LANDSLIDE-ENHANCEMENT IMAGES FOR THE STUDY OF TORRENTIAL-RAINFALL LANDSLIDES

Jin-King LIU*

Chun-Cheng WONG**

Jin-Hong HUANG***

Min-Jong YANG****

*Senior Research Scientist & Head of Mineral Resources Department
E-mail: JKLiu@itri.org.tw

**Research Scientist
Energy and Resources Laboratories, Industrial Technology Research Institute
Bldg. 26, 195-6, Sec. 4, Chung-Hsing Road, Chutung, Shin-Chu Hsien 310, CHINA TAIPEI
Tel: +886-3-5916352; Fax: +886-3-5820017

***Assistant Research Scientist
Energy and Resources Laboratories, Industrial Technology Research Institute
Bldg. 26, 195-6, Sec. 4, Chung-Hsing Road, Chutung, Shin-Chu Hsien 310, CHINA TAIPEI
Tel: +886-3-5916352; Fax +886-3-5820017

****Associate Research Scientist
Energy and Resources Laboratories, Industrial Technology Research Institute
Bldg. 26, 195-6, Sec. 4, Chung-Hsing Road, Chutung, Shin-Chu Hsien 310, CHINA TAIPEI
Tel: +886-3-5916352; Fax: +886-3-5820017

ABSTRACT

Torrential-rainfall landslides are characterized by distinct features which can be readily identified on remotely-sensed images such as tone, position, shape, direction, and shadow. Landslides are the most important natural disaster in Taiwan, and are mainly caused by torrential rainfalls in rainy season, especially in Typhoon season.

Typhoon TORAJI hitted Taiwan on 28-31 July 2001 and cause a damage of more than 10 billians of New Taiwan Dollards. The area size affected by this typhoon is 8000 Km^2, which is five more times the area size of landslides triggered by 1999 Ji-Ji Earthquake. SPOT images were applied for the inventory of landslides for a general planning for mitigation measures for the TORAJI study area. In this paper, the generation of landslide-enhanced images as well as the features and criteria for identifying landslides are presented. Various composite approach and NDVI contours approach are tested, it is concluded that pseudo-true color enhancement approaches coupled with ancillary information operated in GIS environment are very helpful for geologists to effectively identify landslides.

Key words: Landslides, Torrential rainfall, SPOT images

1 INTRODUCTION

The major features of torrential-rainfall landslides are very-localized mass movements such as earth or debris slumpings, falls and flows. This is the most important type of landslides in Taiwan due to the frequent visits of tropical storms which usually come with heavy rainfalls. For imergency response, a practical approach to quickly evaluate damages would be highly important in decision-making process. This leads to a need of using remote sensing approach.

It has been proved that remotely-sensed data can be applied to various areas of engineering geological investigation (Liu & Tseng, 1983; Liu Jin-King, 1985; Liu et al., 1991). It has also been verified that for regional innumeration of the total amount (area and numbers) of landslides after rainfall seasons, aerial photos as well as satellite images are the most important tools (Liu JK, 1998; Liu JK, 2001). Agriculture and Forestry Aerial Survey Institute of Agriculture Council is a dedicated institution for taking aerial photos of natural disasters. Images taken soon after disasters are open to the public for dedicated purposes within only a few days. Therefore, the status is operational, not merely theoretical. It is our interest to verify whether satellite images can give a result for operational applications after a heavy rainfall event, such as this study case on the Typhoon TORAJI.

Typhoon TORAJI hitted Taiwan on 28-31 July 2001 and cause a damage of more than 10 billians of New Taiwan Dollards (roughly 300 millions of US Dollars). The region affected by this event is 8000 Km^2, 5 more times the area size triggered by the catastrophe of 1999 Ji-Ji Earthquake. Thus, in this study SPOT images were applied for the inventory of landslides for a general planning for mitigation measures.

Two major merits for using SPOT images instead of aerial photos. The first is for time saving, using 4 SPOT scenes instead of 6000 air-photos. The second is for simplicity, going straightforward for merging with GIS. Sophisticated steps have to be taken to interpret airphotos and to digitize results into a GIS. However, digital satellite images can be readily entered into a computer-based environment and obtain a geocoded result.

In this paper, the generation of landslide-enhancement images as well as the features and criteria for identifying landslides are presented. Various composite approach and NDVI contours approach are tested to find out a practical enhancement approach for effectively and efficiently identifying landslides.

2. FEATURES OF TORRENTIAL-RAINFALL LANDSLIDES

2-1 Landscape Features of Torrential-Rainfall Landslides

In case that an accumulative rainfall in one day will exceed 130cm, the Central Weather

Bureau will give an early warning on "Torrential-rainfall". On 30th of July, 2001, as reported by CWB the rainfall amount was 179.5cm. Due to the effects of gravity acceleration of water-saturated land mass and runoff concentration, unconsolidated materials on steep slopes were mixed with w ater and slide down the slope like "fluid", a fluid with high viscosity and high density. The energy carried on by this fluid is so large which can lift a building blocking on the runway until a plan area is reached, where the fluid starts to settle down a nd sediments with very low sorting are accumulated. There are six major landscape features which are useful for guidelines when interpreting this type of landslide (Figure 1 and Figure 2):

(1) The semi-stable rock body on steep slopes suffering both gravity and erosion becomes a viscous fluid when saturated with water, flowing in a very high speed. Thus, thIS type of landslides are in a slim lenticular types with a fan shape in front when interrupted in a plan area or met with main stream.

(2) Due to fluid concentration on concave slopes, landslides will develop into tree-like pattern, comparable to a dentritic stream system.

(3) A spoon-like shape is usually formed in the first order of stream.

(4) Large amount of materials are accumulated in lower-gradient valley.

(5) Landslides are often developed in cut-off sides of a river bank, where lateral erosion is prevailed.

(6) Landslides areas are usually bare or covered by disturbed materials. Thus, landslides are non-vegetated.

2-2 Spectral Features of Torrential-Rainfall Landslides

Torrential-landslides are non-vegetated. Therefore, vegetation indices are useful for a computer-assisted approach to interpret landslides and making a landslide map. NDVI (Normalized Difference Vegetation Index) is derived from the reflectance of red image and near infrared image. Normalization is made to regulate the output value in the range of –1 and +1. A negative value would indicate a low-vegetated or non-vegetated area. As in our study area, the NDVI is peaked in 0.66 for forest and heavy-vegetated area, whereas it is –0.05 for river-deposits. In general, NDVI for landslides area is in the range of 0 to –0.3. To identify landslide area solely on basis of NDVI values is not possble, because all landslides, river vally, residential areas, or other building up areas are designated as low-vegetated or non-vegetated areas.

Therefore, the derived NDVI image in our study is further processed to filter out (with a single value) all the positive pixels. Then, a contour map is computedto obtain a vector map of iso-ndvi contour map, which is kept for a refernce layer in a GIS environment when a geologist is carrying out visual interpretation of landslides.

3. GENERATION OF A LANDSLIDE-ENHANCED IMAGE

A conventional color composite (Figure 3) used to code forest area with a red or redish color tone. This is not a common perception for a traditional geologists. Thus, a landslide-enhanced image, or more precisely called a pseudo-natural color image, is created (Figure 4), on which forest is i n green color and landslides or non-vegetated area is in brownish or earth color, which is comparable to natural color aerial photos. Therefore, a geologist is able to read or interpret landslides easily.

4. A TEST CASE IN DA-SING VILLAGE

4-1 Raw Materials and Methodology

Two SPOT images taken before (2001/07/03) and after (2001/08/19) typhoon TORAJI were used in this study. They are both processed in Ground Receiving Station in National Central University to a precision of Level 10 with a spatial resolution of 12.5 meters. Subsequently, these images were entered into IDRISI software for enhancement and composing into landslide-enhanced images. Lastly, images are exported to become GIS data layers in Mapinfo GIS system. The vector iso-ndvi conours as discussed in section 2.2 are also imported into a GIS data layer.

Geologist sits in front of an ordinary PC starting to identify a landslide and delineate the boundaries of the landslide with the assistance of various data layers under GIS working environment, including the enhanced images, the iso-ndvi contours, and 1/5000 topographic maps. Bearing in mind the five criteria to be discussed in next section, geologists can interpret landslides effectively.

4-2 Criteria for Landslides Interpretation

Stereoscopic photo-interpretation is a more common practice for a geologist than the 2D perception of satellite images on a PC screen. To effectively avoid mistakes, five criteria should be followed.

The first criterion--Color Tone Criterion: brown, dark brown, light brown, greenish brown, earthy brown. The second criterion--Position Criterion: near ridge, cut-off slope of river bank, road cut. The third criterion --Shape Criterion: lenticular or spoon-like shape or tree -like pattern, rectangular or triagular in case the position is near river bank. The fourth criterion -- Directional Criterion: the longitudinal axis of a landslide should go along with the direction of gravitation. The fifth criterion--Shadow Criterion: the interpreter should try to percept where is valley and where is ridge on basis of shadow effect.

4-3 Results of Test Case

As shown in Figure 5, on an landslide-enhanced image it is easy to identify a landslide, and with the assistance of ndvi contours and other information it is also reliable to delineate the boundaries of a landslide. When the 3d images taken before and after the Typhoon is compared, it is obvious that deposits are accumulated in valley after Typhoon. Area size of landslides and valley deposits on image 2001/07/03 is 2343803 , that on image 2001/08/19 is 7122757 .

5. CONCLUDING REMARKS

Landslides trigered by torrential rainfall are characterized by landscape and spectral features which can be used to generate criteria or useful data layers for geologists to effectively interpret landslides under a geocoded environment. The landslide-enhanced images are useful as tested in a practical case. And, thus, a practical approach is established by using satellite images for imergency response to a torrential-rainfall disaster.

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Figure 1 Natural color aerial photographs taken after a few days of torrential-rainfall.

Figure 2 Photo taken after a few days of torrential-rainfall in the area shown in Figure 1.

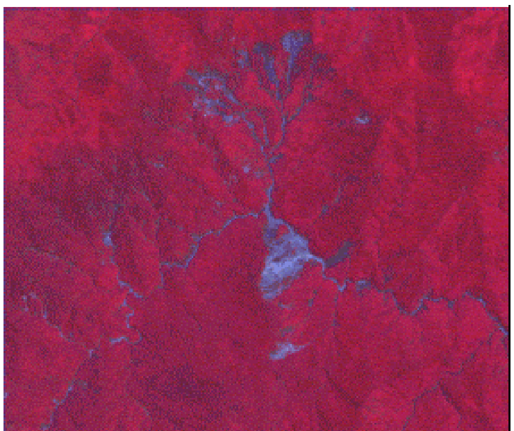

Figure 3 A color-composite SPOT image.

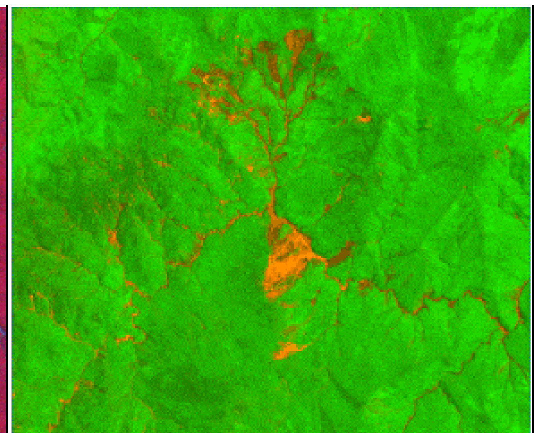

Figure 4 A Landslide-enhanced SPOT image.

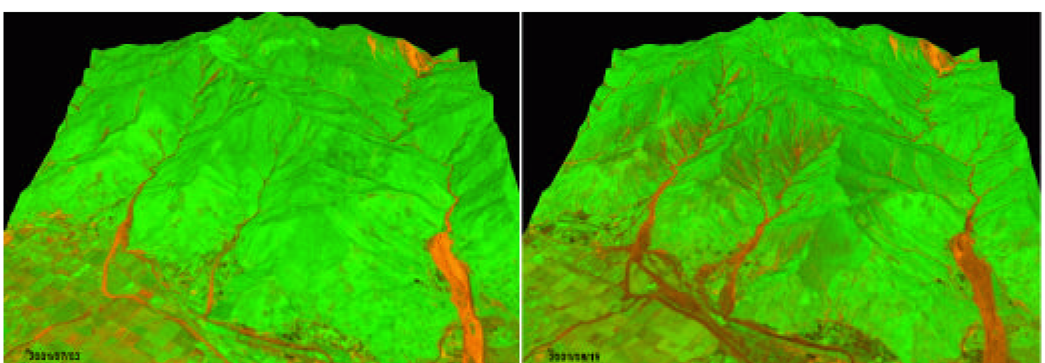

Figure 5 Images with landslide-enhancement, before (Left) and after (Right) Typhoon.