Case study of landslide hazard assessment in Himi district, Toyama Prefecture

Xiaoduo PAN*, Hiroyuki NAKAMURA (Tokyo University of Agriculture and Technology),
Tamotsu NOZAKI, Mayumi OBATA (CNK Geotechnical Institute Inc.)

Keywords: Landslide hazard assessment; GIS; Regression analysis; Coverage; DTM

1. Introduction

The occurrence of slope failures generally depends on complex interactions among a large number of partially interrelated factors. Analysis of landslide hazards requires evaluation of the relationship between various terrain conditions and landslide occurrences. It is appropriate to use the regression analysis for prediction of presence or absence of certain phenomena for a given set of independent variables, such as slope, geology, land use, soil, bedrock aspect, and so on.

The objective of this paper is to make landslide hazard assessment by linear and logistic regression analysis based on GIS for Himi district, Toyama Prefecture.

2. Method

2.1 Research region

Himi district of Toyama in Japan is selected as a research site, because hundreds of landslides are distributed in 145 km^2 area. The longitude is from 136° 52\`30\` to 137° 3\`, the latitude is from 36° 55\` to 37°. The elevation is from 0m to 508m. (See Fig. 1)

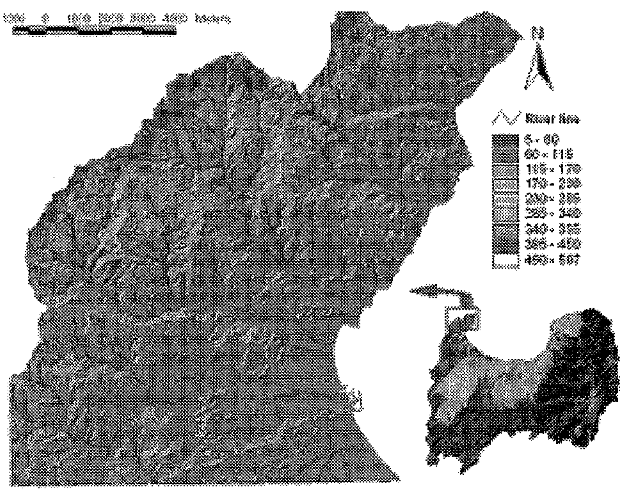


Fig. 1 Research site

2.2 Data preparation

The factors related to landslides depend on research regions and researchers. In Himi district, the authors think geology, land use, soil, slope and strike value (bedrock aspect relative to the landslide direction) are important factors affecting landslides. So the original data are the landslide distribution map (including the slide direction) interpreted from aerial photographs by one of the authors Nozaki, geological map compiled by Nozaki, bedrock aspect map classified from geological maps and landslide distribution map, topographical map, land use map and soil map.

2.3 Construct spatial data

After digitizing maps and editing coverages, they were projected and transformed by the same parameters, and then generated the digital terrain models (DTM, which include the digital elevation model (DEM)) to construct the spatial data. These DTMs should be in the original bottom, and they have the same grid size and are in the same region. The DTM of slope factor was derived from the digital elevation model (DEM) which was generated by the topographic point, arc and boundary coverages. It is a little complex to make the strike value DTM: in the landslide area, it is the bedrock aspect DTM minus landslide slide direction; in the other area, it is the bedrock aspect DTM minus aspect DTM derived from DEM. The other factors were generated directly using polygon-grid method.

2.4 Classification

There are many different integer values or continuous values in DTMs from string or numeric coverages. It is too detail to make the statistic analysis by so many values, even if the assessment was made by so detail information, it will make the assessment map cracked fragmentized. So every DTM was grouped into fewer ranges by its similarity attributions.

Geology DTM was grouped into 6 ranges according to geological formations: A (Quaternary & Hanyuh formation), B (Himi formation), C (Otogawa formation), D (Yatsuo formation (I)), E (Yatsuo formation (II)), F (Anamizu formation & Pre-Neogene Tertiary); Landuse DTM was grouped into 8 ranges according to land using pattern: A (Paddy), B (Field), C1 (Artificial forest), C2 (Natural forest), D (Bamboo), E (Lakes & marshes), F (other use); Slope DTM was grouped into 7 ranges according to slope classification map (made by Toyama Geoscience Society in 1984) classifying method: A (0～3°), B (3～8°), C (8～15°), D (15～20°), E (20～30°), F (30～40°), G (more than 40°); Soil DTM was grouped into 5 ranges according to soil type: A (Brown forest soil), B (Wet brown forest soil & Gray upland soil & Gley upland soil), C (Gley Soil), D (Dry brown forest soil), E (Others); Strike value DTM was grouped into 5 ranges according to the modified classification of Fig.2

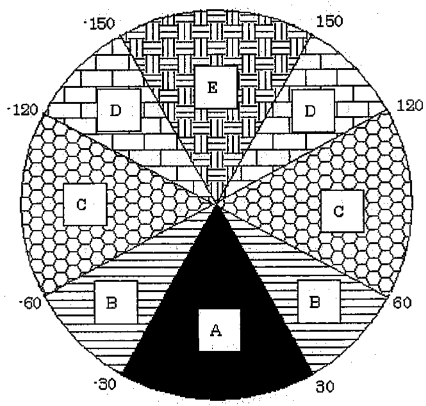


Fig. 2 Strike value that develop on sedimentary rocks that was originally proposed by the professor of British Colombia Univ., Dr. Cruden: A (30～- 30° : Cataclinal), B(30～60° & -30～-60° : Plagio -cataclinal), C(60～120° & -60～-120° : Orthoclinal), D(120～150° & -120～-149° : Plagio-anaclinal), E(150～-150: Anaclinal).

2.4 Statistical analysis

After grouping the spatial data, the weight W_{ij} was calculated based on GIS by statistical analysis. The weight W_{ij} was assigned as below:

$$W_{ij} = P_{ij} \div Q_{ij} (i = 1,2,...m, j = 1,2,...,n)$$

$$P_{ij} = SL(P_{ij}) \div \sum_{j=1}^{n} SL(P_{ij})$$

$$Q_{ij} = S(Q_{ij}) \div \sum_{j=1}^{n} S(Q_{ij})$$

In the above equations: m is the number of factor (In geology factor, m is equal to 1; in landuse factor, m is equal to 2; …; in Strike factor, m is equal to 5, the maximum of m is 5.); n is the type number after the classification in every factor (Such as, there have 6 types in the geology factor after the classification, so the n for geology factor is 6; n for landuse factor is 7; …; n for strike factor is 5.); P_{ij} is the area-cover percent for the jth type in the existing landslide area for the ith factor, in GIS software, it can be calculated by count percent simply; Q_{ij} is the area-cover percent for the jth type in the whole research region for the ith factor.

As known, because of labor hard work, the weights for landslide factor in previous research were calculated only in existing landslide area and equal to P_{ij}. With the development of GIS software, it makes us easier to compare the factor distribution percent in existing landslide area with the whole research site and get more reasonable weights W_{ij}. For example, one type of geology is dangerous and almost distributed in existing landslide area, but the total area of this type is scare, so the weight (P_{ij}) is small, as far as the weight W_{ij} is concerned, because the Q_{ij} is much smaller than P_{ij}, the weight ($W_{ij} = P_{ij} / Q_{ij}$) is higher and more reasonable than P_{ij}. See Fig. 3, we can compare the difference between the result of P_{ij} in deep color and Q_{ij} in light

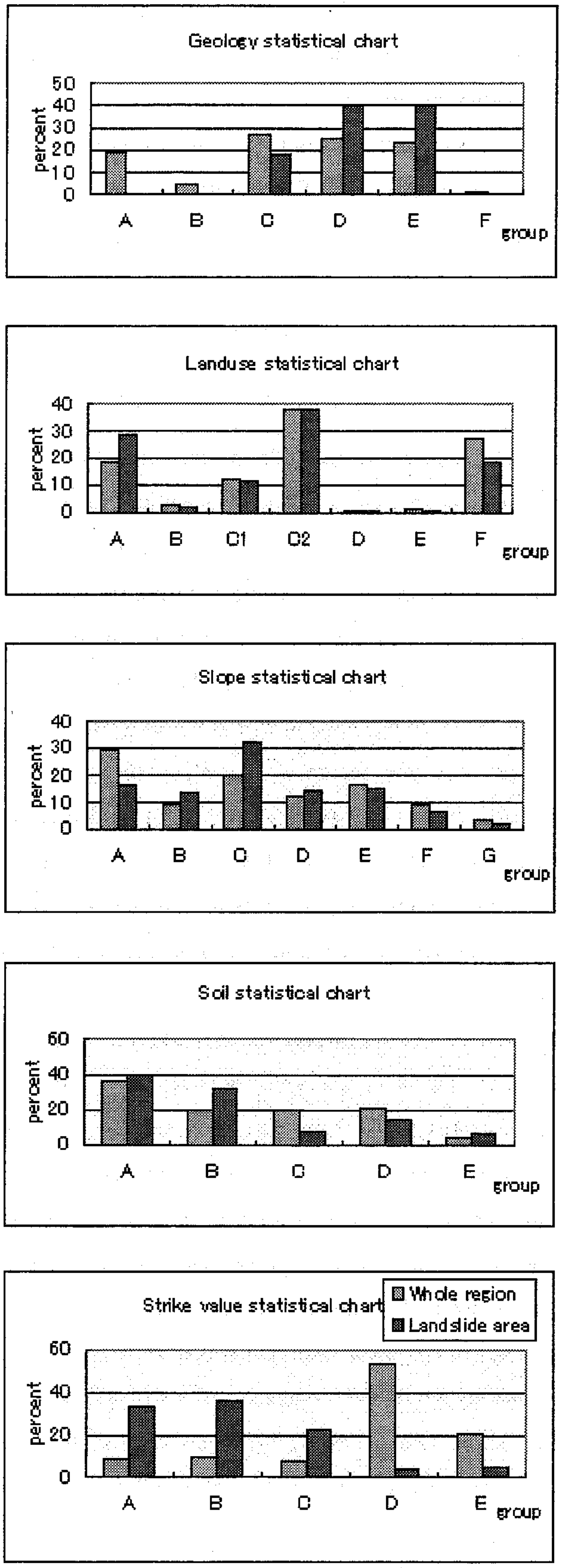


Fig. 3 statistical Chart of landslide factors

color in Himi district. Before doing the regression analysis in GIS software, the factor weights were standardized by following equation:

$$W_{ij}^{'} = \frac{W_{ij}}{Max(W_{ij}, j = 1,2,...,n)}, (i = 1, 2, ..., m)$$

2.5 Regression analysis

Based on the standardized weights, the regression analysis is done in GIS software. Regression analysis is to calculate the coefficients between numerous input variables. It can be used to predict the susceptibility that a phenomenon will exist at an unsampled location.

The linear and logistic regression equations are shown as below:

$$Z_1 = \sum a_i X_i$$
$$Z_2 = \frac{1}{1+\exp(-\sum a_i^{'} X_i)}$$

Where Z_1 or Z_2 is the dependent variable for linear and logistic regression analysis respectively, a_0, a_1, a_2, etc. are linear regression's coefficients, $a_0^{'}$, $a_1^{'}$, $a_2^{'}$, etc. are logistic regression's coefficients and X_1, X_2, X_3, etc. are the independent variables.

In ArcInfo software, we can use the SAMPLE command in GRID mode to input the landslide distribution, and other factors (DTM in grid format) to create an ASCII file listing the x and y coordinates of cells selected in the landslide distribution grid, and the respective cell values of rock facies, land use type, soil type, slope and strike value, then use the regression command in GRID mode to calculate the factors coefficients (shown as below).

Tab. 1 the factors coefficients

Factor		Geology	Strike	Land	Slope	Soil
Coefficien	a0	a1	a2	a3	a4	a5
Linear	0.01	0.330	0.305	0.238	0.223	0.131
Logistic	-78.0	52.496	48.50	37.84	35.48	20.93

3. Result

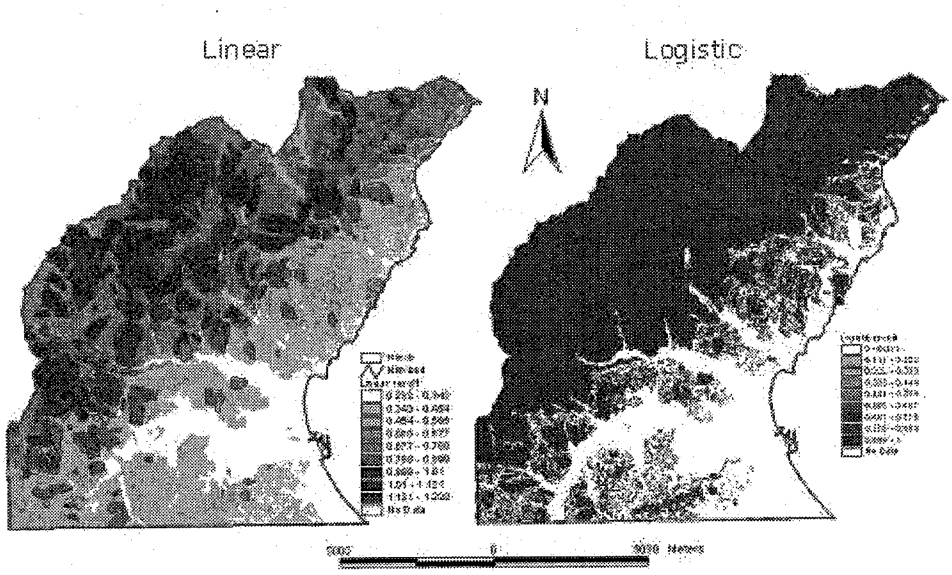
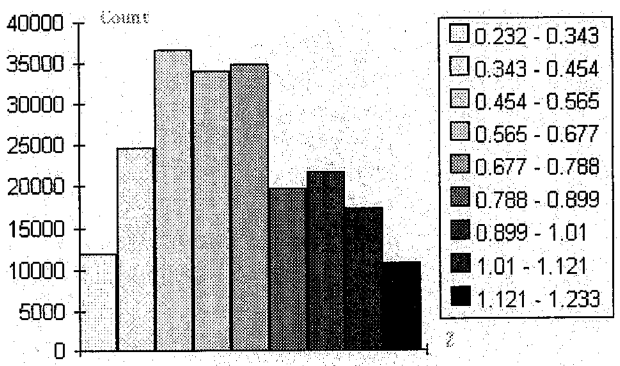


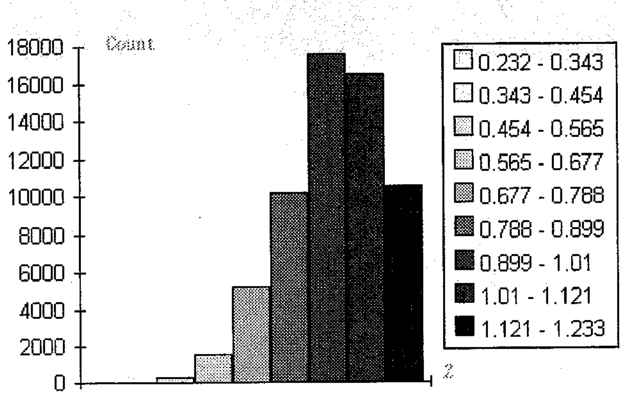
Fig. 4 Landslide hazard assessment

After getting the susceptibility values for the whole region, we displayed the result in ArcView software, and got the landslide hazard assessment as Fig. 4.

By the spatial analysis in ArcView, we got the charts of landslide hazard assessment for the whole region and the exiting landslide area as Fig. 5. We can see most of the existing landslide susceptibility values are around 1.



a In whole region



b In existing landslide area

Fig. 5 The chart of susceptibility distribution

4. Conclusion

It is a convenient and suitable approach to make landslide hazard assessment by regression analysis based on GIS.

In Himi district, Toyama Prefecture, geology and strike factors are the most sensitive ones. Soil factor is not so notable in this area, though it may be significant in other research regions.

Comparing the two graphs in Fig. 4, it can be found the result from linear regression is more precise than the one from logistic regression analysis.

Acknowledgement

We would like to express many thanks to the president of CNK Geotechnical Institute Inc., Mr. Hruaki Tsushima. His support was important to finish this research work.

Reference

Saro Lee, Joo-Hyung Ryu, Joong-sun Woo, Hyuck-jin Park (2003): Determination and application of the weights for landslide susceptibility mapping using an artificial neural network. Engineering Geology, Vol. 71, p. 289-302