Rainfall Induced Landslide Hazard Analysis of Shimen Catchment Area

Twin Hosea
Advisor: Prof. Chyi-Tyi Lee
2018 November 22
1. INTRODUCTION
2. STUDY AREA
3. METHODS
4. PRELIMINARY RESULTS
5. FUTURE WORKS
1. INTRODUCTION
Landslide is one of the natural disasters causing significant damages to lives and properties.

Dilley, 2005
1. INTRODUCTION

- AFFECTING FACTORS

- Geology
- Geotechnics
- Topography
- Environment

Suzen and Kaya, 2011
# 1. INTRODUCTION

- **LANDSLIDE AFFECTING FACTORS**

<table>
<thead>
<tr>
<th>Grouping type</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Anthropogenic parameters</td>
</tr>
<tr>
<td></td>
<td>Position within catchment</td>
</tr>
<tr>
<td></td>
<td>Rainfall</td>
</tr>
<tr>
<td></td>
<td>Land use/land cover</td>
</tr>
<tr>
<td>Geotechnical</td>
<td>Soil texture</td>
</tr>
<tr>
<td></td>
<td>Soil thickness</td>
</tr>
<tr>
<td></td>
<td>Other geotechnical parameters</td>
</tr>
</tbody>
</table>

- **Topographical**
  - Drainage
  - Surface roughness
  - Topographic indices
  - Elevation
  - Slope aspect
  - Slope length
  - Slope angle
  - Slope curvature

- **Geological**
  - Strata-slope interaction
  - Lineaments/faults
  - Geology/lithology

Suzen and Kaya, 2011
1. INTRODUCTION

- TRIGGERING EVENTS

Earthquake

Flooding

Strom/Typhoon

Marano et al., 2010
1. INTRODUCTION

- Landslide Inventory Map

  - Past and current landslide occurrence.

  - Produced by:
    - Comprehensive paper datasheets.
    - Detailed geomorphological maps.
    - Processing and analysis of remotely sensed digital imagery and DEM.

  Analysis in different time periods

  Multi-temporal landslide inventories

Gringnon et al., 2004,
Hervas and Bobrowski, 2009
1. INTRODUCTION

- Event Based Landslide Inventory Map

Distribution of landslides triggered by a Typhoon Herb in 1996 and b the Chi-Chi earthquake in 1999, (Chang et al, 2007)
1. INTRODUCTION

- Landslide Susceptibility Map

  - Landslide susceptibility refers to the PROPENSITY of an area to landslide occurrence.
  - The probability of occurrence of landslides of a particular type in a given location.
  - Simply classifies a region into several classes with different potential of landsliding.

Landslide Susceptibility Map

- Landslide Inventory
- Conditioning Factors

Hervas and Bobrowski, 2009
Pradhan and Abdulwahid, 2017
Landslide Hazard Assessment (LHA) is usually stated as the **landslide probability** at a *specified period of time and given area* (Varnes, 1984; VanWesten et al., 2006).

*Landslides are secondary or induced features*, whose recurrence is controlled by the repetition of triggering events.

Thus, LHA may be separated into at least two stages: **Spatial Probability Stage** and **Temporal Probability Stage** (Lee, 2015).
1. INTRODUCTION

- Landslide Hazard Map

  - *Landslide hazard* refers to the probability of occurrence of landslides of a particular type and magnitude in a given location within a reference period of time.

  Hervas and Bobrowski, 2009

  Pradhan and Abdulwahid, 2017
1. INTRODUCTION

Recent Approach

- Deterministic Approach
  (Iverson, 2000; Claessens et al., 2007)

- Probabilistic Approach
  (Guzzetti et al., 2005)

- Statistical Approach
  (Lee et al., 2008)

Landslide Hazard Assessment
## 1. INTRODUCTION

Which one is more appropriate?

<table>
<thead>
<tr>
<th>Approach</th>
<th>Landslide Inventory</th>
<th>Advantage</th>
<th>Dis-advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic</td>
<td>Event-Based</td>
<td>Theoretically perfect</td>
<td>• Difficulty to collect engineering properties in region scale (practically doubtful)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Shallow landslide only</td>
</tr>
<tr>
<td>Probability</td>
<td>Multi Temporal</td>
<td>• Clear and simple in methodology</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not restricted to shallow landslide</td>
<td>• Long-period landslide inventory is not easy to be collected.</td>
</tr>
<tr>
<td>Statistical</td>
<td>Multi Temporal Event Based</td>
<td>Event-based landslide inventory is enough</td>
<td>• Shallow landslide only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Landslide magnitude and run out could not be determined yet</td>
</tr>
</tbody>
</table>

*(Lee, 2015)*
1. INTRODUCTION

➢ Objectives

1. Build event-based landslide susceptibility map of the area
2. Define the relationship between the probability of landslide failure and a triggering factor of a certain event.
3. Build Landslide Hazard Map under a certain return-period rainfall.
2. STUDY AREA
2. STUDY AREA

➢ The Shihmen watershed straddles Taoyuan, Hsinchu, and Yilan counties
➢ The reservoir is mainly fed by the Dahan River.
➢ This watershed has an area of approximately 760 km², and the Shihmen Reservoir is the third largest reservoir in Taiwan and one of the main water sources for northern Taiwan.
2. STUDY AREA

➢ Rocks are composed of folded and faulted Miocene and Paleogene indurate sandstone and mudrocks (Fig. 1).
➢ Terraces on the river sides are composed of sandy gravels and they may be covered by lateritic soils on high terraces.
➢ Nearly 90% of the study area is forested.

(Lee, 2014)
3. METHODS
3. METHODS

Selection of Effective Causative Factors

Selecting Triggering Events

Event-Based Landslide Inventory Map

Event-Dependent Landslide Susceptibility Model (Logistic Regression)

Extract the component of triggering factors

Event-Independent Landslide Susceptibility Model = Basic Susceptibility of the Region

Analyze the relationship between the probability of landslide failure and a triggering factor of a certain event.

Landslide Probability of Failure map under a certain return-period rainfalls = Landslide Hazard Map

(Lee, 2015)
3. METHODS

➢ Recent Studies in Statistical Approach

A. Selecting Causative factors

➢ Many different landslide-related factors commonly used for Landslide Susceptibility Assessment (Lin, 2003) but not all factors are effective.

➢ It is used 4 testing criteria for choosing the effective causative factors, they are:

(a) Frequency distribution curves, (b) P-P plot,
(c) Probability of failure curve, and (d) Success rate curve.
3. METHODS

Recent Studies in Statistical Approach

B. Basic Susceptibility of a Region

- Selecting Triggering Events
- Event-Based Landslide Inventory Map
- Selection of Effective Causative Factors

Event-Dependent Landslide Susceptibility Model

Extract the component of triggering factors

Event-Independent Landslide Susceptibility Model = Basic Susceptibility of the Region

(Lee, 2015)
3. METHODS

➢ Recent Studies in Statistical Approach

B. Basic Susceptibility of a Region

Basic susceptibility map at mountain terrain of the Choswei River catchment in Central Taiwan, (a) that from event-independent model of Typhoon Toraji event and (b) that from multi-temporal landslide inventory

(Lee, 2015)
C. Probability of Failure Surface

It was tested, in Kaoping River Basin, the relationship between the probability of failure and the rainfall intensity, as well as the total rainfall at each basic susceptibility bin.

\[ y = 26.815 \lambda (1 - e^{-3.758 \lambda^{0.760}} ) (1 - e^{-2.0175 \left( \frac{x_1}{100} \right)^{1.836}} ) , \quad [1] \]

\[ y = 32.357 \lambda (1 - e^{-3.843 \lambda^{0.768}} ) (1 - e^{-1.6835 \left( \frac{x_2}{2000} \right)^{2.445}} ) , \quad [2] \]
3. METHODS

➢ Recent Studies in Statistical Approach

B. Probability of Failure Surface

The relation is good; the probability of failure \(y\) increases with an increase in (max and total) rainfall and susceptibility

(Lee, 2015)
Recent Studies in Statistical Approach

3. METHODS

C. Probability of Failure Surface

- Analyze the relationship between the probability of landslide failure and the rainfall intensity

The probability of failure surface may be used to map and/or predict landslide spatial probability over the study region under a scenario rain event or return-period rainfall.

(Lee, 2015) 100-year rainfall landslide hazard map for Kaoping River basin
4. PRELIMINARY RESULTS
4. PRELIMINARY RESULTS

➢ Causative Factors

A. Slope

B. Slope Aspect
4. PRELIMINARY RESULTS

➢ Causative Factors

C. Lithology

D. Elevation
4. PRELIMINARY RESULTS

➢ Causative Factors

E. Terrain Roughness

F. Slope Roughness
4. PRELIMINARY RESULTS

➢ Causative Factors

G. Slope Height

H. Relative Slope Height
4. PRELIMINARY RESULTS

➢ Causative Factors

I. Top Slope Elevation

J. Total High
4. PRELIMINARY RESULTS

➢ Causative Factors

K. Profile Curvature

L. Plane Curvature
4. PRELIMINARY RESULTS

➢ Causative Factors

M. Tangential Curvature

N. Total Curvature

Tangential Curvature (rad/100m)

Value

High : 21.8274
Low : -12.9287

Total Curvature (log(rad/100m))

Value

High : -0.670148
Low : -20
4. PRELIMINARY RESULTS

➢ Triggering Factors

A. Aere Max Rainfall

B. Aere Total Rainfall
4. PRELIMINARY RESULTS

➢ Triggering Factors

A. Nari Max Rainfall

Max Rainfall (mm)
NAR_Max
Value
High : 106.249
Low : 29.0406

B. Nari Total Rainfall

Tot Rainfall (mm)
nar_tot
Value
High : 1427.32
Low : 389.481
5. FUTURE WORKS
5. Future Works

➢ Finish the causative factor of Shimen Catchment Area
➢ Choose more triggering events in the research area (± 10)
➢ Build the event-based landslide inventory data.
➢ Build the basic landslide susceptibility of the area.
➢ Find the relationship of the probability of failure and the triggering factor (rainfall event).
➢ Make landslide hazard map
Thank You
Fig. 3. Schematic map showing the definition of factors. (A) elevation of crest, (B) horizontal distance to drainage, (C) height relative to riverbed, (D) elevation of toe, (E) total slope height, (F) height relative to crest, (G) height relative to toe, (H) horizontal distance to crest, (I) horizontal distance to toe, (J) horizontal distance between crest and toe, (K) slope length.
**Curvature**

The **Profile curvature** is parallel to the slope and indicates the direction of maximum slope. A negative value (A) indicates that the surface is upwardly convex at that cell, and flow will be decelerated. The profile curvature affects the acceleration and deceleration of flow and, therefore, influences erosion and deposition.

The **Planform curvature** (commonly called plan curvature) is perpendicular to the direction of the maximum slope. Planform curvature relates to the convergence and divergence of flow across a surface. A positive value (A) indicates the surface is laterally convex at that cell.

Curvature

The total curvature generates both profile and planform curvatures.