Determining the most efficient method for applying precipitation data to slope stability studies in Korea

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Introduction

GIS technique and Bayesian methods have been intensely applied for slope stability studies. These approaches considers input parameters such as stratigraphy, structural geology, petrology, geomorphology, earthquake, precipitation, and mechanical properties of rocks and soil. Among these parameters, precipitation is one of the most critical factors that may trigger landslide (2). Precipitation is a temporal and spatial parameter. Therefore, a variety of methods should be tested to find which will be the most efficient method for generating precipitation maps and its influence on slope failure for slope stability studies. This study attempts to verify the most affective compiling method for the temporal precipitation data for the slope stability analyses of constructed slopes in Korea.

Methodology

There are two type of database used in this study. Constructed slope data used in this study was taken from Korea Highway Corporation collected from 1991 to 2002. This constructed slope database does not show the exact date of individual slope failure occurrences, the failure is assumed to occur between 1990 and 2002. Precipitation database, however, was taken from Pluviometrical data of 71 Korean stations for the analysis. From the whole precipitation database, 1990 to 2002 data were extracted to fit the constructed slope database. In order to generate series of precipitation maps, for each observation station, the following data can be generated and calculated: Annual (P), average July (P7), average August (P8), Average July to August (P78), average June to September (P69) (1), cumulative rainfall event (Cu) (5), Maximum day (maxday), the Precipitation coefficient (PCn).

The PCn can be calculated by following formula:

$PCn = \sum_{i=1}^{n} 0.9^{n-i} H_i$ where: *Hi*: rainfall amount for the *ith* day *n* is size of selected temporal window.

Fournier (F) and two modified Fournier methods, MFIavg, MFI, are calculated by:

$F = \frac{1}{n}\sum_{i=1}^{n}\frac{\left(p_{\max_i}\right)^2}{p_i}$ where, *pmaxi* is rainfall among of the wettest month for the *ith* year *Pi* is average annual precipitation for the *i*th year and *n* is

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the number of years.

$$MFI_{avg} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{12} p_j^{\,2}}{P_i}\right)$$

where, *pj* is rainfall among in the *jth* month of the *ith* year

$$MFI = \frac{\sum_{i=1}^{12} \overline{p}_i^{\,2}}{\overline{P}}$$

where, $\overline{P}_i$ is the mean value of monthly precipitation for the whole period $\overline{P}$ is the mean value of annual precipitation for the whole period

Season precipitation concentration index (PCI) and temporal season precipitation concentration index (PCIavg) can be generated by following relationship:

$$PCI = \frac{\sum_{i=1}^{12} \overline{p}_i^{\,2}}{\overline{P^2}}$$

where, $\overline{P}_i$is the mean value of monthly precipitation for the whole period and $\overline{P}$is the mean value of annual precipitation for the whole period

$$PCI_{avg} = \frac{100}{n}\sum_{i}^{n}\left(\frac{\sum_{j=1}^{12} p_j^{\,2}}{P_i^2}\right)$$

where, *pj* is rainfall among in the *jth* month of the *ith* year *Pi* is the average annual precipitation for the *ith* year and *n* is the number of years.

Moreover, the Season index (4) is generated by following formula:

$$Si = \frac{(s-w)}{s+w}$$

where, *s* is average rainfall for summer (half of the year) and *w* is the average rainfall for winter (the other half of the year).

The interpolation method in Arcview components were applied to generate (failed, unfailed, total and normalize failed) slope intensity maps for constructed slope database and precipitation indices.

A correlation coefficient were carried out for all precipitation indices with respect to the spatial intensity of failed and unfailed slope locations. The intensities are considered in different points of view, and these include simple distribution of all slopes in database, of unfailed slopes, of failed slopes. To normalize the density of slopes in database, normalize failed slope map is constructed by dividing the map pixels of failed slopes to that of total slopes.

Results

In Figure 1, four precipitation indices, namely P7, P78, Cu and SI show high correlation (R) with slope failure intensity, 0.21, 0.21, 0.12, and 0.15, respectively. It also shows the relationship between precipitation indices maps and three slope intensity maps (failed, unfailed and total slope intensity) is of similar trend and mostly are positively correlated. However, the normalize failed slope method, the trend is significantly different from the other three. Also, the correlation coefficients given by the normalized method are all negative except precipitation coefficient (PCn) index.

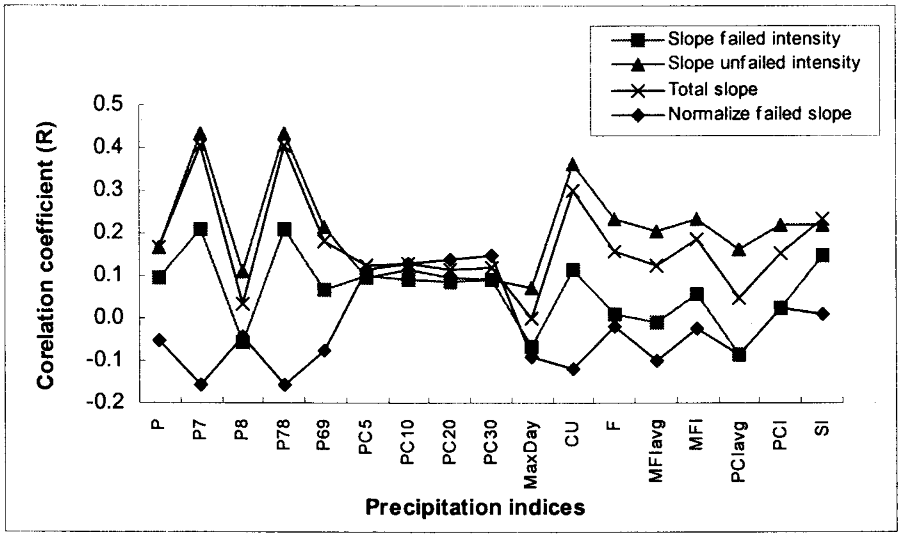

Figure 1. *Correlation coefficient of slope intensity maps with precipitation indices*

Extracting PCn from the normalized method, as shown in Figure 3, the trend shows an increase in R from 0.11 to 0.15 as size of temporal window of the precipitation data is increased from five to thirty days.

Discussion and Conclusion

The correlation given by P7, P78 and SI are showing direct relationship between slope failures and rainfall season (Figure 2). Furthermore, the high correlation of Cu with slope intensity shows the effect of long rainfall event or typhoon to slope instability. These results confirm that most of the failure occurs during the rainy season which is July to September (3).

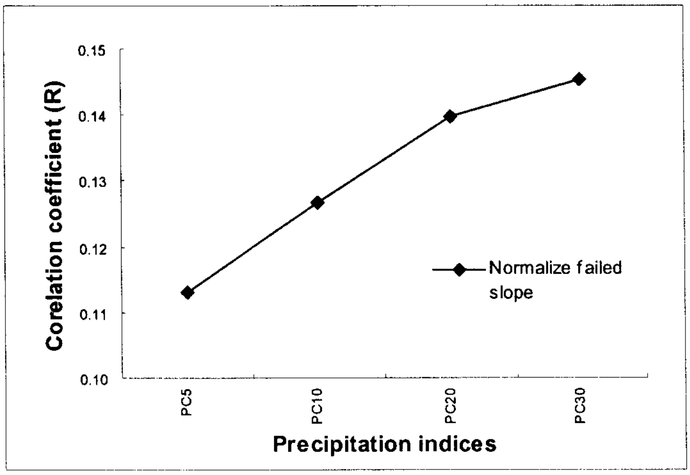

Figure 2. *The increase R between PCn and normalize failed slope intensity when expanded the size of temporal window*

Among all the considered methods, P7, P78, Cu and SI tend to be more reliable, if correlation coefficients are considered alone. However, simple statistics of the total trends of failed and unfailed slope maps do not incorporate the density of slopes in database. Thus, it may not as effect data map as the normalize failed slope map. In normalize failed slope map correlations, the PCn method tend to show significantly higher correlation to the precipitation. Therefore, we conclude that, the PCn tend to be the most favorable data for the GIS based statistical analyses of the slope stability studies. It not only has high relationship with the normalized map, but also it presents the real physical system by increasing the correlation when the size of temporal window is expanded from 5, 10, 20, to 30 days.

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