Optimizing the Relative Contribution of Preparatory and Triggering Factors in Landslide Analysis System with an Eight-year Landslide Inventory - Validation with typhoon events and operation with real-time precipitation -

Cheng-Chien LIU,[1,2,*] Mei-Chen CHEN,[3] Yi-Ting LIN,[2] Sheng-Feng ZENG,[3] Hui-Lin WEN,[2] Hsiao-Yuan YIN,[3] En-Ju LIN,[1] and Nguyen Thi To NGAN[1]

[1] Department of Earth Sciences, National Cheng-Kung University, Taiwan

[2] Global Earth Observation and Data Analysis Center, National Cheng-Kung University, Taiwan

[3] Debris Flow Disaster Prevention Center, Soil and Water Conservation Bureau, Council of Agriculture, Taiwan

[*]Corresponding author. E-mail: ccliu88@mail.ncku.edu.tw

INTRODUCTION

Taiwan is the place on Earth most vulnerable to natural hazards. According to a recent survey funded by World Bank, more than 90 percent of Taiwan′s populations live in areas at high relative risk of death from earthquake, typhoon and slope hazards. This research aims at developing a landslide hazard model for monitoring slope hazards triggered by typhoon or extreme weather events. To meet the requirements of operational service, a total of six strategies are developed and employed in the Landslide Analysis System (LAS), as summarized as follows:

LANDSLIDE ANALYSIS SYSTEM

1. Preparing a long-term and detailed inventory of landslide for entire Taiwan area.
   Formosat-2 launched on May 21, 2004 has a unique orbit configuration to enable high spatial resolution imagery acquisition on a daily basis. Formosat-2 has been acquiring more than 25 million km^2 images of Taiwan area available for 2m in panchromatic and 8m in multispectral with swath of 24 km. We integrate all useful spatial information to prepare an eight-year inventory of landslide for entire Taiwan area in a quick and accurate fashion.
2. Evaluating and selecting various preparatory factors of landslide.
   With this long-term and detailed inventory of landslide for Taiwan area, we are able to evaluate each preparatory factor by relating its values with the occurrence of landslides for the past eight years. The results show that the slope, aspect and geological composition are the most important factors that should be considered.
3. Introducing a new preparatory factor of Total Flux.
   Almost all preparatory factors proposed and employed by various researchers in the past are pixel-based properties, which can only represent the characteristics of that particular pixel. The occurrence of landslide at one pixel, however, would be effected by the properties of other pixels surrounding that particular pixel as well, for example, the runoff contributed from the adjacent pixels. To address this kind of contiguous effect, we introduce a new preparatory factor of Total Flux that quantitatively specifies the amount of runoff based on the topographical variation.
4. Optimizing the relative contribution of various preparatory factors.
   With all preparatory factors available, the general approach to evaluate the susceptibility of landslide is to calculate the geometric or arithmetic means of all preparatory factors, under

the assumption that all preparatory factors are equal weighted. The expert grading method is another way to specify the weighting value for each individual factor, which however, is inevitably biased by the subjective grading system of different expert. Since the long-term and detailed inventory of landslide for Taiwan area is available, we are able to employ various techniques of non-linear optimization to derive the optimized weight for each factor, as well as to determine the relationship among these factors.

5. Introducing the concept of the smallest watershed to address the contiguous effects.
   Although the prediction of landslide susceptibility is much improved by taking the optimized weight of each preparatory factor into consideration, there are still some landslides occurred at those pixels with low value of landslide susceptibility. After carefully examining those pixels, we realized that the landslide would be triggered if their contiguous pixels are collapsed. To address such kind of contiguous effects, we introduce the concept of the smallest watershed to treat all pixels within the same watershed as an entity. As a result, the accuracy of landslide susceptibility is further improved.
6. Determining the weighting of QPESUM precipitation by historical typhoon events.
   The landslide susceptibility is calculated from the preparatory factors and their optimized weighting values. The actual occurrence of landslide, however, requires the trigging factor of precipitation as well. The QPESUMS system provides a ten-minute-updated precipitation at the resolution of 1.3km over the entire Taiwan area. We are able to determine the weighting of QPESUM precipitation by historical typhoon events.

APPLICATIONS OF LAS IN TYPHOON SAOLA

Typhoon Saola struck Taiwan on 2 July 2012 and brought substantial precipitation. One debris flow hit He-Jung Village and buried several houses instantly. We applied our LAS to revisit this event by analysing landslide susceptibility and hazard, as well as using the archive of QPESUM data to make a series of nowcasts. The ultimate goal is to provide early warnings to the general publics to reduce the risk of slope hazards. To illustrate the matches between the predicted hot spots of landslides and the actual region of landslide, two regions are overlaid with landslide layer and displayed on Google Earth, as shown in Fig. 1. This result encourages us to employ this new LAS to provide nationwide nowcasts of landslide, using the pre-calculated LSI and QPESUMS product of $3Hr_{max}$.

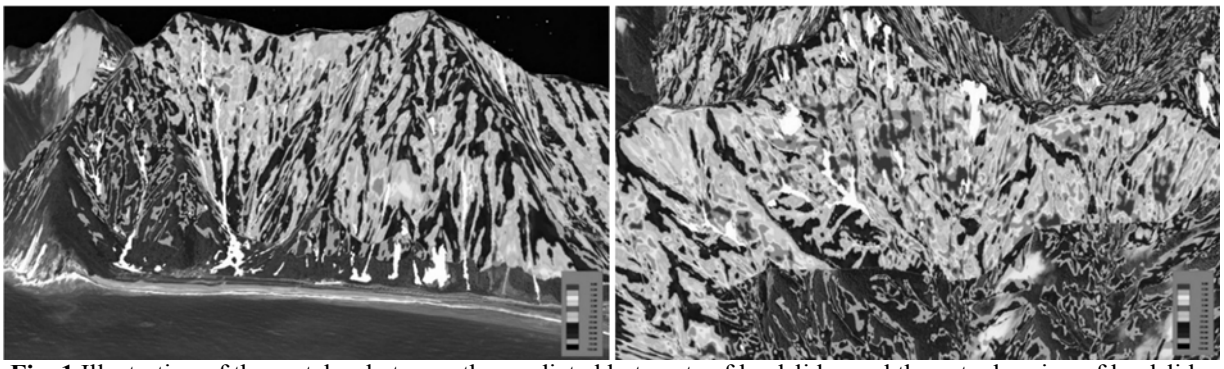

Fig. 1 Illustration of the matches between the predicted hot spots of landslides and the actual region of landslide. (a) He-Jung Village, and (b) the upstream of Shakadang Trail.

Keywords: preparatory factor, triggering factor, landslide susceptibility index, landslide hazard index, landslide inventory