APPLICATION OF REMOTE SENSING AND GIS IN LANDSLIDE DETECTION

Yung-An Yang
Department of Civil Engineering National Taiwan University
* 1F., No.52, Lane 14, Liren St., Jhonghe City, Taipei County 235, TAIWAN
r94521110@ntu.edu.tw

Pai-Hui Hsu
Information Division, National Science & Technology Center for Disaster Reduction
9F., No. 200, Sec.3, Beisin Rd., Sindian City, Taipei County 23143, TAIWAN
Tel: (886)-2-66286066 ext.672 Fax: (886)-2-66286588 E-mail: hsuph@ntu.edu.tw

KEYWORDS: Landslide Detection, Decision Trees, Vegetation Index, Digital Terrain Models.

ABSTRACT: Because of the precipitous terrain and short rapid rivers in Taiwan, the landslides usually happen after heavy rains and the resulting floods. Landslides are natural hazards that often cause series property damages and even life losses. This makes the landslide monitoring and mitigation techniques an important study issue for the related professional disciplines in Taiwan. Wtih the development of remote sensing technology, both the spatial and spectral resolution of satellite images become more mature for objection identification and detection. In this paper, the landslide areas are detected using the pre- and post-images by the decision trees classifier. Firstly, the thresholding method according to the variety of Normalized Difference Vegetation Index (NDVI) is used to remove the vegetation areas. Then, a supervised classifier is used to distinguish the river zones from the bare lands and identify different types of landslides. Finally, based on the spatial analysis of digital terrain model (DTM) using GIS technology, more information about the landslide areas can be integrated according to the geometric characteristics of the terrain such, as the slope, aspect and watershed analysis. The detected landslide information could be utilized as a reference for the mitigation of the future landslide hazards.

1. INTRODUCTION

Because of the precipitous terrain and short rapid rivers in Taiwan, the landslides and slope failures usually happen after heavy rains and the resulting floods. Landslides are natural hazards that often cause series property damages and even life losses. This makes the landslide monitoring and mitigation techniques an important study issue for the related professional disciplines in Taiwan. With the developing of remote sensing technology, both the spatial and spectral resolution of satellite images become more mature for objection identification and detection. A variety of methods has also been developed to access landslide hazards and the environmental and geomorphic consequences of slope failures. In this paper, the landslide areas are detected using the pre- and post-images by the decision trees classifier. In the first stage of the decision tree, the thresholding method according to the variety of Normalized Difference vegetation index (NDVI) is used to separate the areas into vegetated and bare lands. In the second stage, Then the principal component transform is performed on the bare lands to increase the separability of different classes of landslides. This will be helpful for the landslides classification in the next stage. In this study, the maximum likelihood classifier is used to distinguish the river zones from the bare land, and identify different types of landslides. Finally, based on the spatial analysis of digital terrain model (DTM) using GIS technology, more information about the landslide areas can be integrated according to the geometric characteristics of the terrain such, as the slope, aspect and watershed analysis. The detected landslide information could be utilized as a reference for the mitigation of the future landslide hazards.

2. TEST IMAGES

The images tested in this study is captured by FORMOSAT-2 satellite operated by Taiwan's National Space Organization (NSPO). FORMOSAT-2 is the first and only high-resolution satellite with a daily revisit capability. Unlike other very-high-resolution satellites, FORMOSAT-2 has the ability to monitor fast-changing situations daily, and is very suitable for the disaster management, as well as for mapping, agriculture, land planning and forestry. The spectral ranges of the four bands of FORMOSAT-2 are B1(blue): 0.45~0.52 μm, B2(green): 0.52~0.60 μm, B3(red): 0.63~0.69 μm and B4(near-infrared): 0.76~0.90 μm respectively. Thus the NDVI can be calculated using the bands of red (B3) and near-infrared (B4). In addition, the FORMOSAT-2's spatial resolution - 2 metres in panchromatic (black and white) and 8 metres in multispectral (colour) mode - is sufficient to detect the locations of the landslides in Taiwan. In this study, the pre-image captured on August 16, 2004 and the post-image captured on September 14, 2004 are used to analyze the locations of landslides which were triggered during the AERE typhoon event.

3. METHODS OF RESEARCH

Figure 1 shows the flow chart for the landslides detection and slope analysis. Firstly, the image are separated into bare lands and vegetations using NDVI thresholding. Then the principal component transform is performed on the bare lands to increase the separability of different classes of landslides. Finally, the maximum likelihood classifier is used to identify the rive zones and different types of landslide. In the slope analysis, the relationship between the landslide locations and terrain slope are summarized.

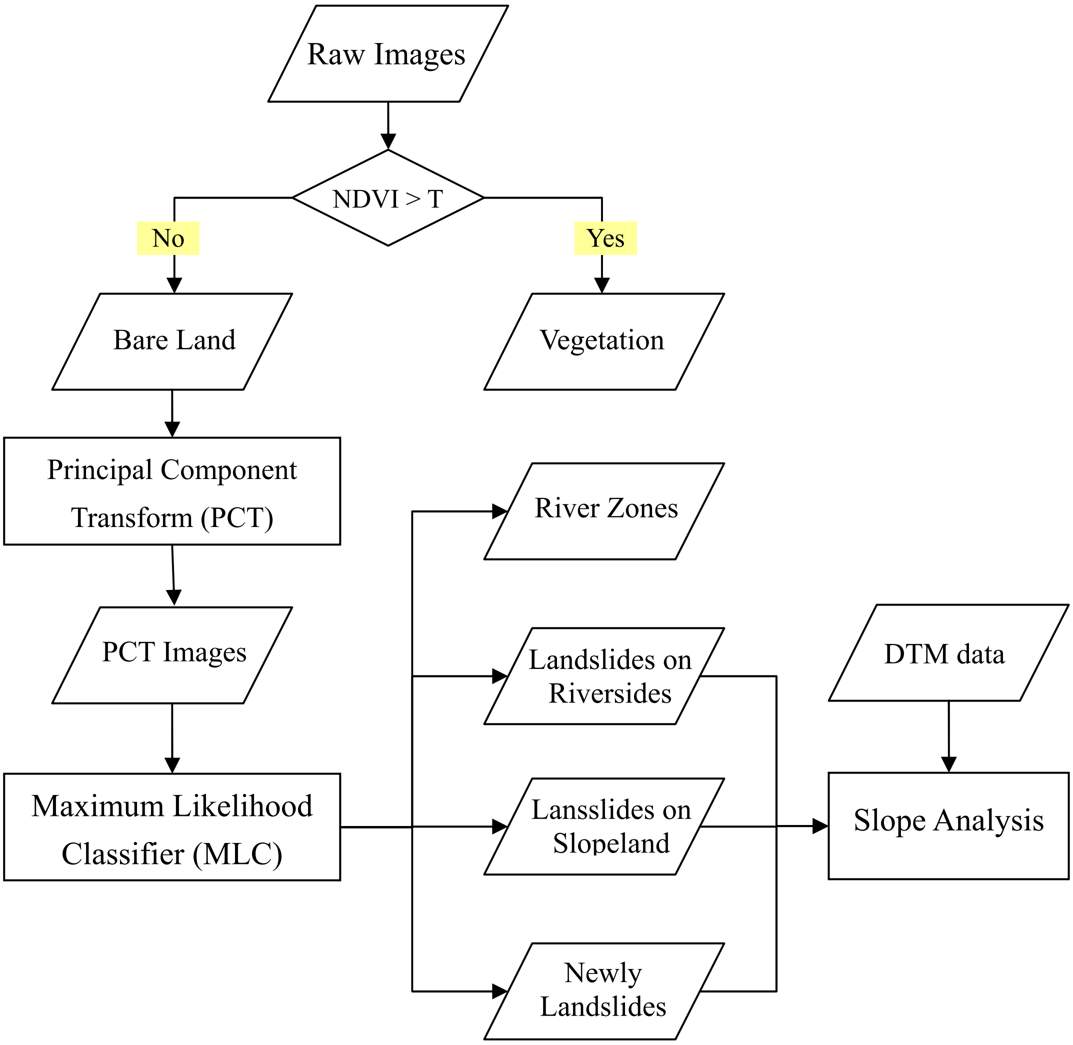


Figure 1, The flow chart for the landslides detection and slope analysis

3.1 Normalized Difference Vegetation Index

The NDVI is an index that provides a standardized method of comparing vegetation greenness between satellite images. The formula to calculate NDVI is:

$$NDVI = \frac{(IR - R)}{(IR + R)} \tag{1}$$

where *IR* and *R* are the reflectance of the near infrared band and red band respectively which are shown in Figure 2. The index values can range from -1.0 to 1.0, and the values of vegetation are higher than the grassland soil. In this study, the NDVI thresholding is firstly used to distinguish the bare lands from the vegetations in the entire image which are shown in Figure 3.

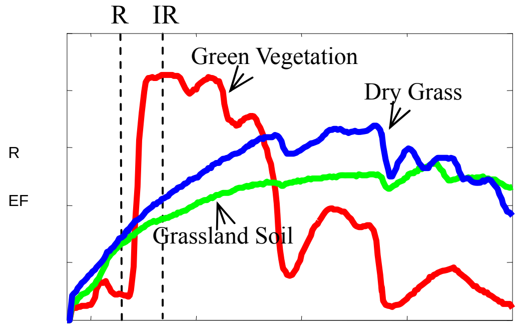


Figure 2, Reflectance Spectra

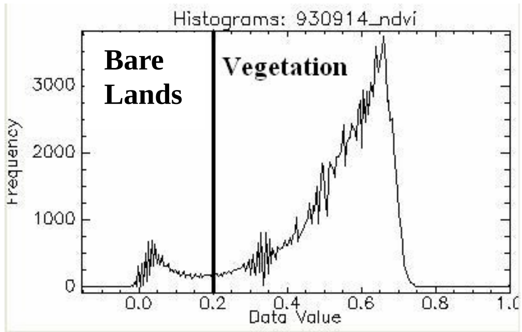


Figure 3, Results of NDVI

3.2 _Principal Component Transform

Principal Component Transform (PCT) is a linear transformation that transforms the data into a new coordinate system such that the first coordinate (the first principal component) has the largest variance of the data, the second coordinate which is orthogonal to the first one has the second largest variance, and so on. PCT can be used to remove the correlation between the different bands and reduce the dimensionality of the multispectral images (Gupta, 2003). In this study, the PCT is applied to the bare lands to increase the separability between different classes of landslides.

3.3 Supervise Classification for Bare Lands

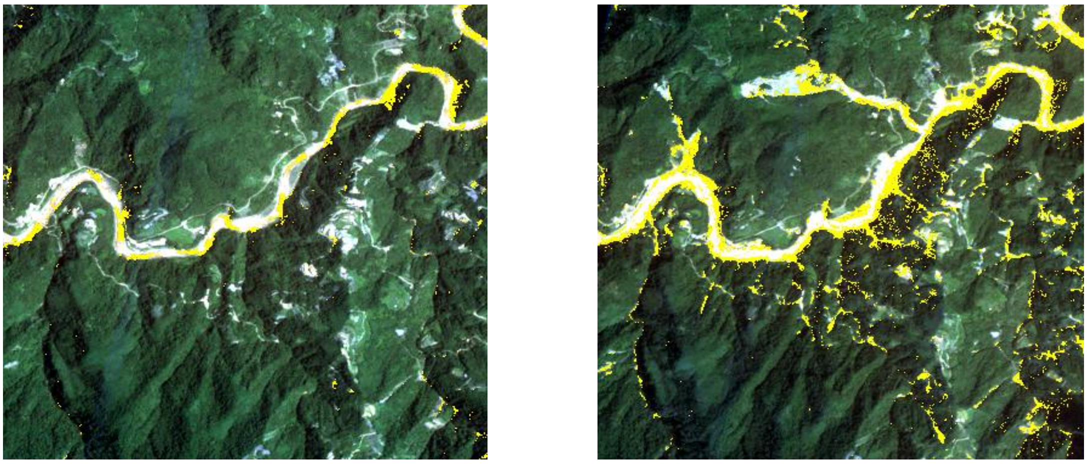
The bare lands may be caused by the forest logging, river scouring or landsliding. In this study, four different bare lands including river zones, landslides on riversides, landslides on slopeland and newly landslides are identified from PCT images of the bare lands using the Maximum Likelihood Classifier (MLC).

3.4 Slope analysis with DTM

Many large scale landslide and slope failures were occurred around the western piedmont districts along the central mountain in Taiwan. The slope of the mountain is one of the important factors of landslides. The relationship between the terrain slope and landslide locations can be connected using slope analysis (Saha, 2002). In this study, the DTM data with ground resolution of 40 meters are used to analyze the relationship between the slope and landslides. Although the resolution of DTM data is lower than the satellite images, some phenomena still can be concluded (Chiang, 2006).

4. ANALYSIS AND DISCUSSION

The purpose of this study is to detect the locations of landslides which were triggered during the AERE typhoon event. Figure 4 showed the results of the landslide detection before and after the AERE typhoon event. The ratio of landslide areas to entire areas is 1.5% before the thphoon event, and the area ratio is 6.26%. after the typhoon attacking. During the typhoon attacking, the Shihmen Reservoir has more landslides and slope failures. This could bring a large amount of rocks and mud to deposit in the river of watershed. The water in the dam would become too polluted to use, even reduce the retain ability of reservoirt.



(a) Landslide locations on 2004/8/16

(b) Landslide locations on 2004/9/14

Figure 4, The results of the landslide locations before and after AERE typhoon event.

In the slope analysis, the relationship between the landslide locations and terrain slope are connected. Figure 5 showed the slope distributions calculated from the DTM data. Table 1 is the technical specification issued by the Water Conservation Bureau in Taiwan. In Table 1, the slope is divided into 7 levels from gentle to steep slope. The results of slope analysis indicated that most of the landslides (49.32%) occurred in the level 7 whose slope is larger than 45°.

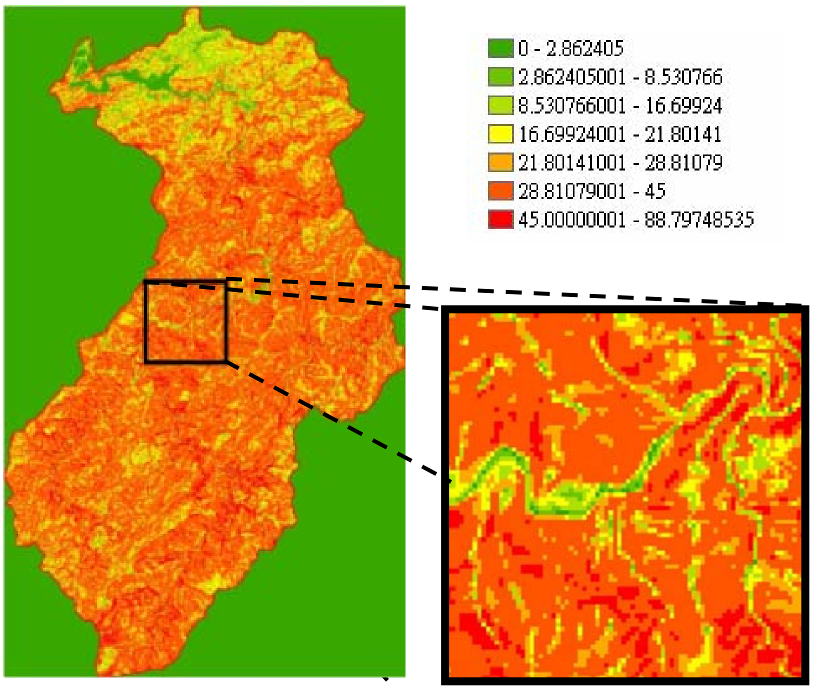


Figure 5, Slope analysis of whole watershed using DTM data

Table.1, The results of the landslide ratio and the corresponding level of slope

Level of slope	Range of slope in degree	Ratio of the landslides
1	<2.86241°	3.22%
2	2.86241° ~ 8.53077°	6.39%
3	8.53077 ° ~16.69924°	9.20%
4	16.69924 ° ~ 21.80141°	5.74%
5	21.80141° ~ 28.81079°	7.90%
6	28.81079° ~ 45°	18.23%
7	>45°	49.32%

6. CONCLUSION

In this study, a general flow chart is developed to detect the locations of landslides. Firstly, the image are classified into bare lands and vegetations using NDVI thresholding. The principal component transform is performed on the bare lands and then the maximum likelihood classifier is used to detect different types of landslide. In the slope analysis, the relationship between the landslide locations and terrain slope are connected. In the future, other detection algorithms and more auxiliary information will be integrated to increase the accuracy of the landslide detection.

REFERENCES

Arora, M. K., das Gupta, A. S., and Gupta, R. P., 2004. An Artificial Neural Network Approach for Landslide Hazard Zonation in the Bhagirathi (Ganga) Valley, Himalayas, Int. J. Remote Sensing 25(3), pp.559~572.

Chiang, Y.-S., Chen, K.-S., Liang, L.-S., Wang, C.-T., 2006. Landslide Identification Using SPOT Imagery and Digital Terrain Model, Proceeding of the 4th Taipei International Conference on Digital Earth, pp.823-831. (in Chinese)

Gupta, R. P., 2003. Remote Sensing Geology, 2nd Edition, Springer Verlag, pp.250-258.

Lin, C.-S, 2002. Study on Deciding the Optimal Number of PCA Components of Hyperspectral Images for Land Use Classification, Department of Forestry, National Chiayi University, pp.471-474. (in Chinese)

Saha, A. K., Gupta, R. P., and Arora, M. K. 2002. GIS-based Landslide Hazard Zonation in the Bhagirathi (Ganga) Valley, Himalayas, *Int. J. Remote Sensing*, 23(2), pp.357~369.

Tsai, K.-J., Liu, M.-Z., Chun, C.-H., 2004. Application of Remote Sensing on the Revegetative Analysis of landslide Stabilization in Central Taiwan, Department of Civil Engineering, National Pingtung University of Science & Technology, pp.813-822. (in Chinese)