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LANDSLIDE DETECTION USING SATELLITE REMOTE SENSING IMAGERY

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ABSTRACT

Landslide detection using satellite remote sensing images has been widely studied. This type of applications often involves either change detection or multi-spectral image classification methodologies. If there is only one set of satellite image, the change detection method has limited use. Collecting and analyzing training area data for image classification are costly and time consuming. This study, therefore, utilize only one SPOT satellite image data for estimating the normalized difference vegetation index (NDVI), and to segregate vegetated and non-vegetated areas of the Ta-An River Basin in Central Taiwan. Slope factor and textural feature are then used to identify the landslide area. Results indicate that the accuracy of landslide detection using NDVI alone is about 88%. Using NDVI with slope factor and textural feature increases overall accuracy to 97%. This study successfully demonstrates the capability of using one set of remote sensing image to map landslide area in a large river basin.

INTRODUCTION

Remote sensing is the science of obtaining and interpreting information from a distance, using sensors that are not in physical contact with the object being observed. Land use classification using satellite multi-spectral scanner image is a typical application of remote sensing to environmental monitoring. Due to high population density housing construction in steep hillside is very popular in Taiwan. With this type of improper land use, soil erosion and debris flow occurs more often. Landslide includes a wide range of ground movement, such as rock fall, slope failure, and debris flow. Landslide detection using satellite remote sensing images has been widely studied in Taiwan (Cheng *et al*., 1998; Kuo *et al*., 2000). This type of application often involves either change detection or multi-spectral image classification methodologies. If there is only one set of satellite image, the change detection method has limited use. Collecting and analyzing training area data for image classification are sometimes costly and time consuming. This study, therefore, utilize only one SPOT satellite image data to estimate the normalized difference vegetation index (NDVI), and to segregate vegetated and non-vegetated areas of the Ta-An River Basin in Central Taiwan. In addition to using just NDVI only, the combined use of slope factor and textural feature will be studied also to identify the landslide area.

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Vegetation Indices

Vegetation indices attempt to measure biomass or vegetative vigor quantitatively based on digital values. Band ratios are computed from two spectral bands. Ratio of near infrared and red bands is useful in mapping vegetation and vegetation condition. The ratio is high for healthy vegetation, but low for stressed or unhealthy vegetation as well as non-vegetation areas. The most widely used index is normalized difference vegetation index (NDVI), which is a variant of the simple ratio calculation. The NDVI can be computed by (Schowengerdt, 1997):

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}} \qquad (1)$$

where ρ_{NIR} and ρ_{red} are the reflectance of near infrared and red bands, respectively. The NDVI values range from –1 to 1. Vegetated area will generally have high values because of their relatively high near infrared and low visible reflectance. In contrast, clouds, water, and snow have larger visible reflectance than near infrared. Thus, rocks and bare soil areas have near zero NDVI value. Clouds, snow, and bright non-vegetated surfaces have NDVI values of less than zero.

Slope Factor

There are three essential causative factors of debris flow. One is high intensity rainfall. The second is abundance of rock or sand sources. The third is steep slope. Landslide or debris flow usually occurs in steep hillside. The following slope function is used to calculate slope factor of Fig. 1:

$$Slope = \tan^{-1}(\sqrt{dx^2 + dy^2}) \qquad (2)$$

where

dx = [I (2,3)-I (2,1)] / k , and k is the distance between I (2,3) and I (2,1)

dy = [I (1,2)-I (3,2)] / k , and k is the distance between I (1,2) and I (3,2)

I (1,1)	I (1,2)	I (1,3)
I (2,1)	I (2,2)	I (2,3)
I (3,1)	I (3,2)	I (3,3)

Fig. 1. Schematic of pixel group matrix

Textural Features

Textural features are derived from original spectral features. From a k by k pixel group (Fig. 1), two textural features used in this study are defined as follows: Let I(m,n) be the radiance at image coordinate (m,n). If pairs of pixels are considered within the pixel group, the gray level radiance difference is

$$g(\theta, d) = \left| I(m,n) - I(m + d_1, n + d_2) \right| \qquad (3)$$

where both d_1 and d_2 can assume values of either 0 or $\pm d$; *d* is the distance separating the pixel pairs and $\theta = \tan^{-1}(d_1 / d_2) =$ 0°,45°,90°,135° is the direction in which the pixel pairs are measured. The histogram of the distribution of radiance difference within a pixel group is $h_{\theta,d}(g)$ and textural features are (Wu and Chin, 1985; Schalkoff, 1992):

(1) Angular second moment

$$ASM(\theta, d) = \sum_{g=0}^{255} 2\left[\frac{h_{\theta,d}(g)}{N}\right]^2 \qquad (4)$$

(2) Entropy

$$ENT(\theta, d) = -\sum_{g=0}^{255} \frac{h_{\theta,d}(g)}{N} \ln\left[\frac{h_{\theta,d}(g)}{N}\right] \qquad (5)$$

where N is the total number of pixel pairs in the pixel group separated by distance *d* and direction θ. In this study, the separation distance of pixel pairs *d*=3 is used.

Study Area and Data Set

Ta-An River Basin is located in Central Taiwan with a total area of about 760 km^2. The length of the main river is about 96 km (Fig. 2). Ta-An River originates from Ta-Ba Mountain of the Sheue-Shan Mountain Range. The elevation of Ta-Ba Mountain is about 3,488 m above sea level. The eastern part of the river basin is higher and declines toward the west. Except for the coastal area, most of the river basin consists of high mountains with limited plain areas. The Li-Yu-Tan Reservoir is located at the midstream of the Ching-Shan River, which is a branch of the Ta-An River. Two sets of data are used in this study. One is a single SPOT HRV multi-spectral image. This level-10 satellite image data was taken at 03/05/2001 and then re-sampled with resolution of 12.5 m by 12.5 m. The other is the detail landslide survey data collected by the Industrial Technology Research Institute (Energy and Resource Lab., 2001). The landslide survey was conducted right after the Chi-Chi earthquake (09/21/1999) and continued through typhoon Toraji (07/21/2001).

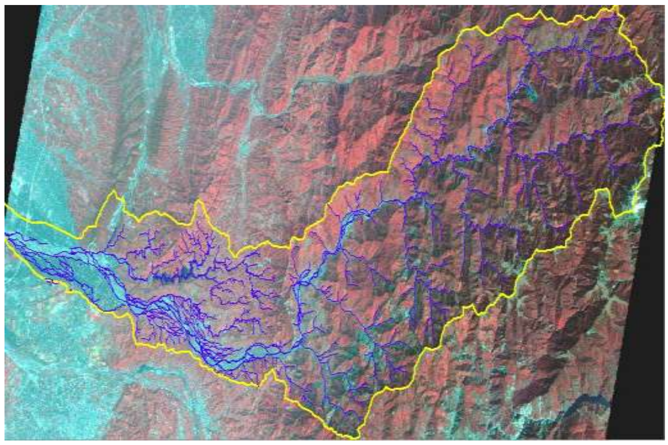

Fig. 2. SPOT image and boundary of the Ta-An River Basin

RESULTS AND DISCUSSION

Three steps are involved in this study to detect landslide:

(1) Selection of vegetated threshold
(2) Selection of non-vegetated threshold
(3) Slope factor and textural feature addition to detect landslide area.

In theory, the NDVI values for vegetated areas are greater than zero and are normally distributed. In this study, we assign the critical region as 95%, and a threshold value of 0.22 for NDVI. Table 1 and Fig. 3 show the error matrix and location for vegetation and non-vegetation area, respectively. Results indicate that using NDVI alone the accuracy of landslide detection is about 88%. Table 2 and Fig. 4 show the error matrix and location for landslide and vegetation area, respectively. Since slope factor can effectively separate stream, building and low-density vegetation. We then combine NDVI with slope factor and textural feature to detect landslide

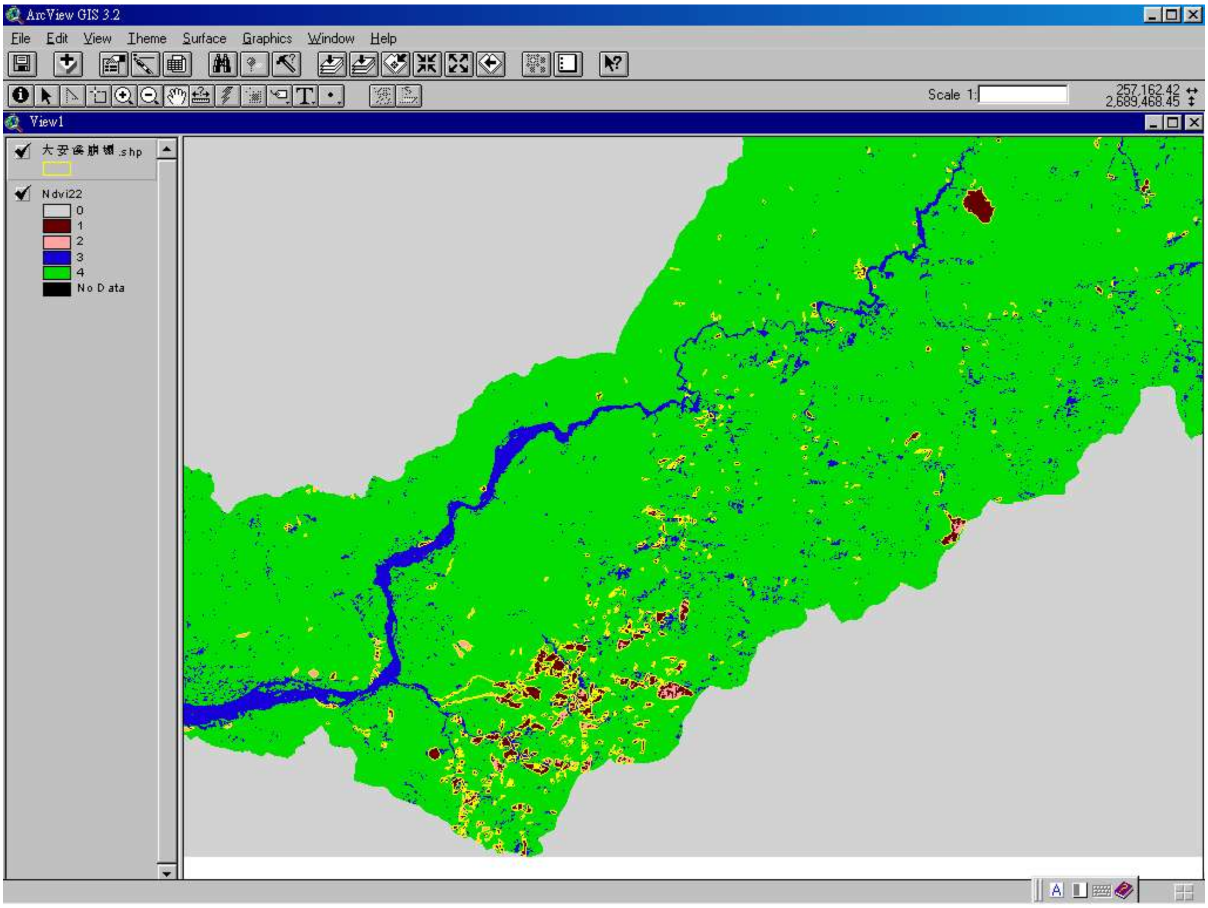

Fig. 3. Image of landslide detected by NDVI

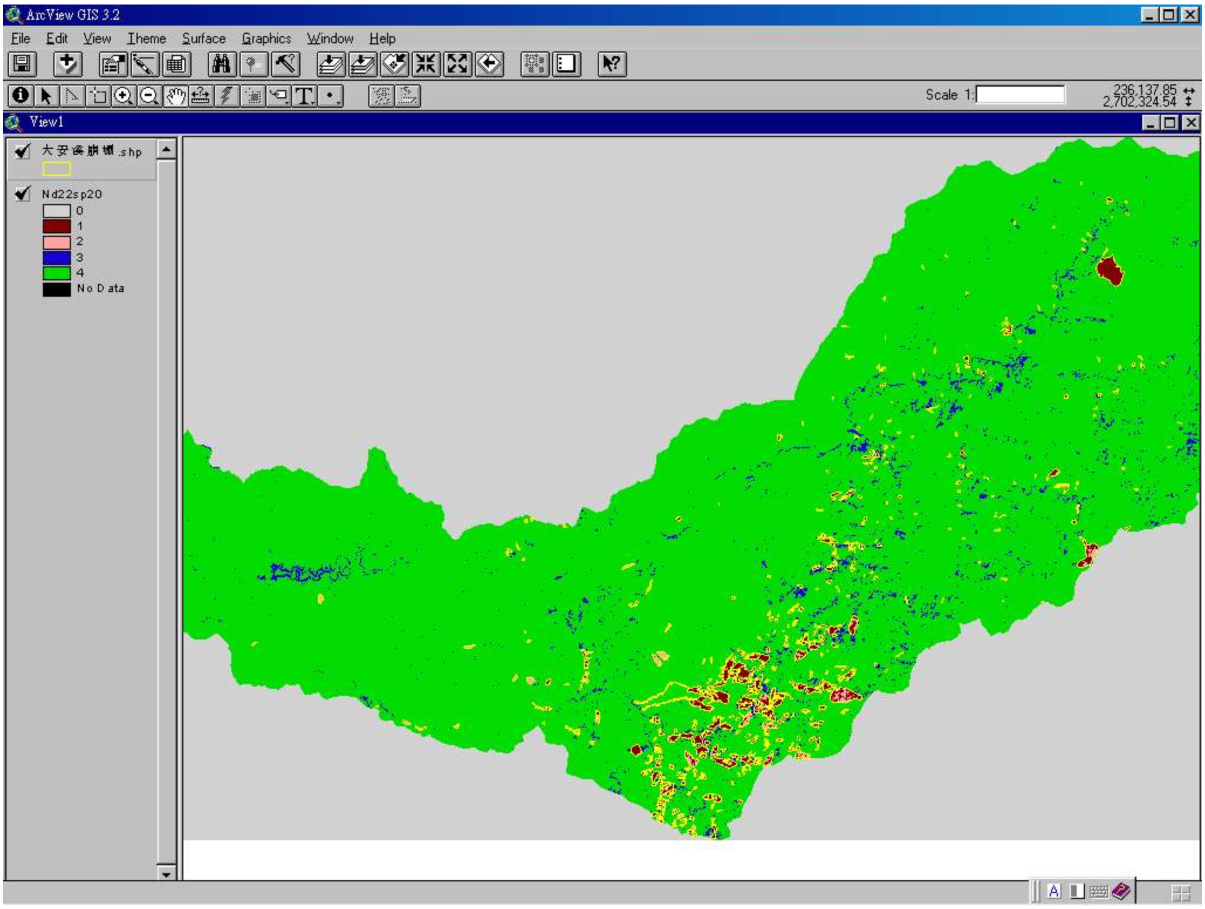

Fig. 4. Image of landslide detected by NDVI and slope

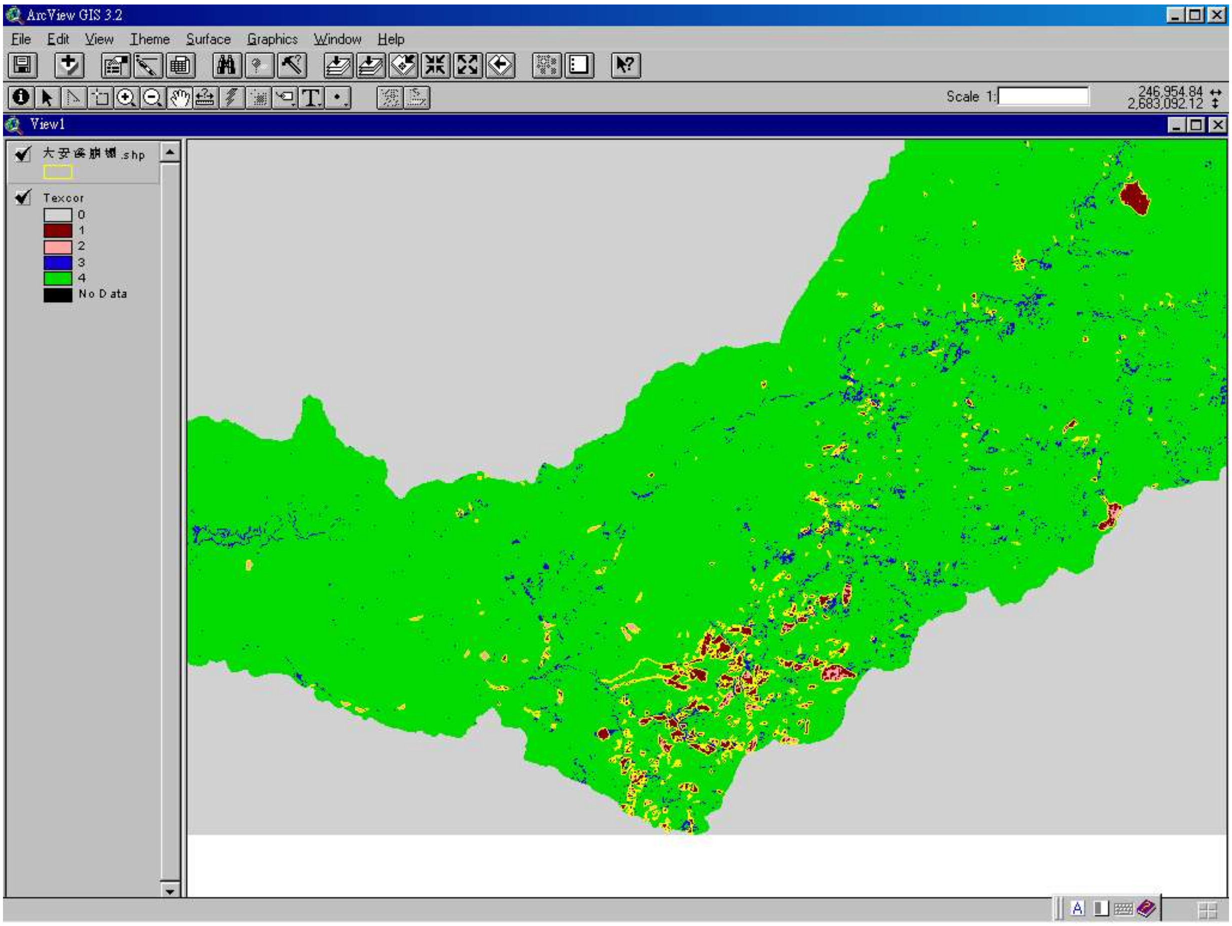

Fig. 5. Image of landslide detected by NDVI, slope, and textural feature

and bare soil for the study area. Error matrix (Table 3) shows that the overall accuracy for landslide detection improves to about 97%. Fig. 5 shows the area of landslide and vegetation which matches extremely well with the actual survey data. This result successfully demonstrates the capability of using one set of remote sensing image to map landslide area in a large river basin.

Table 1. Error matrix for vegetation and non-vegetation with NDVI=0.22

	Non-vegetation	Vegetation	Producer's Accuracy (%)
Non-vegetation	64,911	34,744	65.14
Vegetation	554,746	4,204,710	88.34
User's Accuracy (%)	10.48	99.18	87.87

Table 2. Error matrix for landslide and vegetation with NDVI=0.22, slope=20°

	Landslide	Vegetation	Producer's Accuracy (%)
Landslide	63,171	36,484	63.39
Vegetation	137,224	4,622,232	97.12
User's Accuracy (%)	31.52	99.22	96.43

Table 3. Error matrix for landslide and vegetation with NDVI=0.22, slope=20°, textural feature=0.2

	Landslide	Vegetation	Producer's Accuracy (%)
Landslide	63,171	36,484	63.39
Vegetation	131,964	4,627,492	97.23
User's Accuracy (%)	32.37	99.22	96.54

CONCLUSIONS

This study utilizes only one SPOT satellite image data for estimating the normalized difference vegetation index (NDVI), and to segregate vegetated and non-vegetated areas of the Ta-An River Basin in Central Taiwan. Slope factor and textural feature are then used to identify the landslide area. Results indicate that the accuracy of landslide detection using NDVI with slope factor and textural feature performs much better than using NDVI alone. This study also successfully demonstrates that using one set of remote sensing image is capable to map landslide area in a large river basin.

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