PREDICTION OF GROUND SUBSIDENCE USING GIS AND THE WEIGHT-OF-EVIDENCE MODEL

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1. INTRODUCTION

The presence of ground subsidence near abandoned coal mine areas can be hazardous to people and property because of its tendency to happen without warning. The prognostication has recently become a serious social problem in Korea, since almost all underground coal mines have been abandoned, and few remain since 1989. However, the effort of scientifically assessment of susceptible ground subsidence areas is very few, especially in coal mining areas where the structures of the geology and mining area complex. Thus, this study aims to quantitative assess and predict ground subsidence for hazard mapping around an abandoned underground coal mines (AUCMs) area by applying the weights-of-evidence method with validation of results. As a basic analysis tool, a Geographic Information System (GIS) was used for spatial and data management and manipulation.

2. DATA AND METHODOLOGY

Many studies have identified important factors that contribute to ground subsidence around coal mines, including depth and height of the mined cavities, excavation method, degree of inclination of the excavation, scope of mining, structural geology and flow of groundwater[1][2]. Therefore, the factors governing the occurrence of ground subsidence were collected and constructed in a vector-type spatial database. These included a 1:50,000 scale geological map, 1:5,000 scale topographic maps, 1:5,000 scale land use maps, 1:1,200 scale mined-tunnel maps, and borehole data. Ground subsidence occurrence areas were detected in the study site by interpretation field surveys.

Using the detected ground subsidence locations and the constructed spatial database, ground subsidence hazard analysis methods were applied and validated. For this, the calculated and extracted factors were mapped to a 1 m

× 1 m grid in ArcGIS GRID format. Next, using the weights-of-evidence method, spatial relationships between the ground subsidence location and each of the subsidence-related factors, such as geology, slope, land-use, depth of drift, distance from drift, depth of groundwater level and permeability were analyzed. The spatial relationships were used as each factor's rating in the overlay analysis. Subsequently, tests of conditional independence were performed for the selection of the factors to be used in ground subsidence hazard mapping. The factors' ratings were summed to calculate a ground subsidence hazard index, and subsidence hazard was mapped for 6 combinations of the factors. Finally, the results of a comparison of the 5 different combinations were validated using previous subsidence locations.

3. RESULT

Using the weights-of-evidence method, the spatial relationship and the contrast value between ground subsidence occurrence location and each subsidence-related factor was derived. The contrast was set to the rating of each factor, because the contrast is related to the ground subsidence occurrence probability. Then the contrast of each factor's type or range were summed to calculate the ground subsidence hazard index (SHI), as shown in equation (1)

$$\mathrm{SHIc} = \Sigma \mathrm{Fc} \qquad (1)$$

(where Fc = contrast of each factor's range or type)

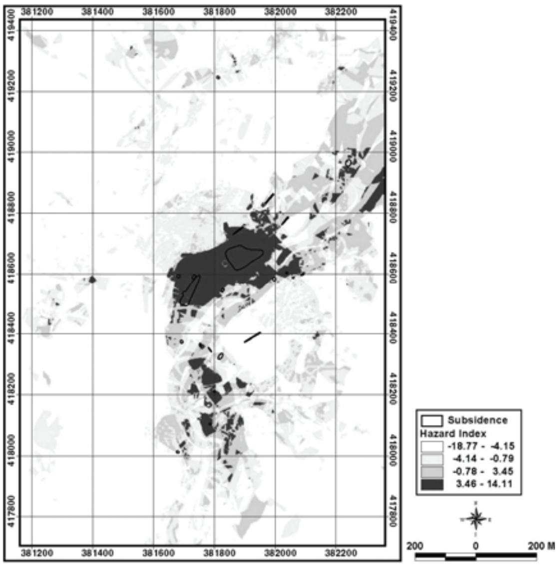
Also, the binary predictor patterns were assigned weights and integrated according to equation (2).

$$\mathrm{SHIw} = \Sigma \mathrm{Fw} \qquad (2)$$

(where Fw = W^+ and W^- of the binary pattern of each factor's range or type)

To generate the binary predictor pattern of the 7 factors, the spatial database was reclassified into a binary pattern as ''favorable'' and the other formations as ''nonfavorable''. To generate the binary predictor patterns of each factor, we had to determine the rating or range for which the spatial association between the ground subsidence occurrences and each factor is optimal. The optimum cutoff for the binary pattern was determined by calculating the c/s(c), studentized value of contrast. Then, the w^+ and w^- values were used as ratings for each factor.

If the SHIc and SHIw value are high, it means a higher hazard to ground subsidence; a lower value means a lower hazard to ground subsidence. Before the integration, the statistical validity of the resulting predictive maps was examined by applying an overall test of conditional independence. The 5 combinations of the factors were determined to be conditionally independent. First, for the case all combination, the ground subsidence hazard



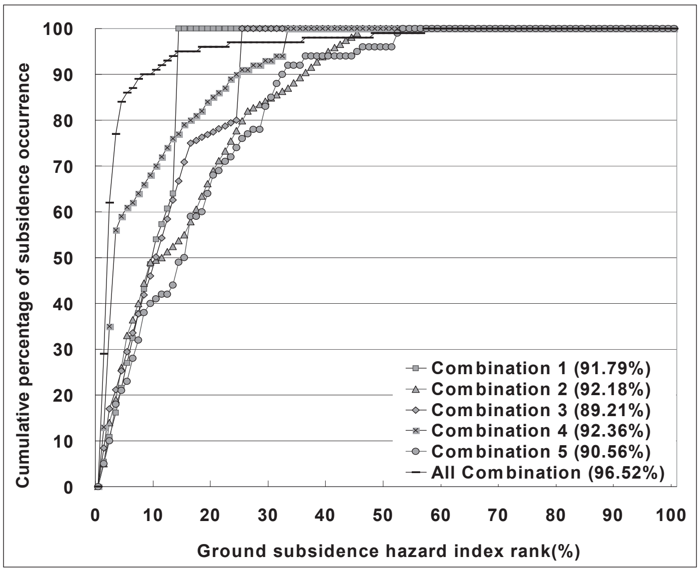


Fig. 1. Predictive subsidence hazard map based on weight-of-evidence analysis; using all contrasts (Left Figure).
Fig. 2. Cumulative frequency diagram showing ground subsidence hazard rank occurring in cumulative percent of ground subsidence occurrence (Right Figure).

map was calculated using all the factors and the SHIc value index for the interpretation is shown in Fig. 1. The index was classified into 4 classes based on area for visual and easy interpretation. After the test of conditional independence was performed, the 5 cases of combinations of the factors were analyzed, and the SHIw values were calculated, for example: using depth of drift and slope (combination 1), using distance from drift and depth of ground water (combination 2), using distance from drift and land use (combination 3), using distance from drift, depth of ground water and land use (combination 4), and using geology and land use (combination 5).

Validation was performed by comparison with existing ground subsidence data, and the result is shown in Fig. 2 using a success rate curve. Each ground subsidence map showed high prediction accuracy; 96.52%, 91.79%, 92.18%, 89.21%, 92.36 and 90.56% with all combination, combination1, 2, 3, 4 and 5, respectively. Among the 5 combinations considered, combination 4 used distance from drift, depth of ground water and land use showed the best result 92.36% of ground subsidence and combination 3 used distance from drift and land use showed the worst result 89.21%.

4. DISCUSSION AND CONCLUSION

Ground subsidence is one of the most hazardous events among the artificial disasters. Government and research institutions worldwide have attempted for years to assess subsidence hazards and risks and to show their spatial distribution. In this study, a probabilistic, weights-of-evidence model approach to identifying hazardous area of subsidence using GIS shows considerable promise. Generally, the validation results showed satisfactory agreement between the observed ground subsidence location and the results. That is the weigh-of-evidence model can be useful model for predict ground subsidence hazard near AUCMs areas.

Ground subsidence hazard maps are very helpful to planners and engineers for choosing suitable locations to carry out development. However, the methods used in this study are valid for generalized planning and assessment purposes, although they may be less useful on the site-specific scale, where local geological and geographic heterogeneities may prevail. For the method to be applied in general, more ground subsidence location data are needed, as well as application of the method to more regions. Fortunately, the subsidence-related spatial database for topography, mining tunnel, borehole, land use, and geology is already available for most areas of Korea; therefore, the ground subsidence analysis can be performed quickly and cheaply for all of Korea.

5. REFERENCES

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