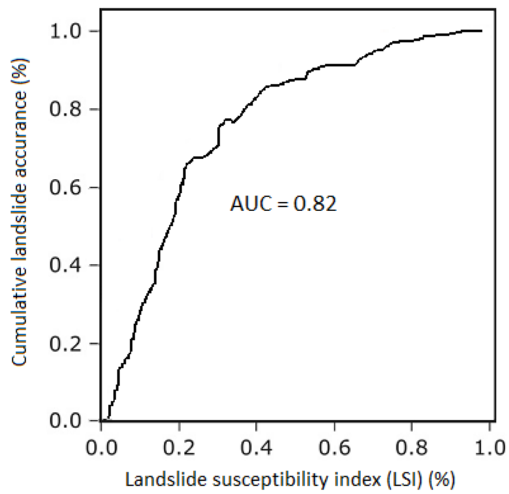

Fig.6. AUC assessment of landslide susceptibility map

DISCUSSIONS

The model for evaluation of landslide susceptibility by combining AHP and BSA method with results in relatively high (AUC = 0.82). It shows a combination of method is needed of region scale consistent with the development of remote sensing and GIS technology as well as can establish landslide susceptibility maps quickly, promptly serve different purposes. Furthermore this combination to maximize the experience of experts and advantages of the analystic tools.

Landslide inventory mapping was establish from multi-temporal remote sensing data, helps researchers gain a precise distribution of landslide across the study area, avoiding the detection of landslide in small area that does not reflect the impact of landslide causative factors.

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