Landslide susceptibility evaluation based on GIS and information value model

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Abstract. The western region of Chongqing seriously suffers from landslides. This paper evaluate the landslide hazard using GIS (Geographic Information System) technology and information value model and selecting seven influential factors including slope, aspect, elevation, rain, river, road and geological structure. The results show that the southern region of the study area are the most hazardous region. From the evaluation results, 20.6% of the total area suffers from high landslide risk and 13.1% suffers from very high risk, which is of important practical and immediate significance to the landslide prevention and reduction in the area. The evaluation result is basically coincident with the reality. The study further demonstrates that the information value model combined with geographical information system can quickly and effectively evaluate the spatial distribution and risk of the landslide hazard.

1. Introduction

China is one of the geological disaster-prone countries. Landslides are one of the most important natural hazards. Every year, the economic losses and causalities as a result of landslides are greater than what is common knowledge. To minimize economic losses and the loss of human life, landslide-prone areas should be identified.

With the rapid development of GIS, the geological hazard researches were dramatically improved and enhanced. Combined with the evaluation models, GIS technology is an effective tool of landslide risk evaluation, and the evaluation results can be used to prevent and mitigate the hazard.

At present, landslide susceptibility evaluation models commonly include: fuzzy evaluation method, artificial neural network model, logistic regression model, information value model, analytic hierarchy process, etc. E. Yesilnacar and T. Topal [1] evaluated the landslide hazard in the Hendek region of Turkey under the medium scale conditions, and compared and analyzed the results of the logistic regression model and neural network model. A Nandi et al. [2] evaluated the landslide susceptibility of Cuyahoga River Basin in northeast Ohio, based on GIS technology and multivariate statistical model; Huo Ai-di[3] research the method of classification for susceptibility assessment unit for geological hazard,and used slope units to evaluate geo-hazard susceptibility based on GIS technology in Huangling County of Yan´an City;Wei Chen and Wenping Li[4] drawed the landslide susceptibility zoning map based on GIS and information value model for the Chencang District of Baoji;L. P. Sharma[5] researched the application of Shannon’s entropy integrated information value model for landslide susceptibility assessment and zonation in Sikkim Himalayas in India.

In conclusion, in the process of the geological hazard susceptibility assessment, previous researches have used a combination of GIS and the statistical method. However, the weights and classification of the influential factors basically depends on the experience,which is lacking in the theoretical fundament,therefore the accuracy of the model calculation will be seriously affected.Information value model is a kind of statistical analysis model.Because of its clear physical meaning and simple operation, information value model has been widely used in the landslide susceptibility evaluation. This paper use the information value model to evaluate the landslide hazard prone of the western region of Chongqing, and compare the evaluation results with the actual situation. Use these results to help the relevant departments to carry out disaster prevention and mitigation work.

2. Methodology

The method used for this study is the evaluation unit classification and information value model.

The theoretical principle of information value model is information theory. Information theory was founded by C.E.S hannon. Mr. Tonzhen Yan firstly applied the theory to landslide forecast, and then it was widely used to the evaluation of geological hazard by many scholars. The possibility of landslide hazard is characterized by the entropy.

As is known to us, whether wills a landslide happen is affected by many factors and different factors play different roles. In different factors, 〝best combinations〞 can always be founded; Its landslide 〝contribution〞 is the largest. Therefore, the research of landslides is to find the 〝best combinations〞. The greater the amount of information, the greater the likelihood of a landslide. The formula is as follows:

$$\mathrm{I}(\mathrm{y}, x_1 x_2 \cdots x_n) = \log_2 \frac{P(y|x_1 x_2 \cdots x_n)}{P(y)} \tag{1}$$

In this expression, $\mathrm{I}(\mathrm{y}, x_1 x_2 \cdots x_n)$ is the information of specific factor combination $x_1 x_2 \cdots x_n$ for the landslide. $P(y|x_1 x_2 \cdots x_n)$ is the probability of landslide occurrence under combinations of factors. $P(y)$ is the probability of landslide occurrence.

The landslide **s**usceptibility evaluation is based on the division of the evaluation cells in the study area. Assume that the region is divided into N units, and there are N_0 units of landslide hazard,M units with the same factor combination $x_1 x_2 \cdots x_n$,M_0 units of landslide hazard with the same combination factor $x_1 x_2 \cdots x_n$ .According to the expression (1),the information of the factor $x_1 x_2 \cdots x_n$ for landslide hazard in the region is:

$$\mathrm{I}(\mathrm{y}, x_1 x_2 \cdots x_n) = \log_2 \frac{M_0/M}{N_0/N} \tag{2}$$

In general, due to the limited number of sample statistics,we use the stepwise calculation of simplified single factor information value model and overlay analysis. The corresponding information model is rewritten as:

$$\mathrm{I} = \sum_{i=1}^{n} I_i = \sum_{i=1}^{n} \log_2 \frac{{S_0}^i/S^i}{A_0/A} \tag{3}$$

I means the information value of the unit in the region. S^i refers to the total area of the factor x_i units. ${S_0}^i$ is the total area of the factor x_i units with landslide hazard. A is the total area of the region. A_0 means the total area of units with landslide hazard.

3. Experiments

Landslide susceptibility evaluation is a comprehensive work based on the enormous data and the influential factors. Our approach is as follows: (1) to prepare the landslide data and environmental factors including elevation, slope, aspect, river, road, structure and rain;(2) to select the evaluation unit;(3) to classify each environmental factor and calculate its information value of each classification of the influential factors using information value model;(4) to determine the comprehensive information value using the GIS spatial analysis;(5) to divide study area into five levels. The levels are very low, low, moderate, high and very high.

3.1 Study area & data sources

This paper select the western region of Chongqing as the study area. The study area is located in the eastern part of Sichuan Basin and bounded roughly by longitudes of 105° 16′ E and 106° 57′ E and latitudes of 28° 35′ N and 30° 26′ N, with complex geological structure, soft surface layer, deep valleys and steep slopes. The mainstreams and tributaries of Jialing River, the Yangtze River run through the whole region. In addition, this area is subjected to the influence of subtropical monsoon climate, with abundant precipitation and stormrain. In recent years, due to the establishment of the municipality and the construction of the Three Gorges project, the impact of human economic activities have become increasingly intensified.Therefore, landslide is the most serious geological hazard in the area.

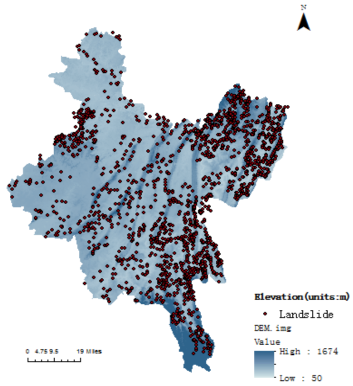


Fig. 1 Topographic map of study area showing the location. Points indicate past of landslide events

In this study, the elevation, slope and aspect are derived from the advanced spaceborne thermal emission and reflection radiometer global digital elevation model (ASTER GRTM). The spatial resolution of the DEM is 30×30 m. The geological structure data are obtained from the geological map of Chongqing. The scale is 1:500000. The river and road data are from the basic geographic information database. The scale is 1:4000000.The rain and landslide data are from Chongqing Institute of Geology and mineral resources.

3.2 The calculation of information value for influential factor

This paper selects the elevation, slope, aspect, the distance from river, road and structure and rain as influential factors. Then grade every influential factor by the reclassify of GIS. Using GIS spatial analysis, the study calculate the information value of influential factors.

3.3 Landslide susceptibility evaluation

We determine the susceptibility by comprehensive information which is calculated by adding the seven information values computed from seven influential factors together. Comprehensive information is divided into five ranks according to the natural breakpoint.

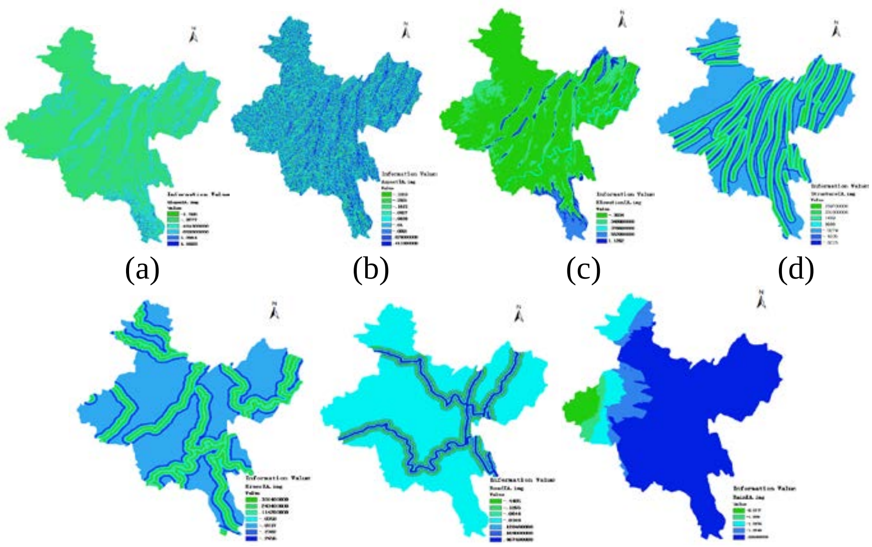
4. Results

Table 1 show the information value of seven influential factors. Information value layer of seven influential factors are shown in the Fig. 2. Table 2 show the classifications of comprehensive information. The final landslide susceptibility mapping is shown in Fig. 3.

Table1 Information value of seven influential factors

Factor	Class	A_0	S_0	I	Factor	Class	A_0	S_0	I
Elevatio-n	204.09	-0.2801	74.69	0.3766	Aspect	Flat	12579	12.26	-0.3353
	300-600	1315682	1325.07	-0.3034		N	189184	237.11	-0.0839
	600-900	317238	613.46	0.3489		EN	198140	204.09	-0.2801
	900-1200	69812	293.69	1.1262		E	251997	353.59	0.0290
	>1200	66812	158.29	0.5520		ES	261233	302.96	-0.1615
Slope	0-10	1356684	1268.62	-0.3777		S	206820	353.59	0.0290
	10-20	334603	876.37	0.6523		WS	197576	258.75	-0.04
	20-30	92876	201.56	0.4643		W	249859	513.70	0.4110
	30-40	18614	75.86	1.0944		WN	239728	323.81	-0.0091
	40-50	4024	0.8	-1.926	River	0-800	187241	286.23	0.1142
	>50	315	42	4.5823		800-1600	156573	297.40	0.3314
	0-5	1365769	2360.24	0.2368		1600-	144768	251.82	0.2434

Rain						2400			
	5-10	167460	57.77	-1.3746		2400-3200	136597	179.73	-0.0358
	10-20	162028	32.47	-1.9176		3200-4000	127803	137.34	-0.2382
	20-30	40260	7.93	-1.935		4000-4800	117082	124.89	-0.2456
	>30	72205	6.81	-2.6717		>4800	937654	1187.79	-0.0737
Road	0-800	103387	225.01	0.4674	**Structu-re**	0-600	103387	403.981	0.2597
	800-1600	97556	124.75	-0.0644		600-1200	231898	386.94	0.2018
	1600-2400	90191	145.64	0.1690		1200-1800	230664	336.97	0.0688
	2400-3200	82032	98.58	-0.1265		1800-2400	217780	343.63	0.1459
	3200-4000	76853	66.93	-0.4485		2400-3000	192603	165.21	-0.4636
	4000-4800	73302	112.75	0.1204		3000-3600	148947	89.33	-0.8215
	>4800	1284397	1691.56	-0.0349		>3600	557343	739.16	-0.0279



(a) (b) (c) (d)

(e) (f) (g)

Fig. 2 Information value layer of seven influential factors. a slope, b aspect, c elevation, d geological structure, e road, f river, g rain

Table 2 Classifications of comprehensive information

Classifications	Very low	Low	Moderate	High	Very High
Comprehensive information	-4.6182--2.0889	-2.0889--0.9399	-0.9399--0.0451	-0.0451-0.9282	0.9282-6.9125

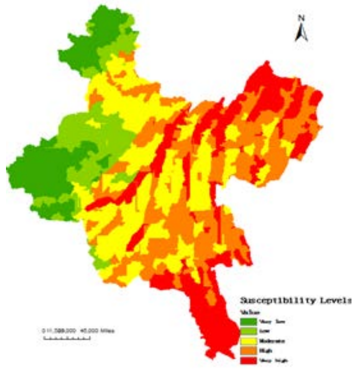


Fig. 3 Landslide risk zonation map

The results of comparing with susceptible classification and the distribution of landslide are shown in Table 3.A is the number of grids in every evaluation classification. R_a is the evaluation classification percentage of the total grid number. L refers to the area of landslide. R is the percentage of the total landslide area. B refers to the proportion covered by the population of the landslide area in the evaluation classification area.I is the information value.

Table 3 Comparison of evaluation results and actual occurrence

Classifications	**A**	$\mathbf{R_a}$	**L**	**R**	**B**	**I**
Very low	318696	0.1766	46.0045	0.0187	0.0178	-2.2452
Low	256925	0.1424	128.73	0.0523	0.0619	-1.0007
Moderate	621530	0.3444	618.5517	0.2515	0.1229	-0.3145
High	371481	0.2058	828.2064	0.3367	0.2752	0.4921
Very high	236088	0.1308	838.2759	0.3408	0.4384	0.9575

5. Conclusion

Landslides are one of the most hazardous nature disasters. This paper use information value model which is a kind of statistic model and GIS to evaluate the landslide hazard in the western region of Chongqing.The conclusions can be summarized as follows:

(1) This paper use GIS and information value model to evaluate the landslide hazard in the study area.High hazard and very high hazard areas are located in the southern region.

(2) This paper selects six indexes to validate the evaluation results. These results indicate that information value model has a high accuracy of landslide susceptibility evaluation.

This paper uses information value model to evaluate landslide susceptibility in the western region of Chongqing. However,information value model neglects the weights of different factors,which will seriously affect the reasonableness of the evaluation results.Our future work will be on the improvement of information value model and the scale effect of landslide susceptibility evaluation.

Acknowledgements

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