INTEGRATED MULTISPECTRAL IMAGE AND LIDAR FOR LANDSLIDES VEGETATION RESTORATION MONITORING

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ABSTRACT:

Landslides are one of the major hazards in Taiwan, especially after typhoon and earthquake, to maintain the slope stability is the most important task after disaster; vegetation cover is the key factor of slope stability. Vegetative cover can contribute to improving the stability of steep slopes by reducing erosion and the its growing are usually controlled by climate, soil, water, topography and geology condition, the growing conditions indicated that vegetation growing condition may also reflect the landslides spatial characteristics.

The landslides and vegetation restoration evaluation was implement by high resolution air-photo, SPOT-5 satellite image and air-borne LiDAR in this study. Landslides were identified by using air-photo in 2004 which before Long -Wang typhoon, the satellite image and LiDAR data were acquired for calculated vegetation restoration rate, two different source data were both taken in the same month in 2005.The LiDAR data are used for derived surface roughness data to obtain the vegetation growing.

The vegetation restoration result shows different spatial distribution in landslide area, the vegetation cover near river bank are less than where in slope area, the growing rate also shows the same appearance. The steep slope appears with low vegetation restoration rate, it may have relations with high frequency of landslides and lower disturbed by human in this area.

1. INTRODUCTION

The slope safety factors associated with topography, geology, and vegetation which can be considered as indices of the parameters of safety factor are quantified to assess their contributions to land-sliding, but for large areas, the variations in parameters included in the analysis of the safety factor are too large to accurately quantify, but the empirical and monitored hazards require continuous, long-term data on the landslides and their causative factors under similar environmental conditions (Dhakal et al., 2000).Slope stability is the key factor for landslide occurred and the cause of recurrence. To maintain the slope stability is the most important task for disaster prevention. The vegetation and deep roots may provide great helpful to maintain stable soils and to limit the potential landslide; however, there are few available data to quantify effects of natural vegetation restoration (Zheng Fenli et al., 2002)

The airborne laser altimetry technology (LiDAR, Light Detection and Ranging) provides high-resolution topographical data, which can significantly contribute to a better representation of land surface. In the field geo-hydrological hazards in mountainous areas and it is possible to mention the use of LiDAR data for the characterization of large landslides, as the basis for numerical modeling of shallow landslides, for the recognition of depositional features on alluvial fans and for the study of the longitudinal profile of rivers.(Cavalli et al., 2008).

The assessment of landslide hazards for a large area are widely employed by remote sensing data, among these evaluations one of the most frequently used vegetation indices is Normalized Difference Vegetation Index (NDVI). Numerous studies have been proposed to deal relate issues (Lin et al., 2004; McKean et al., 1991).This index could reflect the vegetation growth efficiency for vegetation assessment, but it can only reflect the 2-D horizontal spectrum vegetation information, the 3-D vegetation information may contribute to improving the vegetation restoration assessment.

2. STUDY AREA AND MATERIALS

The study area with 5 ×5 km^2 is located on the southeast part of Taoyuan County of Taiwan and it is situated in a sub-basin of Shimen Reservoir. The sub-basin of Shimen Reservoir is the area with the high frequency of landslides in Taiwan and the geological lithology was deposited with alternation of sandstone and shale. Serious landslides occurred after typhoon and rainfalls, especially on river banks and the proximity of provincial highway.

The materials used in this study include ortho-rectified aerial photos, SPOT images and Airborne LiDAR Digital Surface Model (DSM) and Digital Elevation Model (DEM). The resolution of ortho-photos is 0.5 meters, which is used for establishing landslides boundary which before the disaster and SPOT-5 is at a resolution of 2.5 meters in super-mode. LiDAR DSM derived from point clouds and resampled to 1 meter. The SPOT images and LiDAR survey are both conducted after Typhoon Long-Wang in November of 2005.

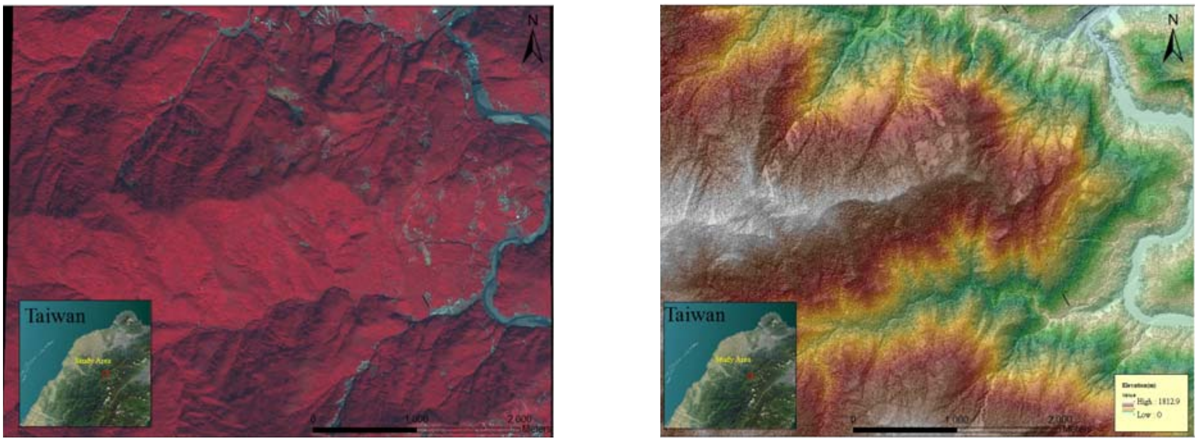

Figure 1 Study Area Image
(Left: SPOT-5 Image; Right: LiDAR DSM Hill-Shade)
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3. METHODOLOGY

3.1 Vegetation Index

To determine the density of green on a patch of land, researchers must observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants. Nearly all satellite Vegetation Indices employ this difference formula to quantify the density of plant growth on the Earth — near-infrared radiation minus visible radiation divided by near-infrared radiation plus visible radiation. The result of this formula is called the Normalized Difference Vegetation Index (NDVI). Written mathematically, the formula as follow:

$$NDVI = (NIR - VIS) / (NIR + VIS) \quad (1)$$

Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.(NASA, 2011), and NDVI, which can be directly calculated from satellite data, is related to vegetation canopy characteristics such as biomass and percentage of vegetation cover and is representative of plant photosynthetic efficiency, and fluctuations due to changes in meteorological and environmental parameters(Gross, 2005).

3.2 Landslides Extraction

The landslides boundary was extract from orthorectified airphoto which before the disaster during July of 2004 and the landslides boundary was layered on LiDAR data as the pre-disaster extent.

3.3 Derivatives of LiDAR Data

High-resolution and high-accuracy topography LiDAR DSM was derived from point cloud and resampled to 1 meter. The 3-D LiDAR DSM was employed with 2-D SPOT multi-spectrum image to derive the Normalized DSM (nDSM)

3.3.1 Normalized DSM

The Normalized DSM was acquired by subtracting DEMs from DSMs, the formula as follow:

$$nDSM = DSMs - DEMs \tag{2}$$

This formula is the most simply and popular method to determine the vegetation height, it's an instinctive assessment method to extract the vegetation from LiDAR data, but it's difficult to understand the vegetation growth efficiency without spectrum information, especially in landslides bare land, the vegetation height are usually less than nature vegetation, such as grassland, it indicated that the value may approach "zero" in previous algorithm.

3.3.2 nDSM Surface Roughness Index

Besides the nDSM and SPOT multi-spectrum image, the nDSM surface roughness was integrated for assessment the vegetation restoration. Calculations of roughness index of nDSM are based on the vegetation height data and the slope algorithm was employed for determine the roughness index, the formula as follow:

$$f(x) = \left(\frac{(nDSMz_3 - nDSMz_1) + 2(nDSMz_6 - nDSMz_4) - (nDSMz_9 - nDSMz_7)}{8 \times cell\ size} \right) \times (NDVI)$$

$$f(y) = \left(\frac{(nDSMz_7 - nDSMz_1) + 2(nDSMz_8 - nDSMz_2) - (nDSMz_9 - nDSMz_3)}{8 \times cell\ size} \right) \times (NDVI) \tag{3}$$

Where *slope* is calculations the within the neighborhood by 3x3 window, the slope gradient algorithm used in this study is the third-order finite difference weighted by reciprocal of squared distance algorithm. This algorithm was developed by (Sharpnack and Akin, 1969). It uses the eight neighboring elevation values bordering the central elevation cell and uses eight grid points to calculate each slope value. This method was modified by (Horn, 1981)using unequal weighting coefficients for the nearer elevation values, and the NDVI was extraction from SPOT-5 image. The result is an index that ranges from -90~90 where 0 indicates a case where the surface is uniform and no vegetation within the neighborhood and the maximum indicate the vegetation appear great condition in landslides area.

4. RESULTS AND DISCUSSIONS

The results of the landslides area vegetation restoration are obtained from different data-sets by using various combinations of LiDAR data.

4.1 Results

The results were dividing into two types of landslides area, the mountain area landslides and the landslides nearby riverbank, the mountain landslides area was estimated at 58111 m^2; the riverbank landslides area was estimated at 55975 m^2. Figure 2 shows the R mean with 3.2 in mountain area; the R with a mean value of 1.1.it indicated that the vegetation restoration of mountain area is good than in river bank area. If the values less than "zero", the land covers type can be regarded as not vegetation or vegetation with poor health condition.

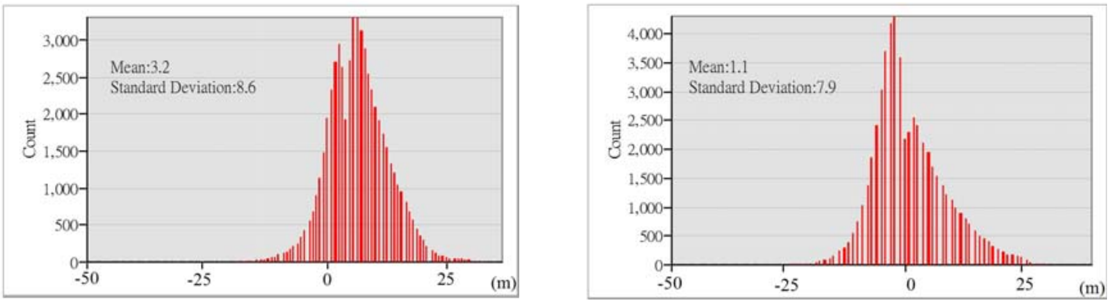

Figure 2 Frequency Distribution of NDVI-based Roughness Index
(Left: Mountain Area; Right: River Bank Area)

The Figure 3 shows the vegetation restoration and an example of profile, the vegetation restoration can be divided into four levels, the “poor” class indicated the no vegetation or vegetation with poor health condition; the excellent class indicated that the dense vegetation or vegetation with great health condition in landslides area. The profile in Figure 3 can be described as the ration of vegetation high and health.

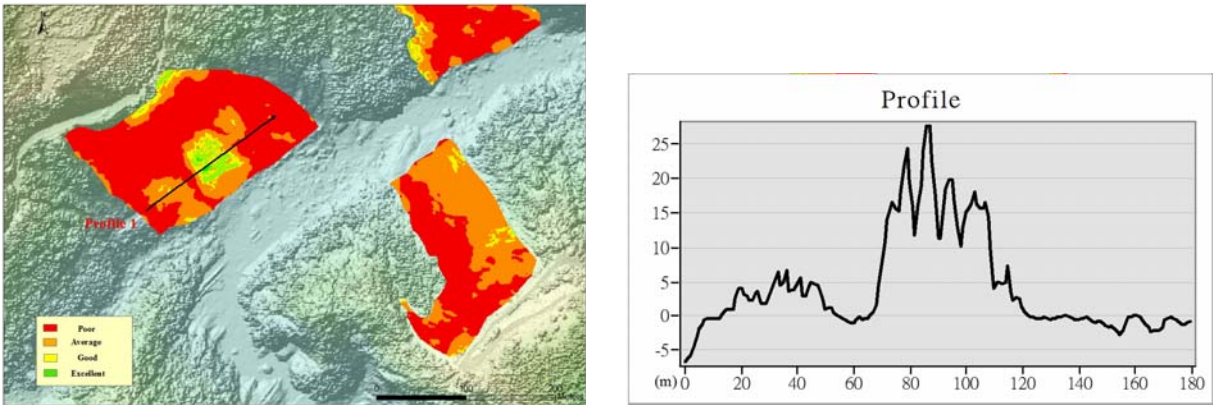

Figure 3 Vegetation Restoration and Profile

5. CONCLUSIONS

SPOT images and LiDAR data taken after the Typhoon Long-Wang in November of 2005 are used in this study to explore the assessment landslides vegetation restoration when LiDAR-derived indices are included.

It is shown in this study that nDSM Surface Roughness Index are effective in landslides vegetation restoration assessment. With the inclusion of LiDAR derivatives, the 2-D spectrum information can be integrated for 3-D vegetation monitoring to achieve the assessment of relative-vegetation restoration by single period data. In the other hand, the multi-temporal data assessment can be achieved by absolute radiometric calibration.

REFERENCES

Cavalli, M., P. Tarolli, L. Marchi, and G. Dalla Fontana, 2008, The effectiveness of airborne LiDAR data in the recognition of channel-bed morphology: Catena, v. 73, p. 249-260.

Dhakal, A. S., T. Amada, and M. Aniya, 2000, Landslide hazard mapping and its evaluation using GIS: An investigation of sampling schemes for a grid-cell based quantitative method: Photogrammetric Engineering and Remote Sensing, v. 66, p. 981-989.

Gross, D., 2005, Monitoring Agricultural Biomass Using NDVI Time Series, Rome, Food and Agriculture Organization of the United Nations (FAO), p. 1-17.

Horn, B. K. P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, p. 14-47.

Lin, C. Y., H. M. Lo, W. C. Chou, and W. T. Lin, 2004, Vegetation recovery assessment at the Jou-Jou Mountain landslide area caused by the 921 Earthquake in Central Taiwan: Ecological Modelling, v. 176, p. 75-81.

McKean, J., S. Buechel, and L. Gaydos, 1991, Remote sensing and landslide hazard assessment, v. 57: Bethesda, MD, ETATS-UNIS, American Society for Photogrammetry and Remote Sensing.
NASA, 2011, http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php.
Sharpnack, D., and G. Akin, 1969, An algorithm for computing slope and aspect from elevations: Photogrammetric Engineering and Remote Sensing, v. 35, p. 247-248.
Zheng Fenli, Tang Keli, Z. Cheng-e, and H. Xiubin, 2002, Vegetation Destruction and Restoration Effects on Soil Erosion Process on the Loess Plateau, 12th ISCO Conference, Beijing.