# GIS-BASED WEIGHTS-OF-EVIDENCE MODELING FOR LANDSLIDE SUSCEPTIBILITY MAPPING AT JAECHON AREA, KOREA

**HoangBac Bui[1], QuocPhi Nguyen[2], VanTrung Nguyen[1]**

[1]Department of Earth System Sciences, Yonsei University, Seoul, Korea.
134 Sinchon-dong, Seodaemun-gu, Seoul, Korea 120-749
Email: hoangbacbui@yonsei.ac.kr
[2]Department of Geotechnical and Environmental Engineering, Paichai University.
439-6, Doma 2 Dong, Seo-gu, Daejeon, Korea 302-735
Email: nguyenquocphi@gmail.com

## ABSTRACT

*Recently, weights-of-evidence method using GIS data is one of the most common approaches, which has been widely used in many fields of earth sciences such as mineral prospecting, geological hazard analysis and assessment of environmental impacts. In this study, the modeling was applied to derive the landslide susceptibility map of the Jeachon mountainous area, Korea. In the initial stage of this study, various factors such as lithology, slope, slope aspect, elevation and vegetation that are related to landslide distributions were generated and analyzed. The positive weight ($W^+$), the negative weight ($W^-$) and the contrast value were calculated for each factor. The results of the test of conditional independence figured out that all pairs of factors are independent and can be combined together to create the landslide susceptibility map. The result shows that about 85% of the identified landslides occurred in the areas that have moderate and high risks. The susceptibility map can be used for predicting landslides and planning for land use and construction.*

*Key words: Weights-of-evidence, GIS, landslide, susceptibility*

## 1. INTRODUCTION

The mountainous area of Jaechon is located in the southern part of Korea with a total area of about 50km$^2$. Results from the field surveys and satellite images indicate that landslides have been happened in this area for a long time. Therefore, to assess impacts of geological hazards and to minimize risks to people who are living in the area, landslide susceptibility mapping is necessary.

The objective of this study is to establish a landslide susceptibility map for the study area. The weights-of-evidence method using the Bayesian probability model was applied to calculate spatial data within a geographical information system (GIS) environment.

## 2. WEIGHTS-OF-EVIDENCE MODELLING

Weights-of-evidence method using the Bayesian probability model was originally developed and widely used for the identification and exploration of mineral deposits (Bonham-Carter *et al.*, 1989; Bonham- Carter *et al.*, 1994, Emmanuel *et al.*, 2000; Harris *et al.*, 2000). Recently, this method has been applied for landslide susceptibility mapping (Lee *et al.*, 2002, Nguyen and Bui, 2004, Bettina *et al.*, 2007, Ranjan *et al.*, 2008).

$$W^{+} = \log_e \frac{P\{B \mid D\}}{P\{B \mid \overline{D}\}}, \quad (1)$$

$$\text{and } W^{-} = \log_e \frac{P\{\overline{B} \mid D\}}{P\{\overline{B} \mid \overline{D}\}} \quad (2)$$

Where P is the probability, B is the presence of potential landslide predictive factor, is the absence of a potential landslide predictive factor, D is the presence of landslide and is the absence of a landslide. A positive weight ($W^+$) and a negative weight ($W^-$) indicate a positive and negative correlation between the presence of the predictive variable and the landslides, respectively. The weight contrast (C) is the difference between two weights ($C = W^+ - W^-$) and its magnitude reflects the spatial association between the predictable variable and the landslides.

In this method, the assumption of conditional independence of factors was checked. Dependent factors need to be rejected from mapping the landslide susceptibility.

The $\chi^2$ values between all pairs of binary patterns for each factor were calculated at the 99% significant level as:

$$\chi^2 = \sum_{i=1}^{4} \frac{(O_{\cdot i} - E_{\cdot i})^2}{E_{\cdot i}} \quad (3)$$

A detailed description of this modeling is available in Bonham-Carter (1994).

## 3. APPLICATION

In the initial stage of this study, the evidential themes such as lithology, slope, slope aspect, vegetation, DEM were constructed and analyzed. The map of landslide distribution in the studying area (66 landslides) was developed by combining data from a detailed field survey and satellite images. A digital elevation model (DEM) was developed by converting a 1:5,000 scale digital topographic data with a contour of 5m interval. From DEM, the slope and slope aspect maps were established. The vegetation data were extracted from Landsat TM satellite image. All these maps were generated using GIS techniques.

**Table 1. An example of weights and contrast values for elevation classes**

| Data layer | Class | No. of pixels in domain | No. of landslide occurrence | $W^+$ | $W^-$ | Contrast (C) |
|---|---|---|---|---|---|---|
| Elevation | < 100 m | 42517 | 0 | - | 0.00004 | - |
| | 100-200 | 215842 | 7 | -0.2172 | 0.00001 | -0.21716 |
| | 200-300 | 890335 | 19 | -1.0258 | 0.00004 | -1.02579 |
| | 300-400 | 344489 | 19 | 0.44927 | -0.00002 | 0.44929 |
| | 400-500 | 127344 | 15 | 1.27703 | -0.00008 | 1.27711 |
| | 500-600 | 43130 | 5 | 1.13486 | -0.00008 | 1.13494 |
| | >600 m | 16303 | 1 | 0.45104 | -0.00002 | 0.45106 |

Application of weights-of-evidence modeling was carried out following the steps that were summarized above. Some examples of weights, contrast values and the contingency table testing conditional independence between two layers are shown in Table 1 and 2. From Table 3, it is seen that all calculated $\chi^2$ values are satisfied with 99% significant level. It means that all pairs of factors are conditional independence and they can be combined together to map the landslide susceptibility.

**Table 2. An example of the contingency table testing conditional independence between vegetation and elevation layers**

| Elevation | Vegetation | | | | | | | | | | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non_Forest | | | Grass | | | Loose | | | Moderate | | | Dense | | | |
| | O. | E. | $\chi^2$ | O. | E. | $\chi^2$ | O. | E. | $\chi^2$ | O. | E. | $\chi^2$ | O. | E. | $\chi^2$ | |
| < 100 m | 0 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| 100-200 | 0 | 0.212 | 0.212 | 4 | 1.803 | 2.677 | 1 | 1.167 | 0.024 | 1 | 3.394 | 1.689 | 1 | 0.424 | 0.781 | 7 |
| 200-300 | 0 | 0.576 | 0.576 | 6 | 4.894 | 0.250 | 3 | 3.167 | 0.009 | 8 | 9.212 | 0.159 | 2 | 1.152 | 0.625 | 19 |
| 300-400 | 2 | 0.576 | 3.523 | 3 | 4.894 | 0.733 | 2 | 3.167 | 0.430 | 11 | 9.212 | 0.347 | 1 | 1.152 | 0.020 | 19 |
| 400-500 | 0 | 0.455 | 0.455 | 3 | 3.864 | 0.193 | 3 | 2.500 | 0.100 | 9 | 7.273 | 0.410 | 0 | 0.909 | 0.909 | 15 |
| 500-600 | 0 | 0.152 | 0.152 | 1 | 1.288 | 0.064 | 2 | 0.833 | 1.633 | 2 | 2.424 | 0.074 | 0 | 0.303 | 0.303 | 5 |
| > 600 m | 0 | 0.030 | 0.030 | 0 | 0.258 | 0.258 | 0 | 0.167 | 0.167 | 1 | 0.485 | 0.547 | 0 | 0.061 | 0.061 | 1 |
| Sum | 2 | 2 | 4.947 | 17 | 17 | 4.175 | 11 | 11 | 2.362 | 32 | 32 | 3.227 | 4 | 4 | 2.699 | 66 |

The landslide susceptibility-index (LSI) map was constructed by summing the contrast of each factor, as follows: LSI = ΣFc (where Fc = contrast of each factor). LSI value is high; it means that the susceptibility of landslides is high and vice versa. The color bar in the final landslide susceptibility map concerted from LSI values shows the susceptibility of landslides from low to high risk.

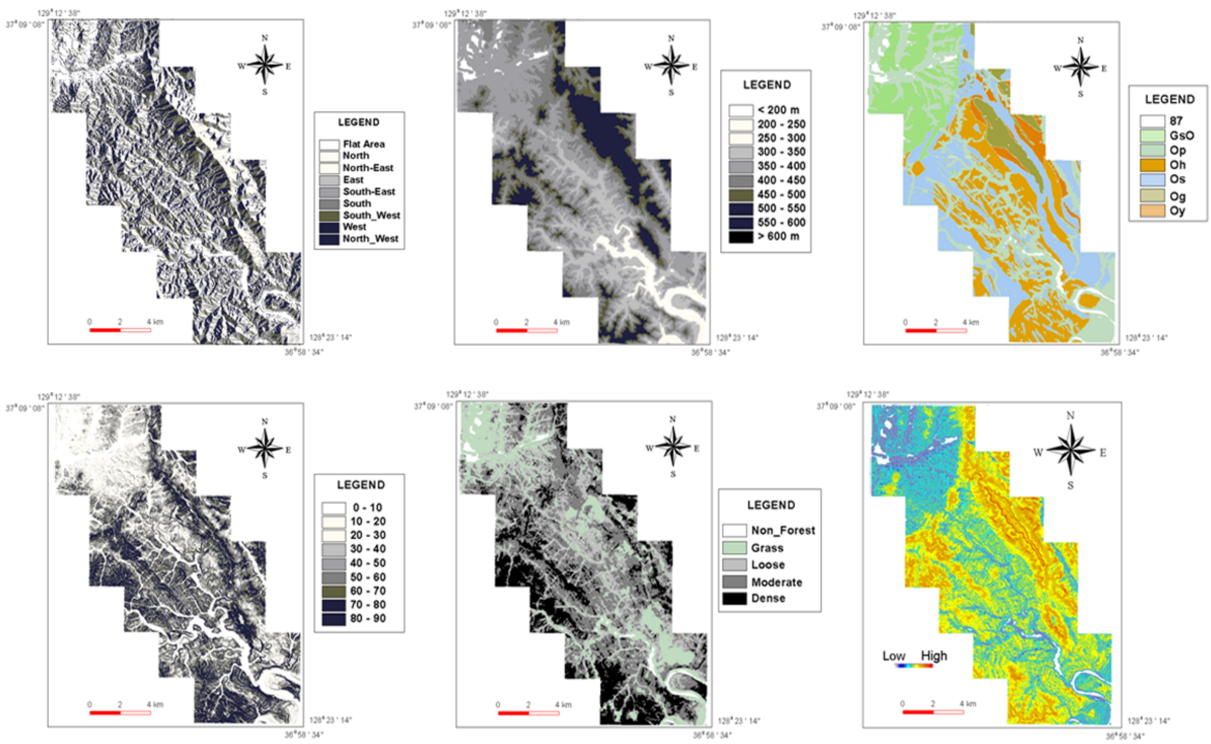


**Figure 1. Various landslides controlling factors and susceptibility map.**

**Table 3. Chi-squared values ($\chi^2$) from the pairwise test of the conditional independence (outside the brackets) and the 99% level (inside the brackets)**

| Factors | Slope | Aspect | Elevation | Lithology |
|---|---|---|---|---|
| **Aspect** | 83.3 (93.2) | | | |
| **Elevation** | 47.2 (83.5) | 32.6 (83.5) | | |
| **Lithology** | 29.7 (63.7) | 28.7 (63.7) | 25.5 (50.9) | |
| **Vegetation** | 35.8 (53.5) | 52.8 (53.5) | 17.4 (43.0) | 26.6 (37.6) |

## 4. CONCLUSION

In this initial study, the landslide susceptibility index map was constructed by a weights-of-evidence method using the Bayesian probability model within GIS environment. The map shows a good matching with about 85% of the identified landslides occurred in the areas that have moderate and high risks. In the near future, to increase the accuracy of the study, more data will be analyzed such as land-use, drainage, structure and so on. The susceptibility map can be used for predicting landslides and planning for land use and construction.

## 5. REFERENCES


Bettian, N., Birgit, T., 2007. Landslide susceptibility assessment using “weights-of-evidence” applied to a study area at the Jurassic escarpment (SW-Germany). *Geomorphology* 86, 12-24.

Bonham-Carter, G.F., 1994. *Geographic information systems for geoscientists: Modelling with GIS*. Pergamon Press, Canada, 398pp.

Bonham-Carter, G.F., Agterberg, F.P., Wright, D.F., 1989. Weights of evidence modelling: A new approach to mapping mineral potential. *Statistical Applications in Earth Sciences* 89(9), 171-183.

Emmanuel, J, Carranza, M, Hale, M., 2000. Geologically constrained probabilistic mapping of gold potential, Baguio district, Philippines. *Natural Resources Research*. 9, 237-253.

Harris, J. R., Wilkinson, L., Grunsky, E. C., 2000. Effective use and interpretation of lithogeochemical data in regional mineral exploration programs: application of geographic information systems (GIS) technology. *Ore Geology Review* 16, 107-143.

Lee, S., Choi, J., Min, K., 2002. Landslide susceptibility analysis and verification using the Bayesian probability model. *Environmental Geology* 43, 120-131.

Nguyen, Q. P., Bui, H. B., 2004. *Landslide hazard mapping using Bayesian approach in GIS: case study in YangSan area, Korea*. GIS-IDEAS Symposium 2004, Hanoi, Vietnam, 125-130.

Ranjan, K D., Shuichi, H., Atsuko, N., Minoru, Y., Takuro, M., Katsuhiro, N., 2008. GIS-based weights-of-evidence modeling of rainfall-induced landslides in small catchments for landslide susceptibility mapping. *Environmental Geology* 54, 311-324.