Mapping Terrain/Slope Stability for Disaster Prevention Using Parameterized GIS Datasets

[1]Kon Joon Bhang, [1]Gyung-Up Lee, [2]Chang Hwan Kim, [1]*Jin-Duk Lee

[1]School of Civil & Environmental Engineering, Kumoh National Institute of Technology, Korea
[2]Department of Geography Education, Kangwon National University, Korea

ABSTRACT

Landslide risk mapping has been frequently conducted for a long time and especially landslide has been a critical issue in the current extreme weather. The causes of landslide are slope, geologic features, soil characteristics, rainfall, etc. and the rainfall event has accepted as a main cause of landslide. Due to the complex mechanism of landslide, however, the causes cannot be formulated to define the exact effect of the slope stability and there are many exceptions following the cases of landslide studies. Therefore, the causes of landslide need to be parameterized to analyze different conditions and circumstances of landslide event. Using GIS, basic spatial datasets were established such as surface slope, effective depth of soil, drainage, angle of shear resistance, angle of internal friction, density of trees and forest physiognomy and level and weight was evaluated based on other similar studies. Using a linear function parameterized with the datasets, possible landslide zones were marked by rank. The resulting map indicated that landslides recently occurred was ranked as top and addition risk of landslide was portrayed. This method showed the flexibility to easily add additional datasets and modify analysis algorithms for better result.

Keywords : landslide, slope stability, GIS, parameterized dataset

1. Introduction

Disaster caused by landslide is occurring typically during severe rainfall events and the frequency is getting increased in current extreme weather condition in Korea. Korea is a hummocky area covering almost 65% of the land surface with mountains so severe rainfall events frequently cause landslide damaging neighboring residents and their property. The average number and size of landslide events for last ten years radically increased from 2000 and they were three times greater comparing to 1980s. Therefore, estimating or evaluating the existing slope surface is one of the current pivotal missions to reduce the disasters by landslide.

The techniques for detecting possible landslide areas can be divided into three categories, empirical, statistical, and engineering analyses. We merged them in a GIS to determine the level and weight of importance for each factors of surface slope, effective depth of soil, drainage, angle of shear resistance, angle of internal friction, density of trees and forest physiognomy and analyzed to map possible landslide areas.

Kumoh National Institute of Technology (KIT),
School of Civil and Environment Engineering, 61 Daehak-ro, Yangho-dong, Gumi-si, Gyungbuk, Korea.
+82-54-478-7619(Tel) bhang.1@kumoh.ac.kr

2. Analytic factors for landslide area detection

Factors affecting landslide are strongly related to rainfall event (Song et al., 2005; Kim and Chae, 2009; Seo and Han, 2003). This means that the soil characteristics like pore and saturation is highly correlated with landslide. Many researches (Kim et al., 1998; Lee et al, 2002; Ma and Jeong, 2007; Park et al., 2010; Kim et al., 2012) broke down the causes and we used seven factors most frequently used. The factors causing landslide are surface slope, effective depth of soil, drainage, angle of shear resistance, angle of internal friction, density of trees and forest physiognomy.

It is known that the steeper the slope, the higher the possibility of landslide. However, many researched reported that it is not commonly applicable and rather mid-range of slope has higher possibility to be destroyed. Kim et al. (2006) showed that 82.7% of landslide occurred at 26-30° and 31-35° so we ranked the weight of landslide possibility as Table 1.

TABLE 1. Weight corresponding to angle of slope

Angle of slope	Level	Weight
< 20°	5	1
20° – 25°	4	2
25° – 30°	3	4
30° – 35°	2	5
35° – 40°	1	6
40° <	4	2

Weights of soil properties such as angle of shear resistance, angle of internal friction depending on soil ingredients are determined as Table 2. Kim et al. (2005) reported that soil with sand has high possibility of landslide because the pore in soil can be easily saturated in a very short time so that the soil loose its internal friction and shear resistance. Even sandy soil with gravel and rock was found to be worst in this sense (Kim et al., 2011).

TABLE 2. Weights for angles of shear resistance and internal friction

Soil	Angle of Shear resistance	Weight	Angle of internal friction	Weight
Gravel	35 - 40	8	32 – 40	8
Sand w/ gravel	35 – 40	8	32 – 40	8
Sand	25 – 35	4	29 – 35	4
Clay	< 25	2	27 - 33	2

Weights for effective soil depth and drainage are shown in Table 3 and 4. The typical depth of landslide is usually within 20cm. Deeper depth of landslide occurs but it rare in Korea.

TABLE 3. Weights for effective soil depth

Depth	Weight
0 – 20	10
20 – 50	6
50 – 100	3
100 <	1

Drainage might be the most important factor in landslide because water in soil significantly changes the characteristics of soil and especially for seepage water. This is strongly related to severe rainfall event but we excluded the rainfall because drainage and rainfall are embracing each other in characteristics. In this study, we divided soil characteristics into five categories by mixture of soil particles and weighted them as Table 4.

TABLE 4. Weights for drainage

Drainage	Weight
Very poor, water level < 50cm	9
Poor, water level 50 – 100cm	7
Moderate, water level ≅ 100cm	5
Good, water level 100 – 150cm	3
Very good, water level ≅ 150cm	1

Density of trees and forest physiognomy are used as is the factors presented above as well and they are shown in Figure 1. The range of weights for factors is basically marked from 1 to 10.

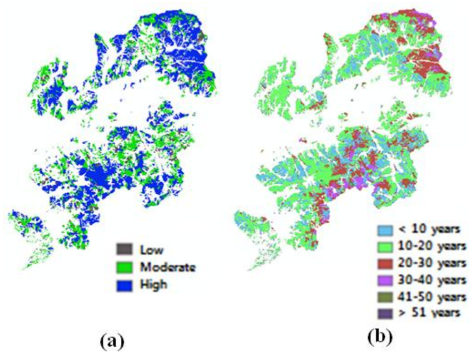

FIGURE 1 GIS dataset for (a) density of trees and (b) forest physiognomy

These weights of the factors were analyzed using a simple linear polynomial function ($y = \alpha a + \beta b + \ldots$ where the Greek alphabets are weighed coefficients and Romans are factors causing landslide). We are currently testing the functions by varying the coefficients of polynomials depending on the importance of each factor but introduced the simplest and the most plausible result herein. The simplest polynomial has coefficients of 1 for all of the factors.

3. Slope stability and landslide risk map

Using the simplest polynomial with coefficients of one, the result map (Figure 1) showed the weight or possibility of landslide for Daegu, Korea. Dark green has the least possibility of landslide and redish colors means higher possibility. This map was compared with the actual events of landslide occurred to check reliability and showed many areas on the map already experienced landslide events, for example, 1) Donggu Nungsungdong Daehanli on September 12, 2003, 2) Bukgu Taejundong in August 19, 2004, 3) and 4) Dalsunggun Okpomyun on July 9 and 10, 2006, etc. All landslide events were not indicated in the map but we made sure that current method could reduce a good result and the rest (red colors) have highly probable areas of landslide, that is, still there are many possibility of landslide in the Daegu area.

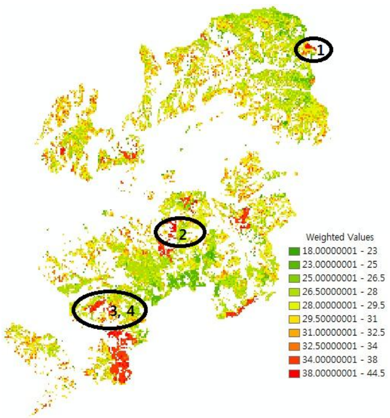

FIGURE 2. Red areas are most probable areas of landslide detected by this study

4. Conclusion

We discussed a mapping technique using a linear function with seven parameters. The function coefficients should be properly evaluated and determined for better result but we used simplest coefficients and the result is competent. However, more parameters should be added for more reliable result. The reliability depends on how and what parameters and coefficient are determined.

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