Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 10 (2011) 2567 – 2573

Procedia
Environmental Sciences

2011 3rd International Conference on Environmental Science and Information Application Technology (ESIAT 2011)

Landslide Risk Analysis of Miyun Reservoir Area Based on RS and GIS

YU Guoqing [1, a], YANG Haibo [2], TIAN Zhizong [1], ZHANG Baosen [1]

[1] *Yellow River Institute of Hydraulic Research, Zhengzhou, China.*
[2] *School of water conservancy and environment engineering, Zhengzhou University, Zhengzhou,China.*
[a] *yujing_zhang@yeah.net*

Abstract

Using RS (Remote Sensing) and GIS (Geographic Information System) technology, the upper part of the Miyun reservoir area was studied to evaluate landslide risk. Adopting the AHP(Analytic Hierarchy Process), six evaluation element including slope, elevation, land use, vegetation cover, soil type, rainfall were selected as the evaluation factors. The research area was divided into five regions as follows, landslide hardly ever happening, landslide difficultly happening, landslide possibly happening, landslide easily happening and landslide extremely easily happening by researching the weighted superposition by spatial analysis in the ArcGIS environment.

Keywords: GIS/RS, landslide, risk analysis, AHP.

Introduction

Landslide disaster is one of the most important geological disasters in China according to China Geological Environmental Information Network "issued by the National Geological Hazard Alert ", With the development of RS(Remote Sense), GIS(Geographic Information System) technology, It's possible to Survey, forecast and assess the landslide disaster by remote sensing image. In this paper, the Miyun reservoir area was studied to analyze the landslide risk of reservoir by using high resolution remote sensing image and the AHP (Analytic Hierarchy Process). Research results are helpful for providing the scientific basis of local landslide prevention.

Study Area and Data

The Miyun Reservoir, located in the central south zone of Yanshan subsidence, is mainly Archean metamorphic rocks and the lower part of the underlying distribution of the Sinian. Reservoir area general elevation is above 1500m, with corroded structures landforms. The type of 83.6% of the watershed area

doi:10.1016/j.proenv.2011.09.399

contains the land of mountain and hill and mountain. Slopes is mostly about the 20° ~ 35°, and Chao, Bai river slope is about the 70° ~ 90°. Watershed area is mainly the mountain. Factors that affect the reservoir topography around the reservoir area are mainly hilly and low mountains, and the vast majority of the upstream mountains.

Research data used includes: (1) Beijing One small satellite multi-spectral data (32 m resolution) and the Beijing One small satellite panchromatic band (4 meter resolution); (2) DEM resolution of 90 meters; (3) The Miyun county boundaries, rainfall station statistics; (4) soil data.

Research methods

The analysis of landslide risk assessment is studied based on the AHP(Analytic Hierarchy Process) by using RS(Remote Sense) and GIS(Geographic Information System) technology. The technical route includes the following five stages (refer with: Fig. 1).

(1) Research the factors that affecting the landslide disaster based on digital image preprocessing technology and processed RS images.

(2)Extract terrain data (slope, aspect), create the three-dimensional imagery and get the real reservoir inversion according to the DEM images from Beijing One satellite.

(3)Six evaluation element including slope, elevation, land use, vegetation cover, soil type, rainfall were selected as the evaluation factors according to understanding and analysis of the reservoir area.

(4)Determine the factor weights that affect landslide disaster susceptibility according to analysis the Existing landslide by AHP method.

(5)In accordance with the superposition of different weights and generate the landslide risk analysis chart by ArcGIS software.

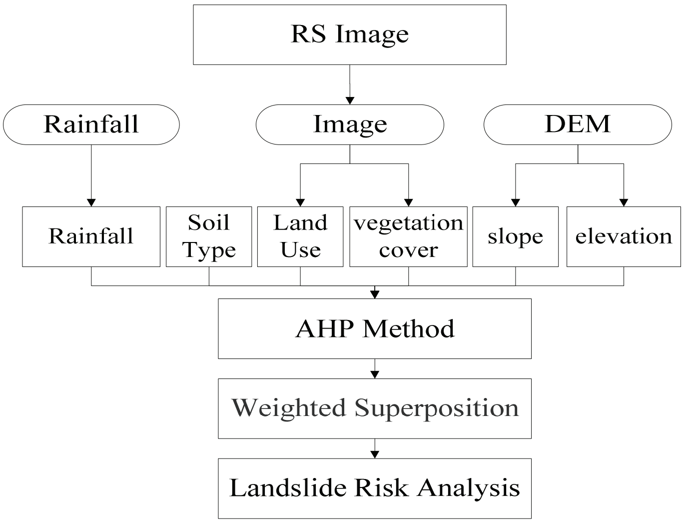


Fig.1 technical route of landslide risk analysis

Landslide Risk Analysis

Six factors are selected to perform landslide risk analysis, which are (1) B1-Vegetation Cover, (2) B2-Soil Classification, (3) B3-Slope, (4)B4-Elevation Band , (5) B5- Rainfall, and (6) B6-Land Use.

Assessment and grading factors

Evaluation of the above factors for each classification to quantify, with 1 to 9 to represent the change factor on the size of the impact of landslides: Level 1 is the greatest influence on the landslide, which most likely lead to landslides; Level 2 is prone to landslide... Grade 9, said the least impact on the landslide. Rank value is assigned the following table (refer with: Table 1):

Table 1 Classification of each factor level

Slope factor						
Range (°)	0 ~ 10	10 ~ 20	20 ~ 30	30 ~ 45	45 ~ 55	55 ~ 86
Level	8	7	1	2	4	5

Vegetation cover factor					
Range	<0.1	<0.3	<0.6	<0.8	<1
Level	5	1	3	7	9

Land use						
Land Type	Unused	plough	Building land	Water area	grassland	Forest
Level	1	3	4	7	9	5

Soil classification						
Soil Type	Brown	Moisture	Cinnamon	Skeleton	Alluvial	Paddy
Level	1	2	3	6	7	9

Rainfall Factor						
Range（mm）	454 ~ 560	560 ~ 600	600 ~ 620	620 ~ 640	640 ~ 660	660 ~ 682
Level	9	6	5	3	2	1

Elevation band factor								
Range(m)	0 ~ 200	200 ~ 400	400 ~ 600	600 ~ 800	800 ~ 1000	1000 ~ 1200	1200 ~ 1400	1400 ~ 1600
Level	9	8	3	1	5	6	7	2

Determine weights factor based on AHP

Determine the size of each factor is an important part of the landslide risk assessment. This paper determines the weight of evaluation factor by AHP method.

(1)Matrix Structure

A	B1	B2	B3	B4	B5	B6
B1	1	5	1/3	6	1/2	3
B2	1/5	1	1/7	2	1/6	1/2
B3	3	7	1	9	2	5
B4	1/6	1/2	1/9	1	1/7	1/3
B5	2	6	1/2	7	1	4
B6	1/3	2	1/5	3	1/4	1

Note: B1--vegetation index; B2--soil type; B3--slope; B4--elevation band; B5--rainfall; B6--Land Use.

(2) Matrix Solution

This paper use square root law to solve the largest characteristic root of the comparison matrix and the corresponding eigenvectors. Follow these steps to gradually solve the largest characteristic root and the corresponding eigenvectors:

Calculate the product of matrix elements of each row $M_i = \prod_{j=1}^{6} b_{ij} (i = 1,2,\cdots,6)$.

After calculation, the products of solving the row elements are as follows:

M_1=15.00000000; M_2=0.004761905; M_3=1890.000000000; M_4=0.000440917;

M_5=168.000000000; M_6=0.100000000 ;

Calculate the 6-th root of M_i $\overline{W_i} = \sqrt[6]{M_i} (1,2,\cdots 6)$

After calculation, the results are as follows:

$\overline{W_1}$ =1.570417802; $\overline{W_2}$=0.410169583; $\overline{W_3}$=3.516227510; $\overline{W_4}$=0.27588774;

$\overline{W_5}$=2.349010079; $\overline{W_6}$=0.681292069

Vector $\overline{W} = \left[\overline{W_1}, \overline{W_2}, \cdots, \overline{W_7}\right]^T$ normalization: $W_i = \overline{W_i} \Big/ \sum_{i=1}^{6} \overline{W_i} (i = 1,2,\cdots,6)$

Find the largest characteristic root of the corresponding eigenvector

$W = [0.178395735, 0.046594291, 0.399435100, 0.031339742, 0.266841970, 0.077393162]^T$

Solve the maximum characteristic root $\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(BW)_i}{W_i}$, in(BW) i is the first i vector component of BW, and

$$BW = \begin{bmatrix} 1 & 5 & 1/3 & 6 & 1/2 & 3 \\ 1/5 & 1 & 1/7 & 2 & 1/6 & 1/2 \\ 3 & 7 & 1 & 9 & 2 & 5 \\ 1/6 & 1/2 & 1/9 & 1 & 1/7 & 1/3 \\ 1/3 & 2 & 1/5 & 3 & 1/4 & 1 \end{bmatrix} \times \begin{bmatrix} 0.178395735 \\ 0.046594291 \\ 0.399435100 \\ 0.031339742 \\ 0.266841970 \\ 0.077393162 \end{bmatrix} = \begin{bmatrix} 1.098151147 \\ 0.285185322 \\ 2.463489771 \\ 0.19266919 \\ 1.631867579 \\ 0.470663728 \end{bmatrix}$$

Calculate the maximum eigenvalue: $\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(BW)_i}{W_i}$ =6.13140838

(3) Consistency Check

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{6.13140838 - 6}{6 - 1} = 0.026281676$$

When n=6, RI=1.24; then:

$$CR = \frac{CI}{RI} = 0.026281676/1.24 = 0.0211949 < 0.100000000$$

Therefore, the Matrix structure is more reasonable. Two decimal places, by the weight factor table (refer with:Table 2) as follows

Table 2 Factors Weights

Factors	Vegetation Index(VI)	Soil type(ST)	Slope(S)	Elevation (E)	Rainfall(R)	Land use(L)
Weights	0.18	0.05	0.4	0.03	0.26	0.08

Landslide risk analysis model in the study area

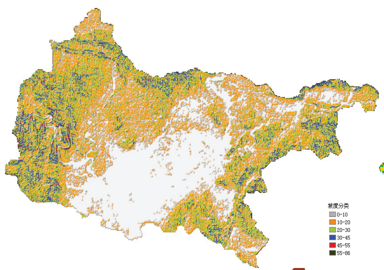
According to the evaluation of selected factors and the calculated weight of each evaluation factor the study area, landslide risk assessment model as:

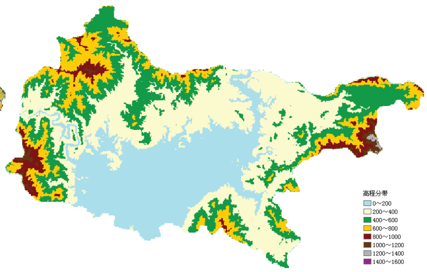
$$E = 0.18*VI + 0.05ST + 0.4*S + 0.03*E + 0.26*R + 0.08*L$$

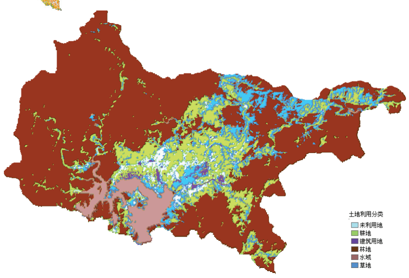
Based on this mathematical model of spatial analysis in the ArcGIS environment, the weighted overlay is operated. The study area is divided into five risk levels: non-hazardous area, low-risk area, in the danger zone, high-risk area, a very dangerous area.

Results and Analysis

Compared the factors participated in the model computation with the calculation results of model (refer with: fig.2-8), we can find that most of the researching regions are stable, just a small area appears landslide more easily in the northeast of Miyun reservoir. The slope is the control factors of landslide, but there are usually building lands in the area which has higher hazard level of landslide.







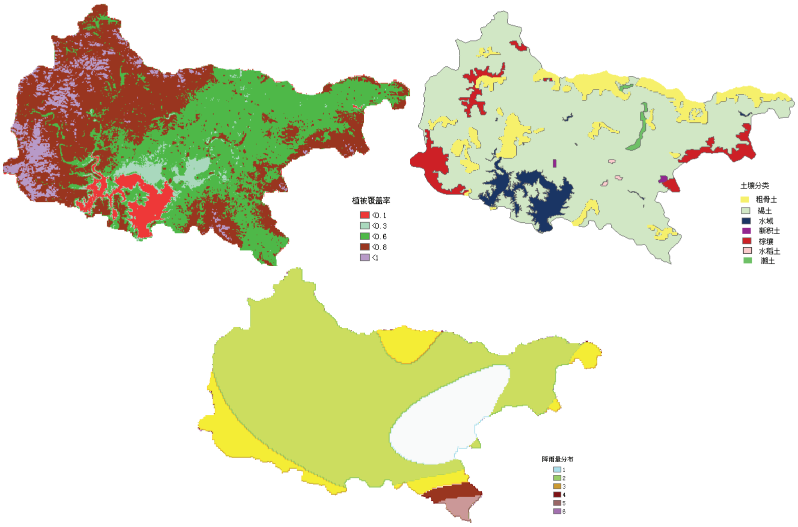


Fig.2 Six factors, including: slope analysis/ Elevation zoning figure/Land use/ Vegetation/Soil / Rainfall

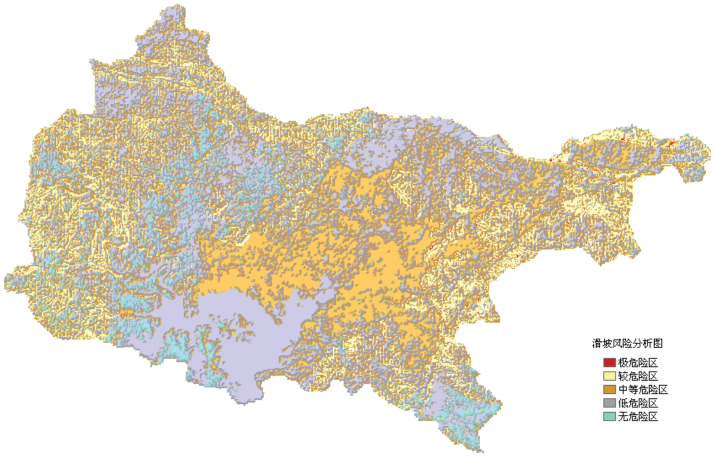


Fig.3 Landslide risk

However, rainfall and vegetation index increased the risk of landslides level, the statistical results of landslide risk level in the study area as shown in Figure 3.

Table 3 statistics of landslide risk zoning in the study area

Type	area（km^2）	percent（%）
landslide extremely easily happening	1.3095	0.09
landslide easily happening	195.2235	13.05
landslide possibly happening	595.5426	39.81
landslide difficultly happening	611.7624	40.89
landslide hardly ever happening	92.1006	6.16

We can find from the table 3 that the area where landslide is never dangerous or less dangerous is 47.05% of the total area, that's to say about half of the study area is stable. And the area where landslide happens dangerously is small. The area is only 1.31km2, only about 0.09% of the total area, mainly distributed in the northeastern valley and valley location, appears scattered point-forming distribution. At the same time, the medium danger zone takes about 39.81% ,it also should be taken attention.

Conclusions

Miyun reservoir area is studied to evaluate the risk of landslide disaster by using GIS and RS technology and AHP methods. Derived from the above analysis, the most dangerous landslide areas are mainly concentrated in the northeast of Miyun Reservoir, with the elevation of 400m ~ 600m above and the slope at 30° ~ 45° or so, and mostly distributed in the brown soil, and this is what we usually took then as factors of landslide. But the heavy risk area shown here is forest and vegetation land where vegetation index are more than 0.6, and it is usual which differs from our routine judgment: more vegetation cover, the more difficult to slide. From the enlarged land use map, we can find that many settlements and construction sites are located in this valley, where precipitation is a little large than average, up to 680mm. These factors are also important conditions induced landslides. Therefore, prevention should focus on the image above the red area of landslide disasters.

References

[1] China Geological Environmental Monitoring Institute disasters room. National Geological Hazards Bulletin 2008

[2] Wang Zhihua. Active tectonics and its secondary disasters along Qinghai-Tibet line [J]. Geosciences, Vol.17(2003), p. 227-236.

[3] Wang Zhihua. Progress and Applications for Digital Landslide [J].Geosciences, Vol. 19(2005), p. 157-164.