Available online at www.sciencedirect.com
ScienceDirect
Procedia Earth and Planetary Science 15 (2015) 513 – 517
Procedia Earth and Planetary Science

World Multidisciplinary Earth Sciences Symposium, WMESS 2015

# Landslide Susceptibility Assessment at the Xiushui Area (China) Using Frequency Ratio Model

Haoyuan Hong[a, b*], Chong Xu[a], Dieu Tien Bui[c,]

[a] *Key Laboratory of Active Tectonics and Volcano, Institute of Geology, China Earthquake Administration, #1 Huayanli, Chaoyang District, PO Box 9803, Beijing 100029, P.R. China*
[b]*Jiangxi Provincial Meteorological Observatory, Jiangxi Meteorological Bureau, No.109 ShengfuBeier Road, Nanchang, 330046, China*
[c]*Department of Business Administration and Computer Science, Faculty of Arts and Sciences, Telemark University College, Hallvard Eika plass, N-3800 Bø i Telemark, Norway*

**Abstract**

Landslide hazards are one of the most dangerous natural disasters all over the world. Landslide susceptibility assessment is useful for land use planners, and it can give the government some guide of management. In the current study, Frequency Ratio model combined with geographic information system are used in the Xiushui area. Firstly, landslide inventory map in Xiushui area come from interpretation of satellite images and field survey data. Then 214 (75%) landslides were randomly selected as sample data, 72 (25%) landslides were selected as verification data. Secondly, the relationship between landslide and influencing factors was described 10 factors were applied in the model including slope, slope elevation, TWI, SPI, LS, distance to river, distance to fault, lithology map, rainfall. By using these factors, – corresponding parameters in FR model simulation – were selected. The results show that the high risk and very high risk of landslide areas - is present/appears for 48.2% of the region. In the course of model validation, the results were validated using ROC curve. The AUC of Frequency ratio model was 80.5%. Therefore, the landslide susceptibility index map of Xiushui is valuable for decision maker in landslide prone area.


Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.

*Keywords:* Frequency Ratio; GIS; landslide; Xiushui area, China.

* Corresponding author. Tel.: +86-010-62009001; fax: +86-010-62009001.
*E-mail address:* honghaoyuan333@gmail.com


Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.
doi:10.1016/j.proeps.2015.08.065

## 1. Introduction

Landslide is one of the most threatening disasters to human life all over the world. Every year, we may read the report about - significant human losses - caused by landslides(Lan et al., 2004). Therefore, it is important to do some research why landslide is so frequent and what in order to prevent it. Many scholars concentrated on the trigger factor of landslide; —with different results (Lee and Oh, 2012; Tien Bui et al., 2012). However, earthquake and rainfall are two major induced factors in landslide occurred(Yilmaz et al., 2011). Besides, there are also a lot of model in landslide susceptibility mapping, such as frequency ratio, artificial neural network, decision tree, weights of evidence, fuzzy logic(Bagherzadeh and Mansouri Daneshvar, 2012; Ilanloo, 2011; Poudyal et al., 2010; Pourghasemi et al., 2013; Tsai et al., 2013).

In the current study, the main aim is to assess the landslide susceptibility in the Xiushui area, the Jiangxi province, China using frequency ratio model. The frequency ratio model is considered as easy to apply in - GIS. No research in landslide susceptibility assessment has been conducted before in this area, so we - used the frequency ratio model in landslide susceptibility mapping.

## 2. Study area and data used

### *2.1 Study area*

The Xiushui area is located in the Northwest of the Jiangxi Province, in the centre of Mufu and Jiuning moutain. The study area lies between - 28 °40’ N and 29°37’ N, and - 113°93’ E and 114°94’ E. It covers an area of about 4504 $km^2$. Xiushui is a typical mountainous county. Territory is surrounded by hills, North Mufushan, South nine Ridge Hill, is Northeast Southwest direction, from the periphery to the center, followed by Zhongshan, low mountains, hills and valley terrain. In the low mountains, accounting for 65% of the total area of the high places, accounting for 20.5% of the total area, accounting for 13.5% of the total area of low hill, valley terrace accounted for only 1% of the total area (Rewrite the sentence or make link to a picture).
Xiushui area belongs to the subtropical monsoon climate, with the average annual precipitation of 1634.1 mm, the average annual temperature is 16.7℃, and the average annual sunshine is 1600.4 hours. In the Xiushui area, no information about earthquake-induced landslides have been reported, the high amount of rainfall is considered as the main trigger factor for the occurrence of landslides. Many rivers in Xiushui county territory, water resources are very rich, the theoretical reserves amounted to 390000 (390 MW) kilowatts, can be developed for the 200000 kilowatts, accounting for reserves of 51.28%. The minerals of Xiushui- are composed of gold, white tungsten, coal, quartz, clay, various stones, etc.

### *2.2 Data*

The landslides inventory database for the Xiushui area is including 288 landslide events (Fig. 1). 214 landslide cases (75 %) out of 288 detected landslides were randomly selected for training, and the remaining 72 (25%) landslide cases were used for the model validation purposes. The condition factor of landslide is very complicate, so in the study area, for landslide susceptibility modeling were used of fourteen conditioning factors namely slope angle, altitude, slope aspect, topographic wetness index (TWI), slope-length (LS), Stream power index (SPI),distance to rivers, distance to faults, , annual rainfall, and Lithology.

## 3. Method

The landslide susceptibility map (LSM) was calculated by summation of each factor’s ratio value using following equation (Lee and Pradhan, 2007)(Eq. 1):

$$\mathrm{LSM} = \sum \mathrm{FR} \tag{1}$$

The calculation steps for an FR for a class of the landslide-influencing factor are below (Lee and Pradhan, 2007)(Eq. 2):

$$FR = \frac{A/B}{C/D} \tag{2}$$

where, A is the number of pixels with landslide for each factor; B is the number of total landslides in study area; C is the number of pixels in the class area of the factor; D is the number of total pixels in the study area; and FR is the frequency ratio of a class for the factor.

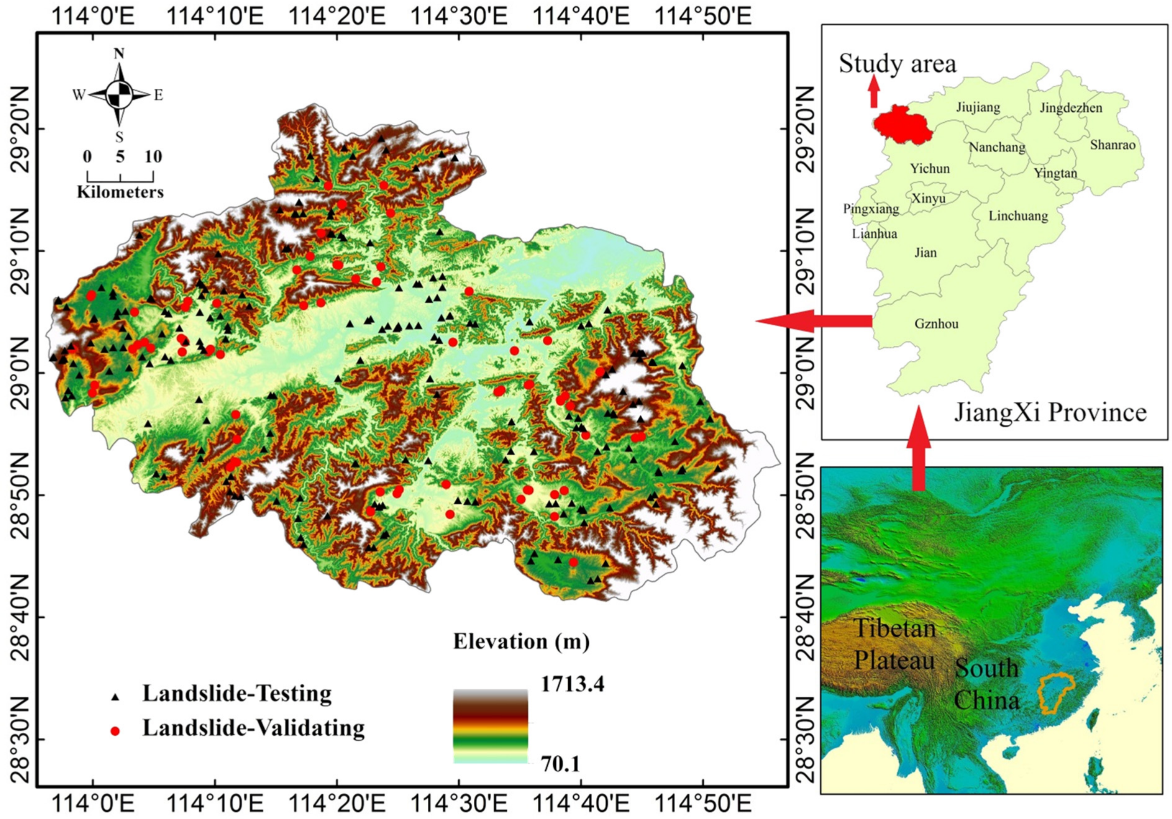


Fig. 1 Landslide location map of the study area.

The ROC curve is constructed by plots the true positive rate (sensitivity) against the false positive rate (1 - specificity) with the various cut-off thresholds(Pradhan and Lee, 2010). Area under the ROC curve (AUC) could be used for quantitatively comparison of these models. An AUC value of 1 indicates a perfect model and when AUC equal 0 it indicates a non-informative model(Lee and Sambath, 2006). The definition is as follow:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (3)$$

$$\text{Sensitiviy} = \frac{TP}{TP + FN} \quad (4)$$

$$\text{Specificity} = \frac{TN}{FP + TN} \quad (5)$$

$$\text{Positive predictive value} = \frac{TP}{FP + TP} \quad (6)$$

$$\text{Negative predictive value} = \frac{TN}{FN + TN} \quad (7)$$

where TP (True positive) is the number of landslide pixels correctly classified to the landslide class, TN- True negative is to the total number of non-landslide pixels correctly classified to the non-landslide class. FP (False positive) is the number of landslide pixels classified to the non-landslide class; FN (False negative) is the non-landslide pixels classified to the landslide class(Xu et al., 2012).

Table.1 Frequency ratio values of landslides-conditioning factors.

| Factor | Class | No.Pixels in domain | No. of Landslides | % Pixels in domain | % Landslides | FR |
|---|---|---|---|---|---|---|
| **Slope angle (Degree)** | 0-5 | 88802 | 46 | 0.20 | 0.21 | 1.08 |
| | 5-15 | 146866 | 104 | 0.33 | 0.48 | 1.48 |
| | 15-30 | 180900 | 60 | 0.40 | 0.28 | 0.69 |
| | 30-50 | 34363 | 4 | 0.08 | 0.02 | 0.24 |
| | ＞50 | 4 | 0 | 0.00 | 0.00 | 0.00 |
| **Altitude (meter)** | 70.1-246.6 | 154138 | 84 | 0.34 | 0.39 | 1.15 |
| | 246.6-408.5 | 134904 | 73 | 0.30 | 0.34 | 1.16 |
| | 408.5-604 | 93504 | 35 | 0.21 | 0.16 | 0.78 |
| | 604-877.7 | 52798 | 10 | 0.12 | 0.05 | 0.40 |
| | 877.7-1706.6 | 16079 | 2 | 0.04 | 0.01 | 0.26 |
| **Slope aspect** | Flat | 29616 | 15 | 0.07 | 0.07 | 1.06 |
| | North | 27840 | 6 | 0.06 | 0.03 | 0.45 |
| | Northeast | 51470 | 16 | 0.11 | 0.07 | 0.65 |
| | East | 54618 | 28 | 0.12 | 0.13 | 1.07 |
| | Southeast | 60821 | 39 | 0.13 | 0.18 | 1.34 |
| | South | 58352 | 33 | 0.13 | 0.15 | 1.18 |
| | Southwest | 54058 | 30 | 0.12 | 0.14 | 1.16 |
| | West | 54516 | 23 | 0.12 | 0.11 | 0.88 |
| | Northwest | 59644 | 24 | 0.13 | 0.11 | 0.84 |
| **TWI** | ＜7 | 322213 | 148 | 0.71 | 0.69 | 0.96 |
| | 7.7-18.3 | 129192 | 66 | 0.29 | 0.31 | 1.07 |
| | ＞18.3 | 18 | 0 | 0.00 | 0.00 | 0.00 |
| **LS** | ＜20 | 287045 | 169 | 0.64 | 0.78 | 1.23 |
| | 20-40 | 95175 | 30 | 0.21 | 0.14 | 0.66 |
| | 40-60 | 37100 | 10 | 0.08 | 0.05 | 0.56 |
| | 60-80 | 14430 | 5 | 0.03 | 0.02 | 0.72 |
| | ＞80 | 17673 | 0 | 0.04 | 0.00 | 0.00 |
| **SPI** | ＜100 | 318769 | 165 | 0.71 | 0.76 | 1.08 |
| | 100-300 | 82395 | 33 | 0.18 | 0.15 | 0.84 |
| | 300-500 | 19793 | 6 | 0.04 | 0.03 | 0.63 |
| | 500-700 | 9175 | 4 | 0.02 | 0.02 | 0.91 |
| | ＞700 | 21291 | 6 | 0.05 | 0.03 | 0.59 |
| **Distance to rivers (meter)** | <100 | 38 | 0 | 0 | 0 | 0 |
| | 100-300 | 5591 | 0 | 0.01 | 0 | 0 |
| | 300-500 | 136992 | 47 | 0.3 | 0.22 | 0.72 |
| | 500-700 | 125319 | 39 | 0.28 | 0.18 | 0.65 |
| | >700 | 183026 | 128 | 0.41 | 0.59 | 1.46 |
| **Distance to faults (meter)** | <500 | 36114 | 3 | 0.08 | 0.01 | 0.17 |
| | 500-1000 | 49657 | 5 | 0.11 | 0.02 | 0.21 |
| | 1000-2000 | 58685 | 26 | 0.13 | 0.12 | 0.93 |
| | 2000-3000 | 112856 | 47 | 0.25 | 0.22 | 0.89 |
| | >3000 | 194112 | 133 | 0.43 | 0.62 | 1.44 |
| **Rainfall(mm)** | 391.2-733.7 | 110227 | 32 | 0.24 | 0.15 | 0.61 |
| | 733.7-837.8 | 114444 | 54 | 0.25 | 0.25 | 0.99 |
| | 837.8-938.5 | 113491 | 53 | 0.25 | 0.25 | 0.98 |
| | 938.5-1247.4 | 113245 | 75 | 0.25 | 0.35 | 1.38 |
| **Lithology** | A | 54482 | 67 | 0.12 | 0.31 | 2.53 |
| | B | 85615 | 49 | 0.19 | 0.23 | 1.20 |
| | C | 38916 | 18 | 0.09 | 0.08 | 0.91 |
| | D | 77832 | 5 | 0.17 | 0.02 | 0.11 |
| | E | 38916 | 4 | 0.09 | 0.01 | 0.16 |
| | F | 70048 | 52 | 0.16 | 0.24 | 1.52 |
| | G | 15566 | 7 | 0.03 | 0.03 | 0.94 |
| | H | 7783 | 1 | 0.01 | 0.01 | 0.27 |
| | I | 62265 | 12 | 0.13 | 0.05 | 0.37 |

## 4. Result

The result of landslide susceptibility assessment based on the FR model are summarized in Table.1.In the case of slope angle, the 5-15 class has higher frequency ratio weight (1.48).In the case of altitude,246.6-408.5 class has higher frequency ratio weight (1.16). In the case of slope aspect, southeast has higher frequency ratio weight (1.34). In the case of TWI, 7.7-18.3 class has higher frequency ratio weight (1.07). In the case of STI, <20 class has higher frequency ratio weight (1.23).In the case of SPI, <100 class has higher frequency ratio weight (1.08). In the case of distance to rivers, >700 class has higher frequency ratio weight (1.46).In the case of distance to faults, >3000 class has higher frequency ratio weight (1.44).In the case of rainfall; 938.5-1247.4 class has higher frequency ratio weight (1.38). In the case of lithology, the class has higher frequency ratio weight (2.53).

## 5. Discussion and conclusion

Landslides are one of most dangerous disaster all over the world. So it is very important to do some research in landslide susceptibility mapping. In the current study, frequency ratio model were applied to construct landslide susceptibility map. 216 (75%) landslides were random selected as train data, 72 (25%) landslides were selected as verification data. Secondly, we contrast the relationship between landslide and each factor, then, the 10 factors were applied in the model including slope, slope, elevation, TWI, SPI, LS, distance to river, distance to fault, lithology map, rainfall, by using these factors, select the corresponding parameters in FR model simulation model. The result show that the high risk and very high risk of landslide areas accounted for 48.2% of the region. The result is useful for land use planner and government.

## Acknowledgements

This research was supported by the National Natural Science Foundation of China (41472202, 41202235)

## Reference

1. Bagherzadeh, A., Mansouri Daneshvar, M.R., 2012. Mapping of landslide hazard zonation using GIS at Golestan watershed, northeast of Iran. Arabian Journal of Geosciences, 6, 3377-3388.
2. Ilanloo, M., 2011. A comparative study of fuzzy logic approach for landslide susceptibility mapping using GIS: An experience of Karaj dam basin in Iran. Procedia - Social and Behavioral Sciences, 19, 668-676.
3. Lan, H.X., Zhou, C.H., Wang, L.J., Zhang, H.Y., Li, R.H., 2004. Landslide hazard spatial analysis and prediction using GIS in the Xiaojiang watershed, Yunnan, China. Engineering Geology, 76, 109-128.
4. Lee, S., Oh, H.-J., 2012. Ensemble-Based Landslide Susceptibility Maps in Jinbu Area, Korea. 193-220.
5. Lee, S., Pradhan, B., 2007. Landslide hazard mapping at Selangor, Malaysia using frequency ratio and logistic regression models. Landslides, 4, 33-41.
6. Lee, S., Sambath, T., 2006. Landslide susceptibility mapping in the Damrei Romel area, Cambodia using frequency ratio and logistic regression models. Environmental Geology, 50, 847-855.
7. Poudyal, C.P., Chang, C., Oh, H.-J., Lee, S., 2010. Landslide susceptibility maps comparing frequency ratio and artificial neural networks: a case study from the Nepal Himalaya. Environmental Earth Sciences, 61, 1049-1064.
8. Pourghasemi, H., Pradhan, B., Gokceoglu, C., Moezzi, K.D., 2013. A comparative assessment of prediction capabilities of Dempster–Shafer and Weights-of-evidence models in landslide susceptibility mapping using GIS. Geomatics, Natural Hazards and Risk, 4, 93-118.
9. Pradhan, B., Lee, S., 2010. Landslide susceptibility assessment and factor effect analysis: backpropagation artificial neural networks and their comparison with frequency ratio and bivariate logistic regression modelling. Environmental Modelling & Software, 25, 747-759.
10. Tien Bui, D., Pradhan, B., Lofman, O., Revhaug, I., Dick, O.B., 2012. Landslide susceptibility mapping at Hoa Binh province (Vietnam) using an adaptive neuro-fuzzy inference system and GIS. Computers & Geosciences, 45, 199-211.
11. Tsai, F., Lai, J.-S., Chen, W.W., Lin, T.-H., 2013. Analysis of topographic and vegetative factors with data mining for landslide verification. Ecological Engineering, 61, 669-677.
12. Xu, C., Xu, X., Dai, F., Saraf, A.K., 2012. Comparison of different models for susceptibility mapping of earthquake triggered landslides related with the 2008 Wenchuan earthquake in China. Computers & Geosciences, 46, 317-329.
13. Yilmaz, C., Topal, T., Süzen, M.L., 2011. GIS-based landslide susceptibility mapping using bivariate statistical analysis in Devrek (Zonguldak-Turkey). Environmental Earth Sciences, 65, 2161-2178.