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Research Article

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The application of GIS software in geo-hazard risk evaluation in Huangling County

Yuxiang Cheng and Aidi Huo

Chang'an University, Xi'an, China

ABSTRACT

In order to design geo-hazard prevention and control planning better, according to a detailed investigation of geo-hazard information, the geological environment conditions and the characteristics of geo-hazard in Huangling County were detailed analyzed, GIS software is applied to determined and quantify the geo-hazard evaluation index, the weights were gotten using a method combining the qualitative analysis with quantitative calculation, geo-hazard risk was evaluated in weighted sum method. The results show that the high-risk areas mainly distributed in Luohe River valley area, Juhe River valley area and Nanchuan River valley area. The areas have great resident population, frequent movement of floating, fast urbanization and strong human engineering activities. The high-risk and middle-risk geo-hazards are widely developed. The risk evaluation result is consistent with the actual situation, and is credible. After contrast the evaluation result with the actual investigation, it can be found that the evaluation result has good agreement with the actual investigation.

Keywords: evaluation index, weights, geo-hazard, Huangling County

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INTRODUCTION

Geo-hazard is a kind of geological process or phenomenon, it can deteriorate natural environment, threaten human life and property, and destroy resources and environment which are necessary to human survival and development. It includes geo-hazard and the object geo-hazard affected. The two aspects are complementing each other and indispensable [1].

Geo-hazard risk evaluation in China began in 1980s.after twenty years of development, it has achieved fruitful results in theory and practice, but several aspects are still in exploratory stage[2].Firstly, the meaning of Geo-hazard risk evaluation is not clear. The activities and intensity of geo-hazard were highlighted during geo-hazard risk evaluation, but it's threaten object is lack of consideration. Secondly, the geo-hazard risk evaluation and risk probability assessment of geo-hazard is confusion. The geo-hazard risk evaluation is still a qualitative to semi-quantitative evaluation, so the evaluation accuracy is lower. It should focus on the detailed investigation of geo-hazard and its threatening objects. The possibility of the impact, damage and destroy on their objects must judge. According to certain standards, geo-hazard risk zonation must be done. Risk probability assessment of geo-hazard is based on risk evaluation result and is quantitative. Based on the formation condition analysis of geo-hazard and long-term monitoring, the probability of occurrence of different intensity geo-hazard must be obtained. The ultimate result should be the probability of occurrence of different time scale and different disaster grade of geo-hazard [3].

Thirdly, the geo-hazard evaluation index system is not unified, the index value is no uniform standard, or the unified standard is very difficult to operate in the actual implementation. It is decided by the complexity of geo-hazard. The reasonable evaluation index system must be established based on the particular analysis on the geological environment condition and influence factors of geo-hazard [4-6].

GIS is a kind of international advanced level geographic information system software. Spatial information and its attribute information will be accurately and truly output to users according to the of users' needs in texts and pictures. Relying on its unique spatial analysis function and visualization capabilities, intuitionist maps can be generated and provide a scientific basis to a variety of decision. Its rapid evaluation unit subdivision and layer overlay analysis function can eliminate a lot of tedious data statistics works during the geo-hazard susceptibility evaluation, and the same time, the evaluation result is more scientific and accurate evaluation [7-11].

GEO-HAZARD FEATURES

According to the geo-hazard survey data in Huangling County, Shaanxi Province, the geo-hazard evaluation index system is established. The assignment principles of evaluation factors are proposed. The geo-hazard evaluation is done and divided in all area. Survey area is located in the southern Loess Plateau. The landscape is complex and diverse. It can be divided into the hilly area, and loess gully and valley area. The main stratum exposed in the area is Triassic, Jurassic, Cretaceous, Neocene and Quaternary. Loess is widely covered on the underlying ancient bedrock. On the role of intermittent uplift of new tectonic movement, under the long-term erosion of Juhe River, HuluRiver,Koujia River,etc. The current topography forming in underrating ridge and hilly and deep river valley topography is performed. Annual average precipitation is 588.1 mm. The precipitation distribution is extremely uneven during the year, rainfall mainly concentrate in summer, accounting for 51% of annual precipitation. Under the special geological environmental conditions, combining with the human activities impact on the geological environment in recent years, the geological disasters in HuanglingCounty became multiple and frequent.

During Geo-hazard detailed survey, 350 survey point is investigated.115 landslide are found, accounting for 32.85% of the total number of geo-hazard points, accounting for 32.85% of the total number of geo-hazard points.32 collapse are investigated, counting for 9.14%.5 debris flow are investigated, accounting for 1.42%.180 unstable slope are investigated, accounting for 51.42%.11 ground subsidence are investigated, accounting for 3.14%; 7 ground fissure are investigated, accounting for 2.03%.

Tab.1 Geo-hazard statistics

Town name	The number of geo-hazards						
	Total	Landslide	Collapse	Debris Flow	Unstable Slope	Ground Fissure	GroundSubsidence
Qiaoshan	61	18	8	0	35	0	0
Diantou	50	12	7	1	25	2	3
Shuanglong	47	6	6	1	32	0	2
Cangcun	37	14	1	0	9	7	6
Longfang	33	11	5	0	17	0	0
Tianzhuang	30	13	2	2	13	0	0
Hexi	25	6	1	0	15	3	0
Yaoping	25	6	0	1	18	0	0
Taixian	19	12	1	0	4	2	0
Adang	18	10	0	0	8	0	0
Houzhuang	13	7	1	0	3	2	0

INFORMATION CONTENT ANALYSIS MODEL

The information content can be gotten in the model as the quantitative indicators for geo-hazard risk evaluation by calculating the amount of information of various influence factors on the geo-hazard deformation and failure. It can accurately reflect the basic law of geo-hazard, but also it is simple, easy, practical, easy to promote. The calculation principle and the process are showed as follows:

a. Calculating the information content I(xi/A) of geo-hazard instability (A) provided by single factors (indicators) xi:

$$I(x_i, A) = \lg \frac{P(x_i / A)}{P(x_i)}$$

Where: P(xi/A) indicates the emergence probability of xi on the geo-hazard deformation and failure conditions; P(xi)indicates the emergence probability of xi in overall condition.

$$I(x_i, A) = \lg \frac{N_i / N}{S_i / S}$$

Where: S indicates the total number of known sample units; N indicates the number of known deformation and failure sample units; Si indicates the number of units xi appear; Ni indicates the number of deformation and failure units xi appear.

b. Calculating the information content Ii of the geo-hazard deformation and failure on some unit provided by combinations with P kinds of factors, namely:

$$I_i = I(x_i, A) = \sum_{i=1}^{p} \lg \frac{N_i / N}{S_i / S}$$

c. Determining the stability level of the unit according to the size of Ii:

Ii <0 indicates that the possibility of deformation and failure of the unit is less than the average possibility of deformation and failure in all regional;

Ii = 0 indicates that the possibility of deformation and failure of the unit is equal to the average possibility of deformation and failure in all regional;

Ii> 0 indicates that the possibility of deformation and failure of the unit is more likely the average possibility of deformation and failure in all regional. The value of the information in some unit is greater, the geo-hazard is more easily to deformation and damage.

d.Identifying mutations point as the cut-off point, by statistical analysis (subjective judgments or cluster analysis), so as to the area is divided into different levels.

Because the basic data of evaluation indictor mainly come from quantitative description, so, they must be dimensionless unified in standardization, normalization, homogenization, or logarithmic, square root and other numerical transformation method, before substitute in evaluation model.

GEO-HAZARD RISK EVALUATION

Evaluation index and its quantization

According to the geological environment characteristics and features of geo-hazard in Huangling County, the geo-hazard risk evaluation indexes are chosen and quantified by GIS software[12-14].

Slope gradient index

The slope information of survey area is extracted and normalized from DEM by GIS software. The frequency of geo-hazard is high on the slopes greater than 40°, so slope index value is defined as 1 while slope gradient is greater than 40°. The frequency of geo-hazard is low on the slopes less than 10°, so slope index value is defined as 0 while slope gradient is less than 10°.In the slope gradient from 10° to 40°, the slope index values are determined by normalized probability of occurrence of geo-hazard(Fig.1).

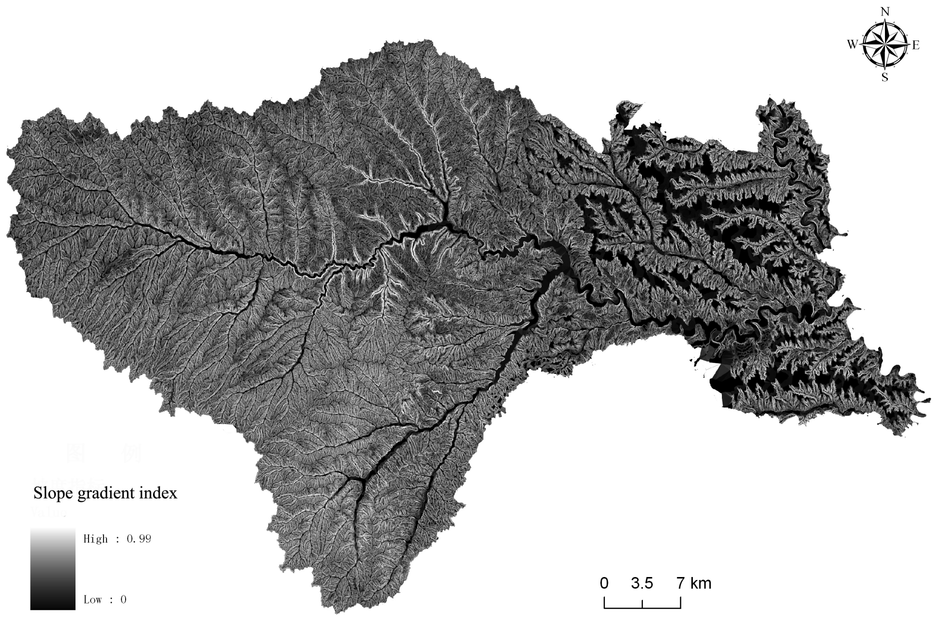

Fig.1 Normalized slope gradient index in Huangling County

Slope height index

The slope information was extracted from DEM data by GIS software. As geo-hazard mainly occurred in the slopes from 50 m to 100m, so the slope height index is defined as 1 where slope height is more than 100m. The slope height index in the slope Less than 100 meters is distributed in linear from 1 to 0(Fig.2).

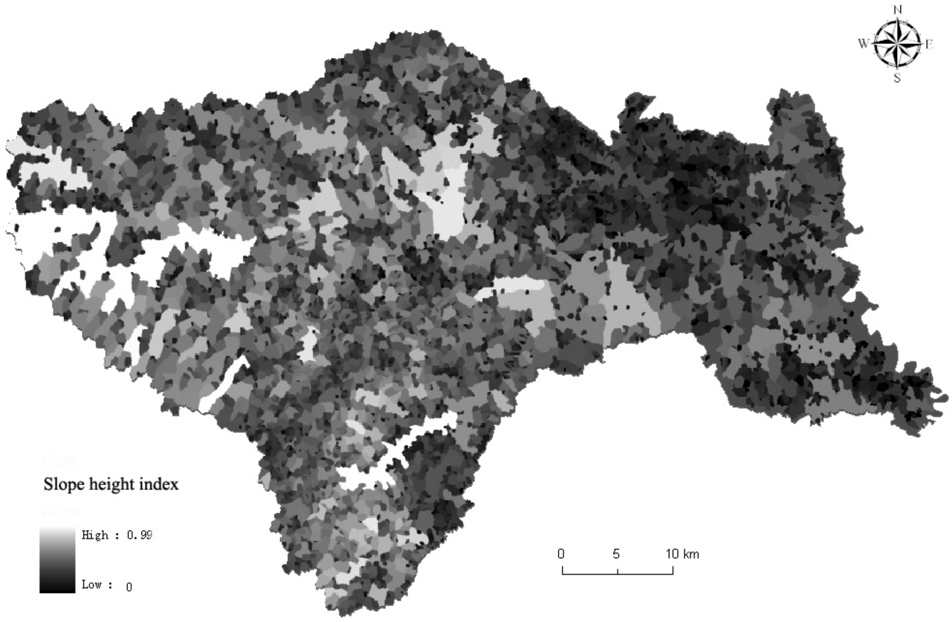

Fig.2 Normalized slope height index in Huangling County

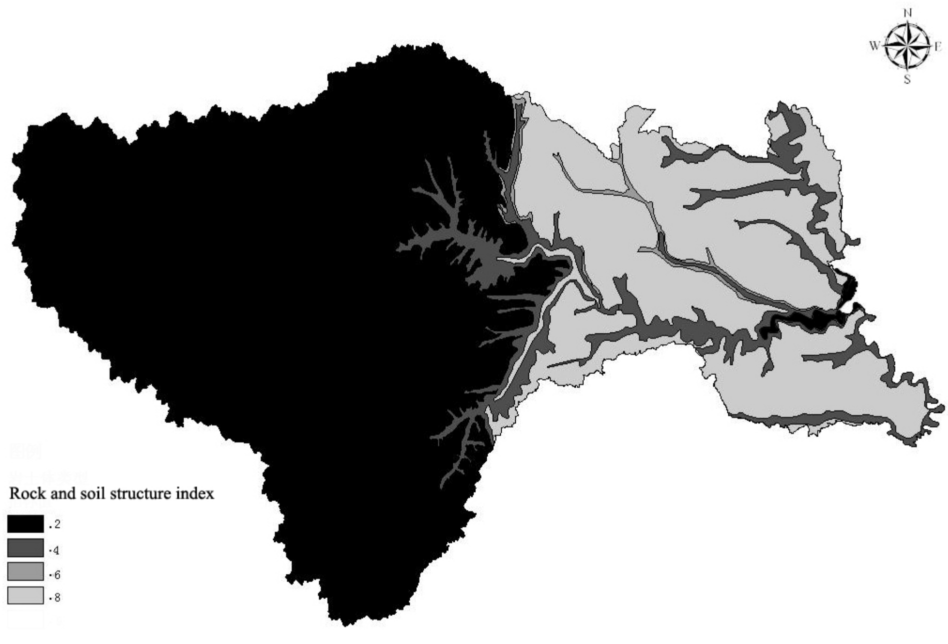

Fig.3 Rock and soil structure index in Huangling County

Rock and soil structure index

There are four types of different rock and soil structure. Thick layered hard rock is mainly distributed in the eastern mountain area, the geological hazard is seldom, so rock and soil structure index is Assigned to 0.Alternating layers of thin layered semi-hard hard rock and middle layered hard rock are distributed in valley sides, the geological hazard is great quantity,. so soil structure index is assigned to 1.Gravel is mainly distributed in valley zone, the geological hazard is seldom, so soil structure index is Assigned to 0.Loess is mainly distributed in the Loess Plateau in eastern study area the geological hazard is great quantity. So soil structure index is assigned to 1(Fig.3).

Precipitation index

According to rainfall characteristics, rainfall uniformity coefficient is selected as the precipitation index. The rainfall uniformity coefficient is defined as the ratio of the average rainy season rainfall (from July to September) to the average annual rainfall, and is normalized and interpolated from 0 to 1 in all study area. The rainfall uniformity coefficient can objectively reflect the heterogeneity of rainfall. The greater rainfall uniformity coefficient, the rainfall more concentrated(Fig.4).

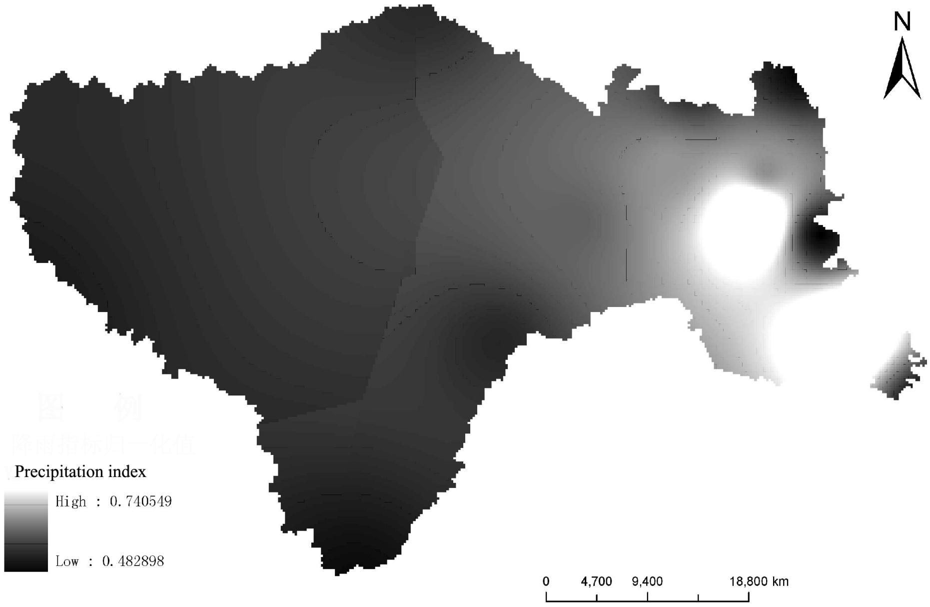

Fig.4 Precipitation index in Huangling County

Human engineering index
The influence of human engineering activities on the formation and development of geo-hazard is very complex, and the same time human engineering activities are important elements in the geo-hazard risk evaluation. The quantity of human engineering index is simplified as follows, the disturbance of the county seat, the main town, highway, railway, national road building to geological environment is the most serious, while the highest degree of their importance, the human engineering index is assigned the value 1.In the influence area of the smaller towns, larger villages, provincial road, the human engineering index is assigned 0.8. In the influence area of a smaller village, county and township roads, the human engineering index is assigned 0.6. In the other area human activities influenced, the human engineering index is assigned 0.4. No fixed human engineering activities of the region, the human engineering index are assigned 0.2(Figure5).The quantitative approach has real physical meaning. The more intense human activities, the possibility of causing geo-hazard is greater, and the risk of geo-hazard is greater.

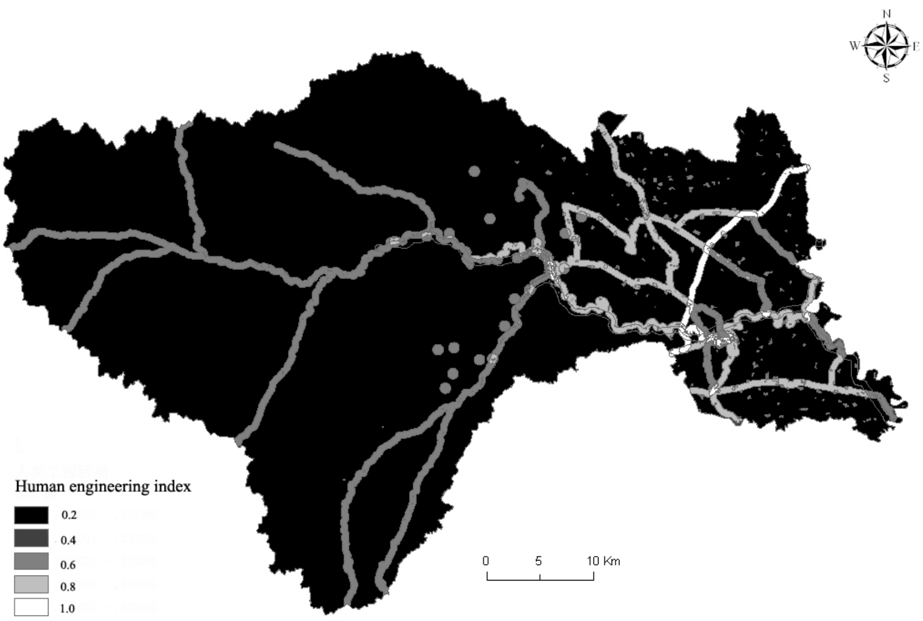

Fig.5 Human engineering index in Huangling County

Evaluation unit

The division of evaluation unit is variety, and each has advantages and disadvantages. The division form and the size of unit have great impact on the evaluation result. On the basis of the DEM data[15-16], all study area is divided into 6258 units using hydrological analysis method by GIS software.

Evaluation weights

The evaluation index weights directly affect the accuracy and effectiveness of the geo-hazard evaluation results. Therefore, the weight is the key of the geo-hazard risk evaluation, and is difficult to gotten. In the existing evaluation model, the main methods commonly used in AHP, gray correlation method, neural networks, etc., these weight calculate methods are summed up in two types: subjective and objective analysis method. Subjective analysis method is through expert subjective analysis in order to achieve qualitative to quantitative conversion. However, this approach is subjective too much, and do not combine with the evaluation results. On the contrary, objective analysis is through the objective information extraction and analysis on statistical data of the factor, finding out the rules to determine the weights. The method is over-reliance on objective data, while ignoring the experts; the calculated results are often unsatisfactory.

Therefore, the two methods are combined. Firstly depending on experts' experience, a set of weights are given, and then selected a number of typical evaluation unit, we can get the qualitative evaluation results through the geo-hazard characteristics and their environmental conditions, then using the evaluation factors and weights given on experts' experience, the geo-hazard risk of the typical evaluation unit selected can be quantitative evaluated, the weights gradually modified until the evaluation results are consistent with qualitative analysis results. The final weights can be used as the weight of the whole region.

Geo-hazard risk evaluation and result analysis

Through the simplest method of weighted sum, geo-hazard risk evaluation is computed. The results are shows in Fig.6.

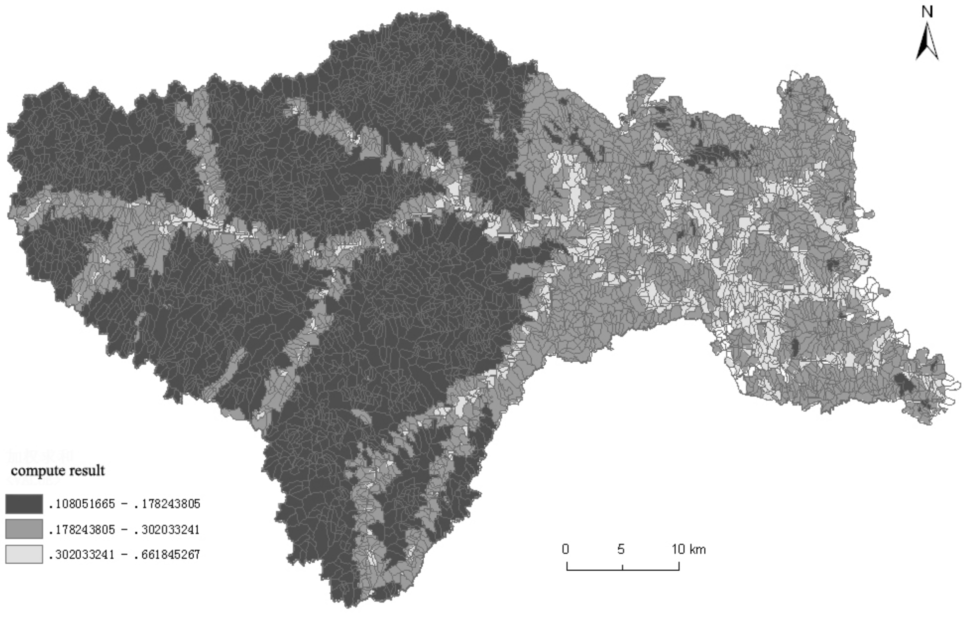

Fig.6 Geo-hazard Risk Evaluation compute result in Huangling County

High-risk areas of geo-hazard are mainly distributed in Luohe River valley area, Juhe River valley area and Nanchuan River valley area, involving Tianzhuang Town, Qiaoshan Town, Hexi District offices, Diantou town, Cangcun Town, YaopingTown,etc. The total area is about 168.49km2, accounted for 7.36% of all regions. it has greater resident population, frequent movement of floating and fast urbanization. The distribution of national roads, railways, town and the famous tomb distribute in high-risk areas. The total number of geo-hazard in the high-risk area is 175. The number of landslides is 48, including 1 high-risk of landslides, 2 middle-risk of landslides and 45 low-risk landslides.12collapses are low-risky. There are 3 debris flow, including 1 high-risk, 1 middle-risk and 1 low-risk. The number of unstable slope is 99, including 6 middle-risk and 93 low-risk. There are 11 low-risk surface subsidence and 2 low-risk ground fissure.

Middle-risk areas of geo-hazard mainly are distributed in the Loess Plateau and the loess hilly area in the eastern of study area and the rocky hilly in the western of area, the middle-risk area involved in almost every town, with a total area of about 788.01km2, accounting for 34.44% of all areas. Urbanization rate is quick in the eastern town. Roads, town buildings, reservoirs, and other important project facilities are more complete. The total number of geo-hazard in the middle-risk area is 164, including 65 low-risk landslides, 17 low-risk collapses,1 middle-risk debris flow,1 low-risk debris flow, 1 middle-risk unstable slope,74 low-risk unstable slope, 1 middle-risk ground fissure,4 low-risk ground fissure.

Low-risk areas of geo-hazard are distributed outside the high-risk area and middle-risk area, mainly in Ziwuling hilly areas in the west of YaopingTown and ShuanglongTown. Area of low-risk areas of geo-hazard is about 1331.5km2, accounting for 58.19%.The area have sparsely population and weak human engineering activities. Geo-hazard developed in the area includes two low-risk landslides, three low-risk collapse and six low-risk unstable slopes.

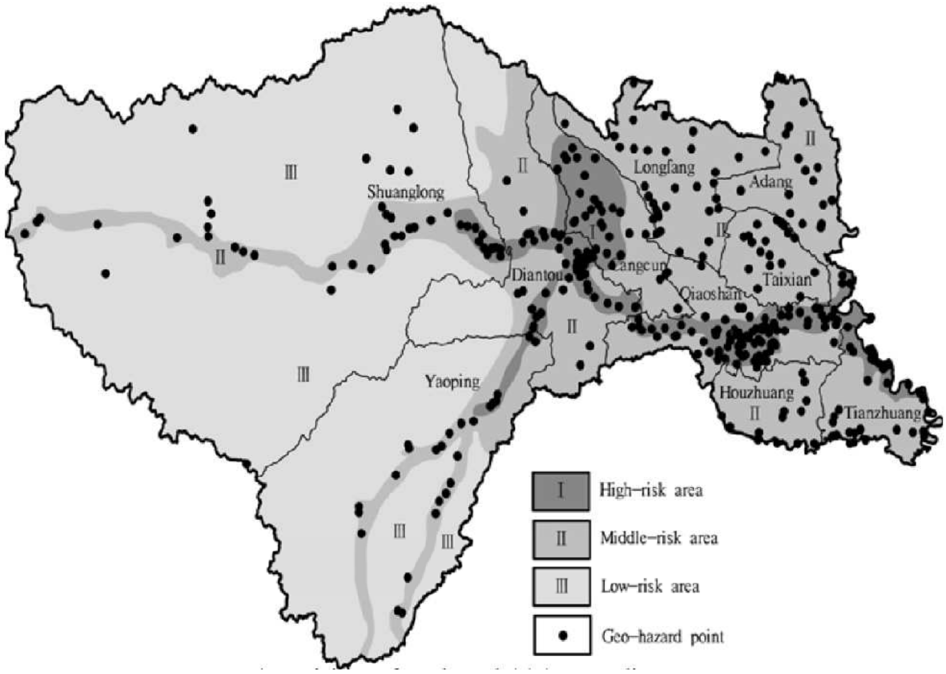

Fig.7 Division of geo-hazard risk in Huangling County

Geo-hazard risk zoning map and the actual survey result are overlaid as shown in Fig.7. It can be seen that the quantitative analysis results are consistent with the actual results; the most of measured geo-hazard points are located in high-risk areas and mid-risk areas. Thus, the geo-hazard risk evaluation result in the paper is creditable.

CONCLUSION

(1) HuanglingCounty is chosen as the research object, select slope gradient index, slope height index, rock and soil structure index, vegetation index, precipitation index, human engineering index as the evaluation index.
(2) On the basis of the DEM data, all study area is divided into 6258 units using hydrological analysis method by GIS software.
(3) Combining subjective and objective analysis method, Evaluation weights are gotten.
(4) The evaluation results of geo-hazard risk show that the high-risk area is about 168.49km2, accounted for 7.36% of all regions, the middle-risk area is about 788.01km2, accounting for 34.44% ,the low-risk area is about 1331.5km2,accounting for 58.19%.
(5) High-risk areas of geo-hazard are mainly distributed in LuoheRiver valley area, JuheRiver valley area and NanchuanRiver valley area, it has greater resident population, frequent movement of floating and fast urbanization. The distribution of national roads, railways, town and the famous tomb distribute in this areas. The total number of geo-hazard in the high-risk area is 175. The evaluation results are consistent with qualitative analysis result.
(6) During geological hazard evaluation process, the evaluation unit dividing, actors quantification and calculation are completed on GIS platform, so GIS software is very useful in regional geological hazard evaluation for its powerful spatial analysis capabilities.

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