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A Production Method of Landslide Hazard Map by Combining Logistic Regression Analysis and AHP(Analytical Hierarchy Process) Approach Selecting Target Sites for Non-point Source Pollution Management Using Analytic Hierarchy Process

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Abstract

The LRA(Logistic Regression Analysis) conducts a quantitative analysis by collecting a lot of samples and the AHP(Analytic Hierarchy Program) makes use of expert decision influenced by subjective judgment to a certain degree. This study is to suggest a combination method in mapping landslide hazard by giving equal weight for the result of LRA and AHP. Topographic factors(slope, aspect, elevation), soil drain, soil depth and land use were adopted to classify landslide hazard areas. The three methods(LRA, AHP, the combined approach) was applied to a 520 km^2 region located in the middle of South Korea which have occurred 39 landslides during 1999 and 2003. The suggested method showed 58.9% matching rate for the real landslide sites comparing with the classified areas of high-risk landslide while LRA and AHP showed 46.1% and 48.7% matching rates respectively. Further studies are recommended to find the optimal combining weight of LRA and AHP with more landslide data.

Keywords : Landslide, Logistic Regression, AHP analysis

I. Introduction

Due to the heavy rain by Jangma and Typhoon from June and September, landslides occur in South Korea. What is more, the recent urbanization is making the situation worse. However, the counter-plan for these recurring landfalls is merely confined to restoration after the mishap. In order to decrease the casualties and material damages resulted from the landslides, a prediction modelling is necessary. The landslide prediction modelling that is to expect the possible area of landslide will momentously help to reduce the damages caused by the landslides if the proper device is utilized with.

The landslide prediction modelling should be made by factual data, and also can be analysed with scientific means. It needs much time and expenses so as to examine a wide scope of region. If we apply GIS(Geographic Information System) and RS(Remote Sensing) techniques to the

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landslide prediction modelling, these problems can be easily solved. Using RS, its satellite image and aerial photograph make it possible to evaluate the present state covering areas that are impossible for the practical observation. GIS is effective in a way that it allows to analyze bulky data at a time. Also, a lot of studies have been conducted by time series analysis with the emergence of management of systematic DB(Data Base).

Lee et al.(2002) drew up the landslide area table with topography, geographical features, and GIS practical program for categorizing level of danger for landslide. Lee et al.(2002b) tried ratings on elevation, aspect, geology, stream accessibility, NDVI, and the usage of land in Gumi city so that they foresee the potential spot for landslides.

Meantime, studies attempting to analyse precisely with exact figure have been tried regarding how the effective factors on landslide impinge on the actual landslide data. Lee et al.(2004) drew up the level of danger for landslide through Logistic Regression Analysis for statistical examination. Oh et al.(2006) made up the level of hazard for landslide with SIMMAP application.

This study coordinates the landslide hazard map based on Logistic Regression Analysis(LRA) and Analytic Hierarchy Program(AHP), and is intended to promote the accuracy of the landslide hazard map through the integration of two methods which utilizes statistical approach and expert guidance respectively.

II. The Study Area And data preparation

The administration zone of Anseong city(520 km^2) located in the upper middle of South Korea was adopted as a study area as seen in Fig. 1.

DEM(Digital Elevation Model), soil and land use for the study area were prepared as input data. A 30 m resolution DEM that is a topography-related layer was produced through TIN(Triangular Irregular Network) and lattice transformation process using the 1 : 5,000 NGIS(National Geographic Information System) digital map. This was used to establish the slope, aspect and elevation data.

Soil data were rasterized from a vector map at a 1 : 50,000 scale that was supplied by the Korea Rural Development Administration. Soil information(drainage and depth) was obtained from soil survey data of the Korea Rural Development Administration.

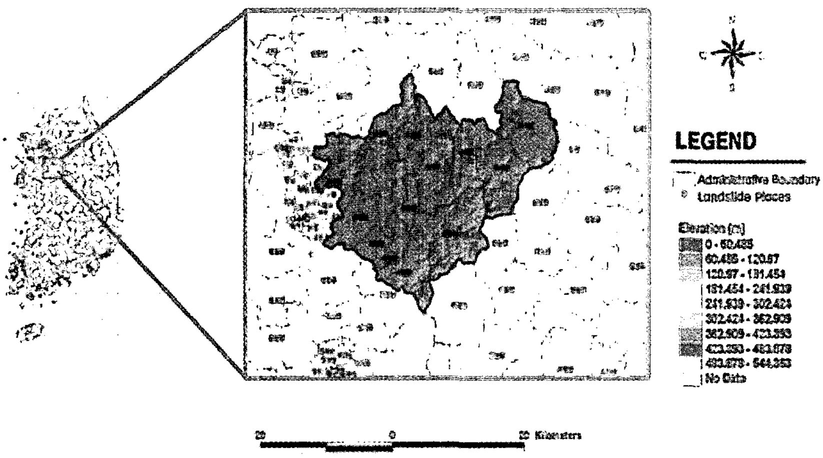

Fig. 1 The study area and elevation

Land use data were generated from 30 m resolution Landsat TM(Thematic Mapper) satellite imageries of 6 June 2000 supplied by RESTEC (Remote Sensing Technology of Japan). Land cover analyses were achieved through a maximum likelihood classification with average overall accuracy of 95.7%.

III. Logistic Regression analysis(LRA)

When trying to analyse the interrelation between one dependent variable and several independent variables, the most commonly used method is the regression analysis. A common regression analysis assumes that independent variables cause the dependent variable to make a linear change, and as such it is not appropriate when dealing with dichotomous cases where dependent variables like landslides are indicated by whether a landslide has occurred or not. Logistic Regression Analysis (LRA) assumes that the relations between the independent variable and dependent variable is non-linear and estimates the logistics regression coefficient. LRA can analyze the relevance between the independent variables and the dependent variable with two values.

Accordingly, LRA was conducted to analyse the landslide for the study area. The relations between dependent variable being whether a landslide occurred or not and 6 independent variables of slope, aspect, elevation, soil drainage, soil depth, land use that influence landslide occurrence was assumed.

Table 1 shows the statistical result of LRA, and Fig. 2 shows the graphical result. The significant difference showed 0.003. This means that the landslide had an appropriate relation with the selected 6 independent variables by LRA. To examine the accuracy of model results, 39 places where landslide had occurred based on disaster recovery data of Anseong city and randomly selected 30 places where no landslide occurred were used. As shown in Table 2 the regression model showed 63.3 % and 87.2 % estimation accuracy for landslide and no landslide places. The model could estimate landslide places by 76.8 % with overall accuracy.

Table 1 Result of logistic regression analysis using stepwise method

Variables	Regression Coefficient	Wald statistics	P-value
Elevation	0.003	0.374	0.541
Slope	0.077	3.034	0.082
Aspect	0.001	0.023	0.879
Soil depth	0.201	0.562	0.453
Soil drainage	-0.204	0.528	0.467
Land use	-0.058	0.051	0.822
Constant	-1.849	0.658	0.417

Table 2 Accuracy of the regression model by LRA

Observed \ Predicted	Landslide	No Landslide	Matching rate (%)
Landslide	19	11	63.3
No Landslide	5	34	87.2
Overall			76.8

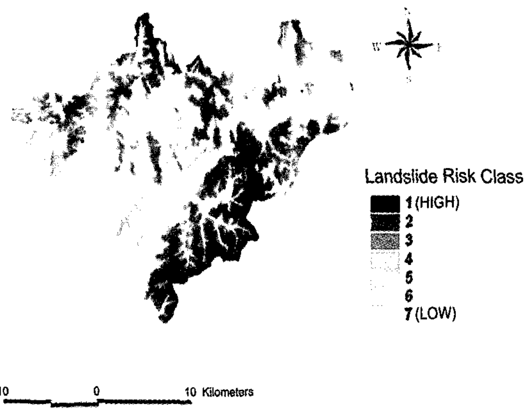

Fig. 2 Landslide hazard map by LRA

IV. Analytical Hierarchy Process (AHP)

The second method employed is the Analytical Hierarchy Process(AHP) which is used to solve uncertainty by structure of layers that was produced at a complicated system consisting of elements having mutual relations. AHP is a method of systemizing the collective decision-making of the experts. It is a useful method to determine the relative importance of the decision makers. Through a structured survey, the opinions of experts are collected and analysed, and a weight that is based on all the opinions of the experts can be calculated. It was deemed an appropriate method for deciding risk factors of landslides.

For the 6 independent variables already selected in LRA, the importance of the factors for landslide risk were relatively compared and evaluated. This was done through the questionnaire survey in order to determine the weight among the factors. For each factor, 9-point scale of questionnaire was used to collect expert opinions. The weight of landslide causes based on the questionnaires was investigated to examine appropriateness. The consistency ratio by Saaty(1990) was used, and it satisfied the results. The landslide causes showed significant difference of 0.02 being less than 0.1. Fig. 3 shows the graphical result by AHP method. Class 1 represents the highest landslide risk area and the risk decreases as the class number increases.

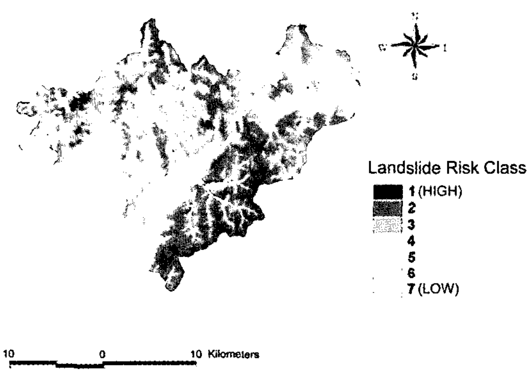

Fig. 3 Landslide hazard map by AHP

V. New Grade method by combining LRA and AHP

The LRA could conduct a quantitative analysis by collecting a lot of samples and the AHP made use of expert decision influenced by subjective judgment to a certain degree. In this study, a combination method by giving equal weight for the result of LRA and AHP was suggested to supplement both techniques. It produces a new grade for the 7 landslide risk classes as shown in Fig. 4, and Fig. 5 shows the graphical result by suggested method.

Fig. 6 shows the classified landslide risk area with 7 classes for 3 methods. The area of class 1 and class 2 by new grade method occupied 24.9 % while LRA and AHP occupy 22.3 % and 23.8 % respectively. As the risk class is low, the sensitivity of class division between landslide risk increases. Thus the evaluated areas by AHP and new grade method showed the maximum difference in class 7 comparing with that by LRA among the 7 classes.

To verify the result of new grade method, the matching rate within class 1 and class 2 for the 39 historical landslide places and the 30 random places of no landslide was calculated for 3 methods. Fig. 7 shows the comparison of matching frequency of landslide in each class for three methods. The new grade method showed 58.9% matching rate within class 1 and class 2 while the matching rate was 46.1% and 48.7% for LRA and AHP respectively. This is because the new grade method shows a mutual supplementary effect for each method.

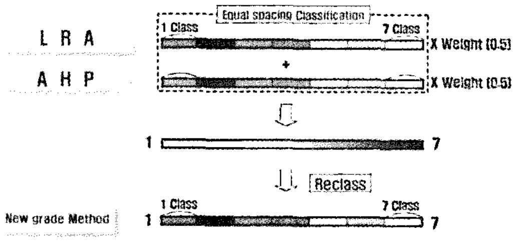

Fig. 4 A Suggested method by combining LRA and AHP grade

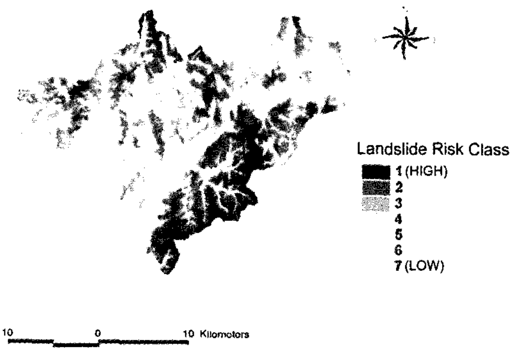

Fig. 5 Landslide Hazard map by New Grade Method

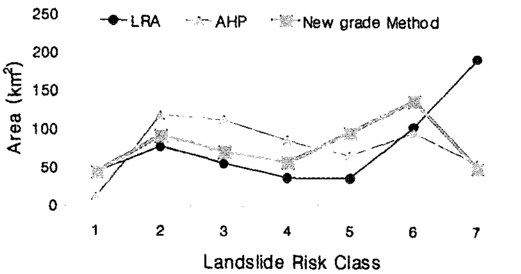

Fig. 6 Comparison of landslide risk area for 3 methods

Fig. 8 shows the spatial comparison of three methods for 2 selected sites. Site 'A' includes landslide places occurred historically and site 'B' does not include. The new grade method represents well for the trend of historical landslide occurrence while the results of LRA and AHP are inclined to high and relatively low landslide risk distribution for both sites respectively.

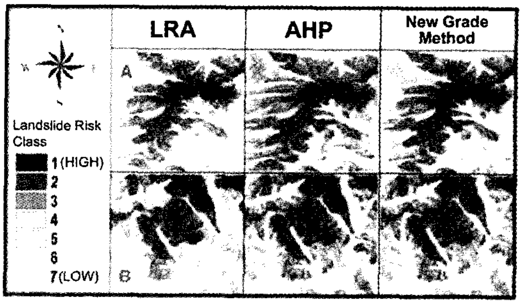

Fig. 8 Comparison of landslide hazard map for 3 methods

VI. Conclusions

Landslide is a natural disaster reiterating annually. The counterplan for this recurring landslide is merely confined to restoration after the mishap. Recently, the landslide risk increases as the rainstorm intensity increases. Thus it is important to have a confidential information of landslide hazard

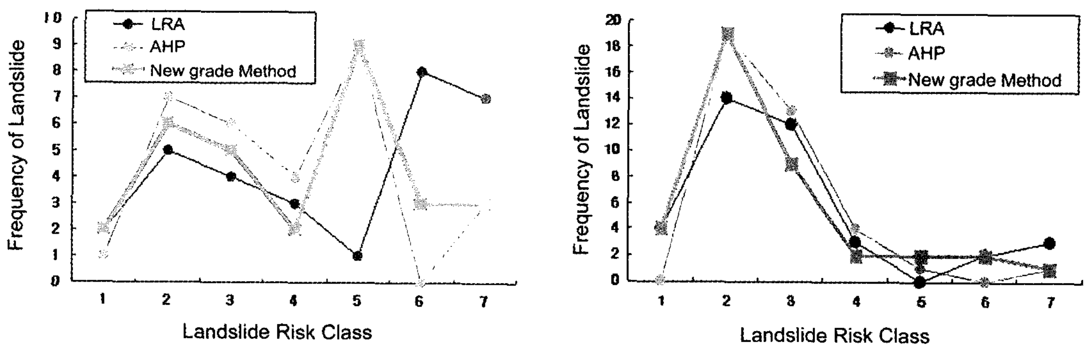

Fig. 7 Comparison of the matching frequency of landslide in each class for three methods (a) frequency of no landslide, (b) frequency of landslide.

area and take some preparations in advance. Up to now, the LRA(Logistic Regression Analysis) and/or the AHP(Analytic Hierarchy Program) were usually adopted to make a landslide hazard map. LRA conducts a quantitative statistical analysis by collecting a lot of samples and AHP makes use of expert decision influenced by subjective judgment to a certain degree.

This study suggested a method in analysing the landslide hazard areas by combining the result of LRA and AHP methods. The suggested method which gives equal weight for the result of LRA and AHP and produces a grade by 7 landslide risk classes improved matching accuracy between the historically occurred landslide places and the highly classified landslide risk class comparing with the matching accuracy of LRA and AHP. The suggested method showed 58.9% matching rate for the real landslide sites comparing with the classified areas of high-risk landslide while LRA and AHP showed 46.1% and 48.7% matching rates respectively. This is because the new grade method shows a mutual supplementary effect for each method. Further studies are recommended to find the optimal combining weight of LRA and AHP with more landslide data.

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