Research on Landslide Disaster Risk Assessment Method Based on GIS and Information Model

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Abstract. In this paper,a geological disaster early warning model is constructed based on GIS,and a susceptibility evaluation system is constructed by using GIS spatial information system to obtain seven influencing factors,including slope,topographic relief,slope shape,rock and soil mass type,geological structure,land use type and vegetation coverage rate.The information quantity value of each influencing factor is determined based on the information model method.At the same time,the hidden points of geological disasters in research area are superimposed and the prone zones are divided to provide reference for the prediction and prevention of geological disasters in this area.

Keyword: Landslide Disaster, Risk Assessment, GIS, Information Model

1. Introduction

Xin County is located in the southern part of Henan Province and is a high-risk area for geological disasters.In recent years,due to frequent rainfall and active engineering and economic activities,it has produced many secondary disasters and is one of the key areas for geological disaster prevention and control in Henan Province.There are many geological hazards of slope type in the research area,which pose great safety hazards and pose a serious threat to the life and property safety of surrounding residents.The geological hazards formed by the rapid sliding of rock and soil along a slope,such as collapse,landslide,and debris flow,are collectively referred to as slope type geological hazards.

The weighted information method fully considers the different degrees of influence of each influencing factor in the process of geological disasters,and multiplies it with its own information to obtain the weighted information,which is then used for susceptibility evaluation.

This article uses ArcGIS software and evaluation methods such as weighted information method to evaluate the susceptibility of slope type geological hazards in the study area,providing reference for the prediction and prevention of geological hazards in the region,and hoping to provide experience for similar areas.

2. Overview of the research area

Xin County is located in the southeastern part of Xinyang City,Henan Province,in the hinterland of the Dabie Mountains and at the junction of Hubei and Henan provinces.It is situated between 114 ° 33 ′ E to 115 ° 12 ′ E and 31 ° 28 ′ N to 31 ° 46 ′ N.The length from east to west is 61.6 kilometers,and the width from north to south is 40.7 kilometers.The county seat is 440 kilometers north of the provincial capital Zhengzhou and 116 kilometers south of Xinyang,170 kilometers south of Wuhan,and 301 kilometers east of Hefei. As of the end of 2019,the administrative area of Xin County was 1554 square kilometers.

The tectonic unit of Xinxian belongs to the Huaiyang Shield of the Dabie Mountains,which gradually uplifted from the ocean and folded into a mountain system during the Paleozoic era.The outline of Xinxian County is approximately rectangular,with the main vein of the Dabie Mountains running through the middle of the area from east to west,resembling a ridge.There are three peak areas in the east,middle,and west of the spine,forming a W-shaped terrain.The main vein of the Dabie Mountains forms the Jianghuai watershed,with Lingnan belonging to the Yangtze River basin and Lingbei belonging to the Huai River basin.The highest point in Xin County is Huangmaojian in the southern part of the county,with an altitude of 1011 meters; The lowest point is the exit of Huanghe River,with an altitude of 60 meters; The relative height difference is 951 meters.The average altitude is 350 meters.Divided by altitude and relative height difference,the area belonging to the deep mountainous area is 1.5515 million mu,accounting for 66.2% of the total mountainous area; The area of the shallow mountain area is 792000 acres,accounting for 33.8%.There are 14 townships with a relative height difference of over 500

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meters,and 3 townships with a relative height difference of less than 500 meters.

Xin County is located in the transitional zone from the northern subtropical zone to the warm temperate zone,belonging to a continental humid monsoon climate with distinct four seasons,abundant rainfall,and sufficient sunlight.The annual average precipitation is 1313.8 millimeters,the sunshine hours are 1742.3 hours,the relative humidity is 77%,and the frost free period is 243.7 days.

The total length of rivers over 5 kilometers in Xin County is 684 kilometers,with a river network density of 0.6 kilometers per square kilometer.The annual average surface runoff is 973 million cubic meters,and the groundwater reserves are 360 million cubic meters.There are 6 major water systems within the territory,with 92 large and small rivers.Among them,the larger rivers originating from the territory include Huanghe River,Bailu River,Zhai River,Zhugan River,Daoshui River,and Jushui River.

According to the investigation,there are many artificial slope cutting and road construction in the study area.The slope after slope cutting is generally steep,and it is generally composed of weathered clay from gneiss.The overall stability of the slope is poor,and it is prone to geological disasters under the influence of rainfall and other factors; The overall stability of the slope in the study area is also poor when the slope gradient is within 30 ° to 50 ° and the vegetation coverage is low.Under the influence of external factors,geological disasters are also prone to occur.According to statistical analysis,factors such as terrain undulation,slope gradient,slope shape,stratigraphic lithology,and human engineering activities have a significant impact on its susceptibility in the study area.

3. Evaluation indicators for the susceptibility of slope type geological hazards

The susceptibility of geological hazards refers to the possibility of geological hazards occurring in a certain area,which is jointly controlled by the basic geological environmental conditions and the development and distribution patterns of geological hazards.To highlight the main influencing factors of slope geological hazards in the study area,drawing on previous achievements and combining with the geological and geomorphological background of the study area,seven influencing factors were selected after comprehensive analysis,including slope,terrain undulation,slope shape,rock and soil type,geological structure,land use type,and vegetation coverage,to construct an evaluation system for the susceptibility of slope geological hazards in the study area.

3.1 Slope factor

The distribution of slope stress is directly affected by the slope.As the slope gradually increases,the stress concentration at the bottom of the slope also gradually increases.The main impact is divided into three aspects.One is to affect the supply,runoff,and discharge of surface water and groundwater on slopes; Secondly,it plays a controlling role in the thickness of the rock and soil on the slope; The third factor is the degree of soil erosion and land use types in the affected area.Using the DEM digital elevation model of the research area and combining with the distribution of geological hazard points,the slope values are divided into four categories:<5 °,5 °~15 °,15 °~25 °,and>25 °.

3.2 Terrain undulation factor

Terrain undulation (i.e.relative height difference)is a macroscopic indicator that describes the terrain characteristics of a region.It is an indicator that characterizes surface erosion and material slope displacement potential energy,represented by normalized length or area.In recent years,the terrain undulation factor has been widely used in geological hazard risk investigation and evaluation,and is one of the most important factors in terrain and geomorphic conditions.Using the DEM digital elevation model of the research area and combining with the distribution of geological hazard points,the terrain undulation is divided into four categories:<5m,5-15m,15-25m,and>25m.

3.3 Slope factor

Slope type geological hazards can be seen as the process in which the internal stress of a slope changes and then reaches a new equilibrium.The slope shape affects the direction of stress divergence within the slope,which in turn affects the internal stress changes and affects the occurrence process of geological hazards.The curvature of the profile represents the rate of change in ground elevation along the maximum slope direction,and can be used to indirectly represent the shape of the slope surface.Using the DEM digital elevation model of the research area,combined with the distribution of geological hazard points,the slope shape is divided into concave slope,convex slope,and straight slope.

3.4 Rock and soil type factor

The lithology of the strata is the material basis and inherent condition for the occurrence of slope type geological disasters.The type of rock and soil,degree of softness and hardness,and interlayer structure of the slope can all affect the stability and erosion resistance of the slope.The combination of rock and soil with different properties not only restricts the way and scale of disasters,but also controls their development and distribution.Therefore,the type of rock and soil plays an important role in the distribution of geological hazards.The rock and soil in the research area are divided into four types,including residual slope soil (I),fully weathered gneiss (II),strongly weathered gneiss (III),and moderately weathered gneiss (IV).

3.5 Geological structural factors

The main impact of structural fractures on slope type geological disasters can be divided into two aspects.One is that the fault zone damages the structure of the surrounding rock and soil,leading to a decrease in the integrity of the slope; The second is that the fault zone,as a groundwater conduit,intensifies the deformation and damage of the slope under rainfall conditions.A buffer zone is set up on both sides of the fault zone within the research area,with dividing points of<200 m,200-400 m,400-600 m,and>600 m into four categories.

3.6 Land use type factor

The occurrence of geological disasters is closely related to human engineering construction.Human engineering construction has changed the stable state of the original slope,leading to changes in the internal stress of the slope.Most of the human engineering activities in the research area are mainly focused on building houses and roads,and cutting through mountains is inevitable.The impact of human engineering factors on geological disasters is characterized by collecting land type data.Land use types are mainly divided into 10 categories: residential land,cultivated land,transportation land,commercial land,forest land,industrial and mining storage land,gardens,grasslands,water bodies and water conservancy facilities,and other land.

3.7 Vegetation coverage (NDVI)factor

The vegetation coverage affects the occurrence and development of geological disasters such as landslides,collapses,and mudslides,mainly through indirect control of rainfall retention,which affects geological disasters.Under the same geological environment conditions,the vegetation coverage is low,and the more exposed the surface is,the stronger the erosion effect of surface runoff is.Landslides and other disasters are more likely to occur.However,when the rainfall intensity is large and exceeds a certain level,the higher the vegetation coverage,the higher the interception rate of rainfall,which is more conducive to enhancing the self weight of slopes and enhancing the occurrence of landslides and other disasters.Divide the vegetation coverage in the study area into four categories:<0,0-0.25,0.25-0.50,and>0.50.

4. Risk assessment of landslide disasters

4.1 Calculation of evaluation factor weights

This study used the Analytic Hierarchy Process to compare and determine the importance ratio between the influencing factors.The weight coefficients of seven influencing factors,including slope,terrain undulation,slope shape,rock and soil type,geological structure,land use type,and vegetation coverage,were 0.130,0.071,0.130,0.350,0.074,0.074,and 0.138,respectively.The consistency test result was CR=0.003<0.1,which passed the consistency test.

4.2 Evaluation methods

The weighted information method adds weights to various influencing factors on the basis of the information model method,which can comprehensively consider the role of different factors in slope type geological disasters and reflect the differences in the degree of impact.

4.2.1 Information model method

The mutual influence of various factors such as geology,geomorphology,and human engineering construction leads to the frequent occurrence of slope type geological disasters,and the rule of information quantity model can reflect the range of the most prone disaster factors in a certain geological environment; The specific method is to compare the probability of geological disasters occurring under the influence of certain influencing factors within a specific evaluation unit with the distribution probability of corresponding influencing factors within the study area.Due to the comprehensive influence of various influencing factors on each evaluation unit,and the existence of different states of each influencing factor,the total amount of information on the occurrence of geological disasters under the combined conditions of various state influencing factors can be determined by the following formula

$$I = \sum_{i=1}^{n} \ln \frac{N_i / N}{S_i / S} \quad \ldots\ldots \ (1)$$

In formula (1): I - the total amount of information corresponding to the occurrence of geological disasters in a specific unit; Ni - Geological hazard area or number of geological hazard points under corresponding state conditions; Si - distribution area under corresponding state conditions (m2); N - total area or total number of geological hazards in the survey area (m2); S - Total area of the survey area (m2).

The research area has a wide geographical distribution.The DEM digital elevation model was rasterized by 50 m x 50 m,and the total information distribution was obtained through the information model method,ranging from -1.056 to 2.361.The larger the total information value of the unit,the more prone it is to slope type geological disasters.

4.2.2 Weighted Information Model Method

The weighted information method is based on the information model method,taking into account the differences in the impact of different factors Xi on event Y.Combining with the actual situation,the evaluation factor weights are given,and the weighted sum method is used to calculate the total information of each evaluation unit.The calculation formula is as follows:

$$I_j = \sum_{i=1}^{n} W_i I\left(Y, X_i\right) \quad \ldots\ldots \ (2)$$

In formula (2): Ij - the total amount of information obtained from the evaluation unit; Wi - the weight of factor Xi; I (Y,Xi)- The amount of information that factor Xi provides for event Y.

The information content and weights of each evaluation factor were weighted and stacked using the weighted information method,resulting in a susceptibility index range of -0.63 to 0.79.

4.3 Evaluation results and validation of evaluation models

4.3.1 Evaluation results

Based on a comprehensive study of the internal and external dynamic geological processes and development conditions of slope type geological hazards,combined with the distribution of geological hazard hazards,the susceptibility is divided into four levels: high susceptibility,medium susceptibility, low susceptibility, and non susceptibility.A geological hazard susceptibility evaluation map of the study area is obtained,with high susceptibility accounting for 5.12%,medium susceptibility accounting for 26.23%, low susceptibility accounting for 36.80%,and non susceptibility accounting for 31.85%.

4.3.2 Evaluation Model Validation

To verify the reliability of the susceptibility evaluation model used,the Receiver Operating Characteristic (ROC)curve was used to test the results.This is a highly effective and commonly used precision evaluation method in the process of geological hazard susceptibility evaluation.Divide the susceptibility into 20 intervals,and gradually count the cumulative frequency of susceptibility from high to low.Draw a success rate curve for the test sample.The vertical axis of the curve represents the true positive rate,which is the cumulative percentage of actual disaster points,and the horizontal axis represents the false positive rate,which is the cumulative percentage of susceptibility area.Calculating the Area Under Curve (AUC)between the curve and the horizontal axis can determine the simulation accuracy of the model.The AUC index is a standard for measuring the quality of the classification model,with a value ranging from 0.5 to 1.The closer it is to 1,the closer the simulated value of the model is to the sample value.

Based on the ROC curve,the AUC value of the susceptibility evaluation model obtained in this study is 0.73.It is believed that the evaluation results of the model meet the accuracy requirements and have a good effect,which can be used for geological hazard susceptibility evaluation in the region.

5. Conclusion

(1)For the risk assessment of landslide disasters,factors such as terrain,geological environment,and human activity level can be used to construct an evaluation model.Then,statistical methods such as Analytic Hierarchy Process and Weighted Information Model can be used to avoid errors caused by human subjectivity to a certain extent,resulting in more accurate evaluation results.

(2)The risk assessment results of landslide disasters in the research area show that high susceptibility areas account for 5.12%,medium susceptibility areas account for 26.23%,low susceptibility areas account for 36.80%,and non susceptibility areas account for 31.85%.

(3)The risk assessment model for landslide disasters in the research area used the receiver operating characteristic curve (ROC curve)to test the results,and obtained an AUC value of 0.73.The evaluation results of the model meet the accuracy requirements and can be used for the susceptibility assessment of geological disasters in the region.

(4)The information content results of the evaluation factors in the research area indicate that the higher the information content values of evaluation factor categories such as land use type,vegetation coverage,terrain undulation,slope,and rock and soil type,the more likely geological disasters are to occur.

(5)The research area uses ArcGIS software to obtain the risk assessment results of landslide disasters,which can provide a more intuitive understanding of the effects of various influencing factors on the occurrence of landslide disasters.

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