Automatic Extraction of Slope Parameters from DEM for Seismic Topographic Amplification Study

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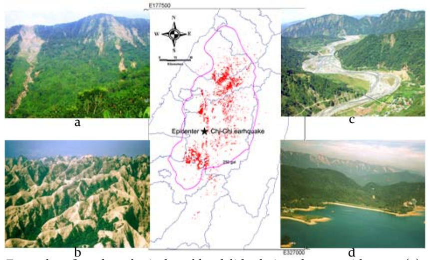
SUMMARY

Factors which may be possibly related to topographic amplification include lithology, geologic structure, topographic gradient, aspect, roughness, curvature, slope-height, relative-slope-height, and height-relative-to-riverbed. It has been found that height-relative-to-riverbed is a good factor to interpret the distribution of earthquake-induced landslides in previous study (Lee et al., 2008). The relative-slope-height is also an important factor controlling seismic slope failure (Lee and Wang, 2008).

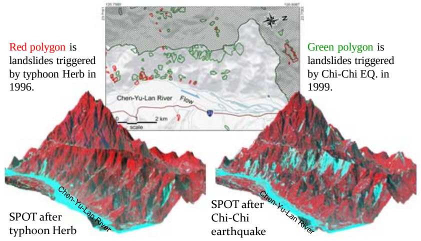
This presentation discusses a stable algorithm for automatic extraction of slope parameters from digital elevation model (DEM); mainly for slope-height, relative-slope-height, and height-relative-to-riverbed. The algorithm for calculation of slope gradient, aspect, roughness, and curvatures has been introduced in many previous studies and software for these is popular in the market, these factors are not discussed in the present study. The computer codes will be opened to our society for free application after the present paper has been published. Example from Kuohsing site is selected for demonstration of this study.

Field Observations



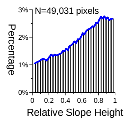
Examples of earthquake-induced landslides being closer to ridge top. (a) Tahengping ridge, and (b) Gio-Gio peaks in Kuohsing quadrangle, (c) Takeshan ridge, north of, and (d) Dongpinglun ridge, south of Kuohsing quadrangle.

Observations from Landslide Inventories

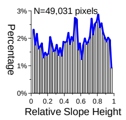


Examples at the ChenYuLan River show that typhoon-induced landslides are closer to river side, whereas earthquake-induced landslides are closer to ridge top.

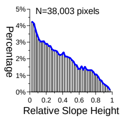
Statistics from Landslide Inventories



Landslides triggered by the Chi-Chi **earthquake** in Kuohsing quadrangle.



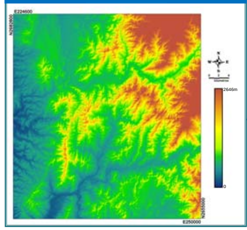
Landslides triggered by the **typhoon** Herb in Kuohsing quadrangle.



Landslides triggered by the **typhoon** Aere in the catchment area of the Shihmen Reservoir.

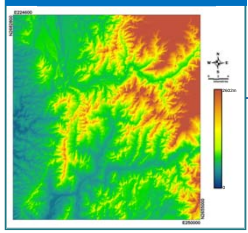
DATA

DEM



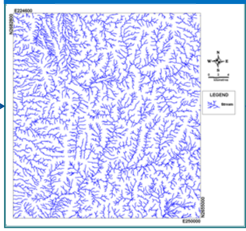
Grid DEM of 20x20m, original.

SMOOTH DEM



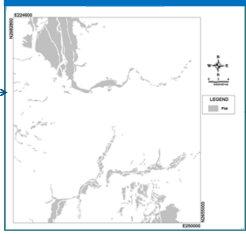
Grid DEM of 20x20m, 3x3 smoothing for 10 times.

DRAINAGE



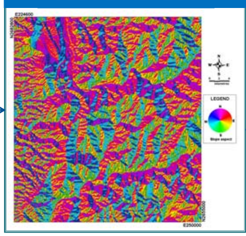
Drainage system calculated from original DEM, using 5 ha. threshold.

FLAT



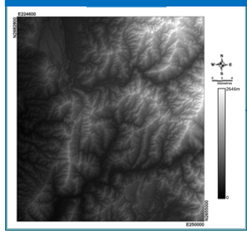
Flat areas of slope less than 10% are calculated from original DEM.

SLOPE ASPECT



Slope aspects are calculated from smooth DEM.

DEM



Grid DEM of 20x20m, original.

APPLICATIONS

1. Topographic Amplification Study

Slope height, total slope height, relative slope height, etc. are used in statistical analysis of topographic amplification using Taiwan dataset (Lee and Wang, 2008).

2. Empirical Formula for Topographic Amplification

The empirical formula proposed by Lin and Lee (2003):

$$I_a' = f I_a , \quad (1)$$

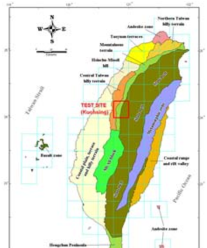
$$f = \sqrt{h / 93.8 + 0.287} + 0.464 , \quad (2)$$

where I_a is the Arias Intensity; I_a' is the corrected Arias Intensity; f is the amplification factor; and h is the height relative to riverbed in meters.

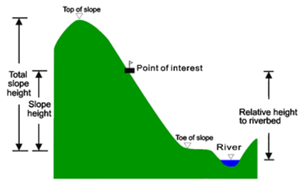
3. Causative Factors for Landslide Susceptibility Analysis

Slope height, total slope height, relative slope height, etc. are used in statistical analysis of earthquake-induced landslide susceptibility (Lee et al., 2008a) and storm-induced landslide susceptibility (Lee et al., 2008b).

PROCESSION



Index map



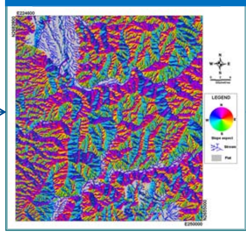
Definition of Slope Height

Slope Height = Presnet Elevation - Toe Elevation

Total Slope Height = Top Elevation - Toe Elevation

Relative Slope Height = Slope Height / Total Slope Height

CONTROL DATA



Slope aspect, flat areas, and drainage stream.

PROGRAM SLOPEH

Purpose: Calculation of **slope height, total slope height,** and **relative height** for every grid point.

Method: Find top elevation and toe elevation along a profile in slope direction. Flat area and stream assist in determination of toe and riverbed.

Input: original DEM.grd, control.grd.

Output: slopeheight.grd, total height.grd, relativeheight.grd.

*grd is Surfer binary grid file.

Height relative to riverbed needs special treatment. Because stream gradient is much steeper for tributary than for main stream, and if our purpose is for studying seismic topographic amplification, than we need to consider relative height to main stream. Right figure is an example for correct selection and incorrect selection of reference point on riverbed.

The last row below is showing the flow chart to find **Height relative to riverbed** for each grid point in the study area.

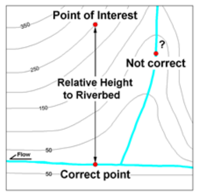
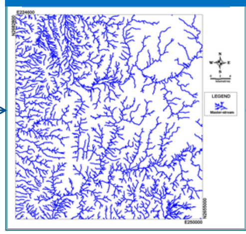


Figure showing correct and incorrect selection of a reference point in the riverbed.

MASTER STREAM



Master stream reduced from the drainage system. Stream gradient larger than 15 degrees are deleted.

PROGRAM HIGH2B

Purpose: Calculation of **height relative to riverbed** for every grid point.

Method: Find nearest point to master stream along the flow path.

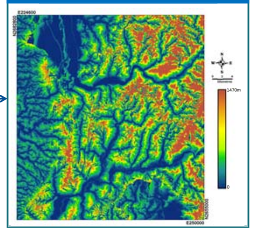
Input: original DEM.grd, flowpath.vec, masterstream.mif.

Output: HIGH2B.grd.

*grd is Surfer binary grid file.
*mif is MapInfo interchange file.
*vec is binary file output from DRAIN program.

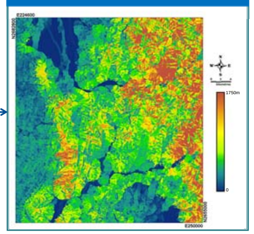
OUTPUT

SLOPE HEIGHT



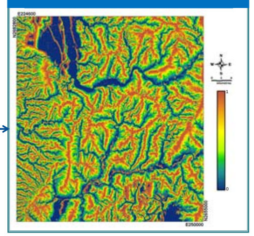
20x20m grid file in grd format.

TOTAL SLOPE HEIGHT



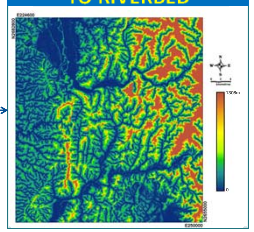
20x20m grid file in grd format.

RELATIVE HEIGHT



20x20m grid file in grd format.

HEIGHT RELATIVE TO RIVERBED



20x20m grid file in grd format.