Vulnerability assessment of landslide to climate change in South Korea

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Abstract

Climate change engages in extreme weather condition, such as flood and drought which cause the natural disasters including landslide and water shortage, etc. The adaptation measures should be prepared with the basis of vulnerability assessment for these disasters.

As the criteria for assessing landslide vulnerability to climate change, the sensitivity, exposure and adaptation indices were employed. The sensitivity was quantified by residential area, industry and commerce area, traffic area, and mining area. The exposure was quantified by landslide risk model for which considers the slope distance, parent rock, slope position, forest type, slope forms, soil depth and gradient must be considered. On the other hand, the adaptability was quantified by forest density. Finally, using these criteria, the vulnerability of landslide to climate change was assessed, and the spatial landslide vulnerability map was prepared in Korea.

Key words: Climate change, Landslide, Vulnerability assessment, GIS

1. INTRODUCTION

According to the IPCC 4th Assessment Report (IPCC., 2007), the human-related global warming and sea level rising would be continued for many centuries, even though the concentration of greenhouse gases becomes stabilized (Kwon et al., 2007). In this case, not all problems, related to climate change, can be only solved by the reduction of carbon dioxide. Therefore, it may be more effective to adapt ourselves to climate changes rather than to prevent the climate change itself. In Korea, most landslides were caused by natural hazards, such as severe rain storm, typhoons, and storm during the wet season (from July to September). The landslide can cause the damages of properties and losses of lives (National Institute for Disaster Prevention., 1998). Therefore, we need to estimate the vulnerability of landslide for adaptation strategies to climate change.

In this study, we assessed the vulnerability of landslide with the help of criteria such as sensitivity, exposure, and adaptability and indicators which can quantify the criteria using GIS-based data set.

2. METERIAL AND METHOD

2.1 Study area

The study area was the entirety of South Korea (latitude 33.09° to 38.72° and longitude 125.76° to 129.66°), (Fig. 1). Total area is 100,032km^2 and 65% of study area is mountainous region. In this area, about 50% to 60% of annual precipitation is concentrated in summer (Yang et al., 2007).

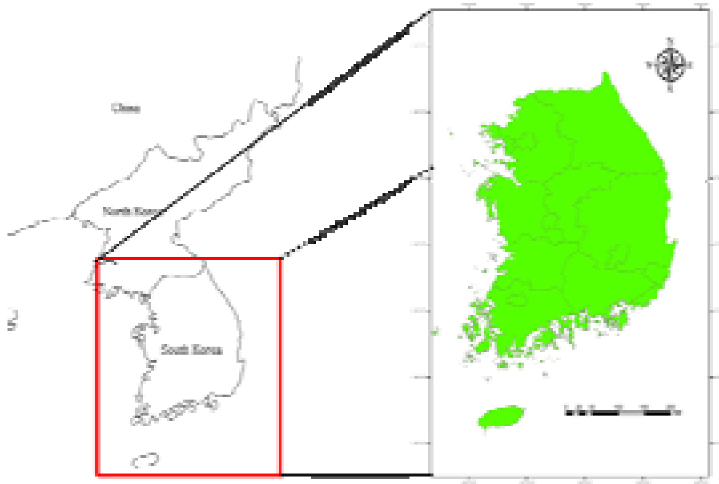


Fig 1. Study area

2.2 Method of vulnerability assessment

The vulnerability is defined as that a system cannot cope with the climatic variability under the extreme climatic exposure (Han et al, 2005). The vulnerability assessment was estimated by Eq. 1. It indicates that the vulnerability is dependent on the sensitivity, exposure and adaptability to climate change.

Vulnerability = (Sensitivity x Expose) / Adaptability ……………………………………..…… (Equation 1)

In vulnerability assessment, related indicators were normalized into the values ranged from 0 to 1 (UNDP., 2005).

2.3 Criteria and indicators of landslide vulnerability □

- Exposure

For the exposure criteria, we selected the significantly destructible areas, such as residential areas, industrial areas and business areas. It was assumed that the sudden evacuation of people due to landslide could have potential risks of deaths. Also, the bare ground from land cover map was selected as indicator of exposure, where the potential danger increases as severe climate change (Kim et al. 2005).

- Sensitivity

To assess the landslide sensitivity index, we employed the landslide hazard model which has been developed by the Korea Forest Research Institute. This model is an empirical model for landslide hazard assessment using only the forest type and topographic factors. It resulted in 4 classes of risk level using the related factors, i.e. the slope, slope distance, shapes of slope, soil depth, and type of bed rock and vegetation. At this point, the result was derived from the actual landslide area using the logistic regression analysis.

However, it is required to prepare the past and future climatic data for assessing the landslide vulnerability due to climate change. The past climatic data was achieved from the 74 climatic observatory of the Korea Meteorological Administration (KMA), and interpolated using the Inverse Distance Squared Weighting (IDSW) method (Lee et al. 2007). Also, the future climatic data was prepared by the National Institute of Meteorological Research using the MM5 coupling with ECHO-G/S under the Special Report on Emission Scenario (SRES) - A1B of IPCC. In this study, we plotted the map of precipitation distribution of the past (1971-2000), near future (2021-2050), and far future (2071-2100). Then, we employed the mean accumulated precipitation of the summer season (July to September) as the sensitivity index, based on the Korean climatic characteristics that most severe rain storms occur.

- Adaptability

We assumed that in high forest density areas, the tree roots effectively prevent the landslide by holding and stabilizing the soil structure. Therefore, in this study, the forest density was employed as an indicator for adaptability. The index of landslide adaptability has been analyzed with forest density from the forest type map. The density information of forest type was categorical data. So it should be converted to numerical data. We defined non-forest area as 0, low density area as 1, mid-density area as 2, and high density area as 3. Finally, forest density information has the value of 0, 0.3, 0.6 and 1 as the result of normalization.

Table 1. Criteria and indicators of landslide vulnerability

Criteria	Indicators
Sensitivity	Scoring system of landslide hazard model, Summer precipitation
Exposure	Residential area, Manufacturing area, Business area. Traffic area, Recreational facilities. Mining area, Bare ground.
adaptability	Forest density

3. REULTS

3.1 Exposure indicators

The residential areas and roads were mainly distributed in metropolitan cities, and the bare grounds were irregularly distributed in the mountain regions (Fig. 2).

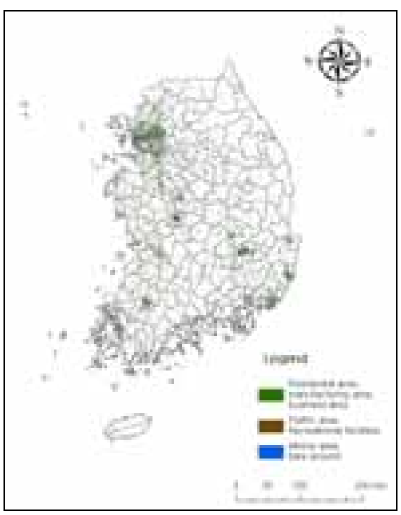


Fig 2. Land cover map exposure

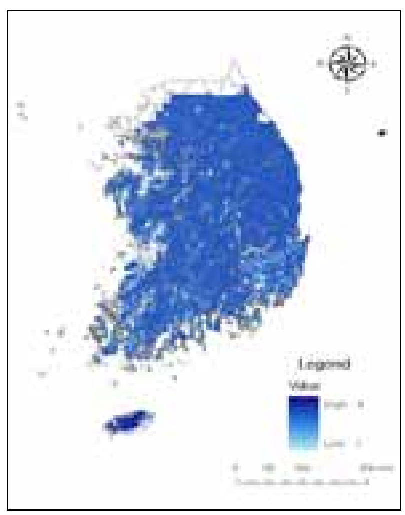
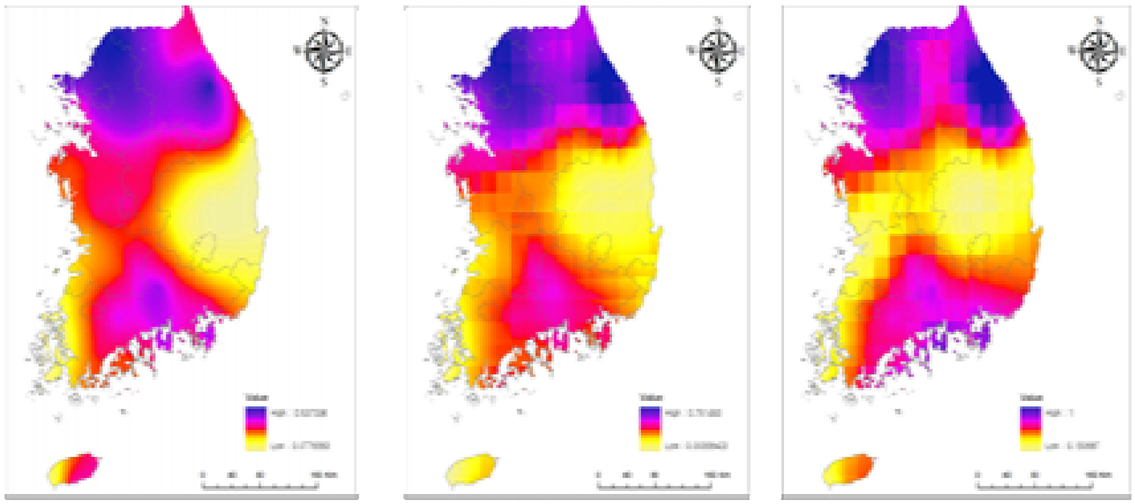


Fig 3. Landslide hazard map

3.2 Sensitivity Indicators

The landslide hazard map was derived from the Scoring System of Landslide Hazard Model. According to the result of landslide risk assessment, the high landslide risk areas were distributed in Gangwon province, Jeju Island, and Ulleung Island (Fig.3). As results of the estimation estimating the mean accumulated precipitation distributions in summer (July ~ September), the high precipitation area was distributed in Gangwon, Gyeoggi, Jeolla-nam and Gyeongsang-nam province. Also, in the future, the localized torrential downpours were increased in above region (Fig. 4).



(a) Past mean accumulated precipitation of summer (July ~ September, 1971~2000).

(b) Future mean accumulated precipitation of summer(July ~ September, 2021~2050).

(c) Future mean accumulated precipitation of summer(July ~ September, 2071~2100).

Fig 4. Precipitation distribution

3.3 Adaptability indicators

Generally, the areas of high forest tree density were distributed in high elevation areas (Fig.5).

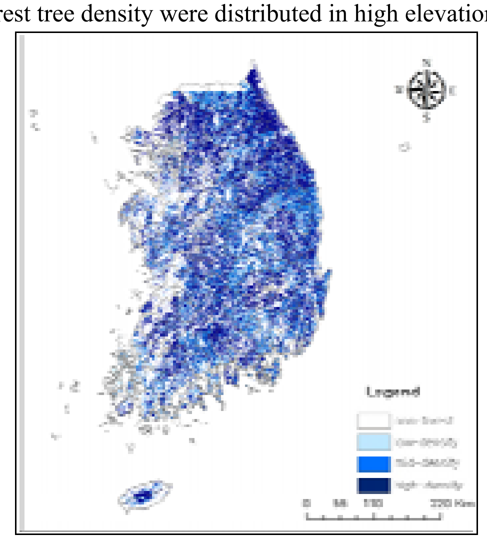
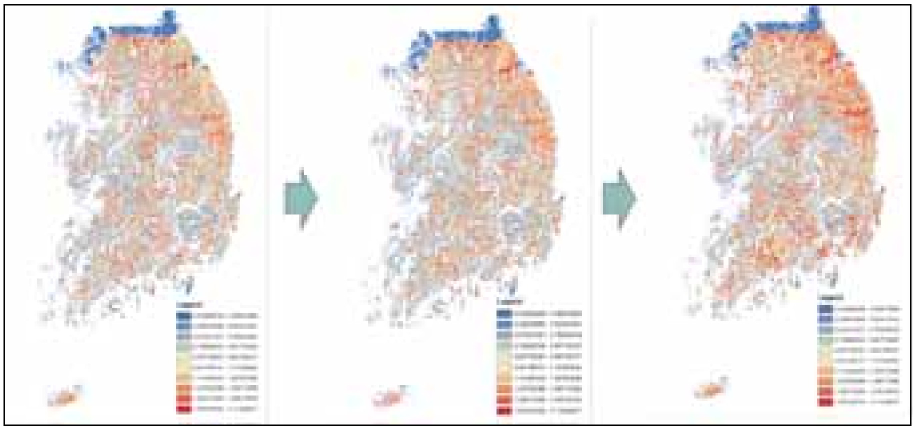


Fig 5. Map of forest density

3.4 Landslide vulnerability to climate change.

The maps of landslide vulnerability were derived using the related indicators, such as sensitivity, exposure, and adaptation. According to the result of landslide vulnerability map, highly vulnerable areas in landslide were regularly distributed throughout the South Korea, whereas relatively lower vulnerable areas were distributed in the western part of Korea as well as the urbanized area. Due to the security issue in the Demilitarized Zone and few parts of Gangreng city, it was difficult to achieve the topography data for vulnerability assessment.



(a) Current landslide vulnerability assessment map (1971~2000)

(b) Near future landslide vulnerability assessment map (2010~2050)

(c) Far future landslide vulnerability assessment map (2071~2100)

Fig 6. Landslide vulnerability assessment map

4. DISCUSSIONS

In this research, we assessed the current and future vulnerability of landslide to climate change. In vulnerability assessment, we prepared future climatic data based on historical precipitation data, and employed the spatial indicators for the criteria of exposure, sensitivity, and adaptation. Finally, we suggested the map of landslide vulnerability by integrating criteria and above indicators. It has showed that the high vulnerability area was distributed in mountainous area, such as Gangwon and Gyeongsang province and mountainous regions in Jeju Island. In the future, the landslide vulnerability will increase, because localized torrential downpours will increase in the future. Therefore, we need to prepare the countermeasure for the landslide vulnerability. However, landslide vulnerability assessment around the demilitarized zone has showed irregular results due to the absence of topography map. Also, in this research, only the future precipitation data for the future vulnerability assessment was employed. In further research, it will achieve more accurate results from the improved vulnerability assessment, if we employ the future population change model and climatic model.

5. REFERENCES

Kwon, W.T., Koo, G.S., Boo, K.O. Progresses of climate change sciences in IPCC assessment reports. Journal of the Korean Meteorological Society, Vol.17, No.4, pp. 483-492, 2007.

Koo, H.B., Koo, J.D. Landslide data base system using GIS technology. The journal of GIS Association of Korea, Vol.3, No.1, pp. 81-90. 1995.

Lee, M.A., Lee, W.K., Song, C.C., Lee, J.K., Choi, H.A., Kim, T.M. Spatio-temporal change prediction and variability of temperature and precipitation. The journal of GIS Association of Korea, Vol.15, No.3, pp. 1-12, 2007.

Choi, S.H., Lee, W.K., Kwak, H.B., Kim, S.R. Predicting the vegetation distribution and terrestrial carbon-fluxes using MC1 model. ESRI User Conference Proceeding, 2009.

Han H.J et al. Climate Change Impact Assessment and Development of Adaptation Strategies in Korea. Vol.-No.RE-01, 2007.

Lee, D.K., Kim, J.U. Vulnerability assessment of sub-alpine vegetations by climate change in Korea. Journal of the Korea society for environmental restoration and revegetation technology, Vol.10, No.6, pp. 110-119, 2007.

Kim, K.T., Jung, S.G., Park, K.H., Oh, J.H. Evaluation of landslide susceptibility using GIS and RS. Journal of the Korean Association of Geographic Information Studies, Vol.8, No.1, pp. 75-87, 2005.

Yang, Y.T., Park, J.K., Jeon, W.H., An assessment for effect of landslide on maximum continuous rainfall using GIS. The Korean Society for Geo-Spatial Information System. Vol. 2007, No.0, pp. 413-423.2007.

National Institute for Disaster Prevention. Preliminary study for investigating slope stability and relieving damage. pp. 233. 1998.

IPCC. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK, pp. 976. 2007.

UNDP. Adaptation policy frameworks for climate change: Developing strategies, policies, and measures. Cambridge University Press. USA. 2005.