Monitoring landscape changes in catchment areas using remote sensing technique

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***Abstract*—This study established a monitoring process for the relationship between vegetation and satellite spectral images. Through a conversion relationship, satellite spectral values can be converted into monitoring data. According to calculation of the normalized difference vegetation index (NDVI), vegetation location can be determined. The threshold of the NDVI was found to be 0.05 for green and non-green cover. This value was further used to automatically generate a green or non-green cover image with a NDVI greater or less than the threshold respectively. In this study, the green parts of the generated image indicated vegetation area and the dark gray parts of the image indicated landscape change areas. After image transformation, the algorithm could automatically compare the pre- and postimages and select the landscape variation from the original green to non-green area. These findings reveal the effectiveness and advantages of using the NDVI to judge landscape change. Patrol personnel may be unable to identify illegal use of a catchment area. Therefore, using hyperspectral remote sensing data to judge illegal development is beneficial for conservation of catchment areas. Future development of smart image interpretation technology, image data collection, and interpretation of illegal development data could assist water resource conservation and land use management.**

***Keywords*—remote sensing data, normalized difference vegetation index (NDVI), landscape changes**

I. INTRODUCTION

Due to frequent incidents of over development and illegal use of catchment areas, land use management must be strengthened by regularly checking for illegal use. Such checks serve to maintain ecological conservation within a catchment area and prevent overutilization and illegal development. Conventionally, patrol personnel conduct routine inspections onsite by using digital cameras, GPS device, and paper records. However, such manual inspection methods are time consuming and labor intensive, resulting in low inspection frequency and varying inspection standards due to personnel differences. Remote sensing images can help monitor large areas and be analyzed algorithmically to find suspicious locations. Remote sensing techniques can provide instant, low-cost, and long-term observation and monitoring of a catchment area. These advantages are especially useful for monitoring overall landscape change trends in catchments encompassing water sources and thus help in the management of these sources. Literature reviews pointed out that China monitored land use with satellite imagery to understand land changes or abnormal development practices. Other countries in the world mainly focused on the basic data survey and research of remote sensing technology and development of land geographic information system. [1-4]

This study evaluated the normalized difference vegetation index (NDVI) using hyperspectral remote sensing data for Taiwan from the FORMOSAT-2 satellite with 8-m spatial resolution. FORMOSAT-2 can provide red spectral band (0.630–0.690 μm) and near-infrared band (0.760–0.900 μm) images that can be used to estimate the NDVI. Chlorophyll in leaves has strong absorption at 0.45 and 0.67 μm and high reflectivity at near infrared (0.7–1.1 μm). In short-wave infrared spectroscopy, vegetation exhibits three absorption characteristics, which can be directly related to the water contained in the absorbed leaves [5]. Because of chlorophyll absorption, plants usually have low reflectivity in the blue and red parts of the spectrum, but they have slightly higher reflectivity in the green part, which is why plants look green to human eyes. Near-infrared radiation energy is strongly reflected from plant surfaces. The amount of reflection depends on the characteristics of the leaf tissue. Contrast between vegetation and soil is largest in the red and near-infrared regions. Therefore, spectral reflectance data can be used to calculate various nutritional indices, which are closely related to agronomic and biophysical plant parameters related to photosynthetic activity and plant productivity [6-8].

Satellite imagery has been widely used for monitoring and researching large-scale water conservation in catchment areas. Using various analytical methods, the relationship between spectral data and land use can be established to distinguish abnormal land use in catchment areas. In the present study, the relationship between vegetation cover and satellite spectral images was established. The location of vegetation cover was selected by calculating the NDVI, and then the empirical coefficient of the output threshold was calculated through statistical regression. The NDVI was employed to interpret the actual application of landform change in the catchment area. The NDVI is given as follows [9-10]:

$$NDVI = (NIR - RED) / (NIR + RED) \tag{1}$$

where NIR is reflectance in the near-infrared band and RED is reflectance in the visible red band.

Using past satellite remote sensing image data, the location for analysis was selected as the upper reaches of the Xindian River catchment area. Landform variation in the water area was interpreted intelligently. Using pre- and postimages, NDVI interpretation was employed to effectively identify the landform variation points (i.e., the threshold of green and non-green covered landforms in the selected catchment area). By comparing the early images with later images, the variation points could be determined in terms of green to non-green coverage. The NDVI was used to interpret the geomorphological variation.

According to the transformation relationship, satellite spectral values can be converted into the information of land use. Therefore, the distribution of the overall use of the catchment area can be obtained quickly so that the correct management strategies for water conservation can be adopted. The following is a description of the monitoring process.

II. METHODOLOGY

A. Satellite image data collection

Selected satellite images were based on the frequency of the satellite passing through the target area and the requirements of the patrol service. In addition, satellite images are affected by cloud occlusion; therefore, reasonable frequency and period were determined according to requirements.

B. Satellite image geometry correction

Satellite image data could not be used to determine the spatial geometric distribution of images in different periods. To ensure that the spatial geometric distribution between multitemporal images corresponded correctly, geometric correction of multitemporal satellite images was conducted.

C. Satellite image correction

The purpose of this step was to correct images under different geometric or irradiation conditions at different times. Analysis and comparison of images taken in different seasons and from different positions requires consideration of varying angles of solar irradiation and different intensities of reflection. Therefore, the follow-up analysis could be conducted for images taken at different times.

D. Establishment of the regression model

According to calculation of the NDVI, the location of plants can be screened, but the threshold of each regional index differs, and therefore, a regression equation was generated by referring to the literature and empirical coefficients of statistical regression output thresholds.

E. Mode verification and amendment

If new satellite imagery is used, the old regression relationship can be validated and corrected, and a new threshold can be established. When the validation is completed, it becomes a new regression model of catchment area, and can be used for long-term monitoring, and can build a good implementation step.

F. Conversion of spectral values to land variation points and establishing a theme map

By changing the spectral values of other satellite images into the regression formula, a land variation map was obtained.

In this study, an automatic conversion module was built. Only after the satellite images and radiometric correction process were completed could the automatic conversion mode be brought into the system and the land variation points generated.

III. CASE ANALYSIS OF A SATELLITE IMAGE

To grasp the practical applications and advantages of using the NDVI to interpret landscape changes in catchment areas, especially when using past remote sensing image data, intelligent interpretation of landscape variations in the catchment area in the upper reaches of the Xindian River was conducted, and the pre- and postimages were used together with the aforementioned processes to effectively identify landform and landscape changes. The case analysis is further explained as follows.

A. Study location

The upper reaches of the Xindian River catchment area were used as the study site (Fig. 1).

Fig. 1. Site map of the case study in the upper reaches of the Xindian River catchment area. (Red square area is selected as study area)

B. Satellite telemetry image data

The satellite telemetry images used were multispectral images from FORMOSAT-2, providing blue, green, and red visible light bands and near-infrared light bands. The image-to-ground resolution was 8 m. The preimage data were from November 13, 2015, and the postimage data were from April 19, 2016.

C. Interpretation of images using the NDVI

According to the selected pre- and postimage data, and after image correction, each band of image data was converted to the NDVI (Fig. 2), where every pixel from dark to light represented its NDVI from small to large (ranging from −1 to 1). If the NDVI is greater than 0, it means that the land is covered with green. If the NDVI is less than 0, it means that the land is not covered with green.

D. Converting images into green and non-green coverage

The empirical formula was estimated by coefficient calculation, and the threshold of the NDVI for green and non-green covered land in the upper reaches of the Xindian River was determined as 0.05. The image was transformed into an image with a NDVI greater or less than the threshold (Fig. 3). The green parts indicate green coverage, and the dark gray parts indicate non-green coverage.

Fig. 2. NDVI in the upper reaches of the Xindian River catchment area.

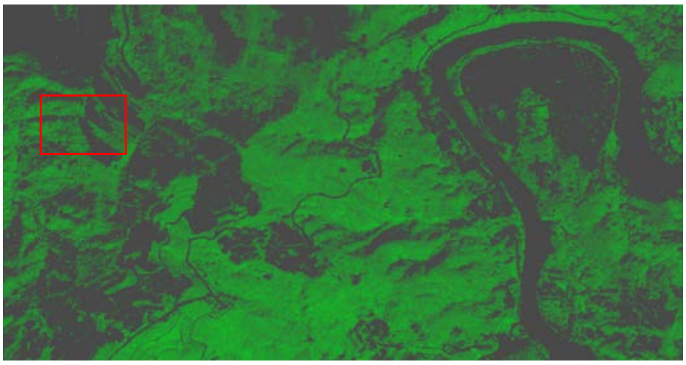

Fig. 3. Image conversion using the threshold.

E. Pre- and postimage interpretation and comparison

After image transformation, the pre- and postimages were compared using the algorithm to locate variation points in the landscape from original green coverage to non-green coverage, thereby establishing the variation areas (Figs. 4–7).

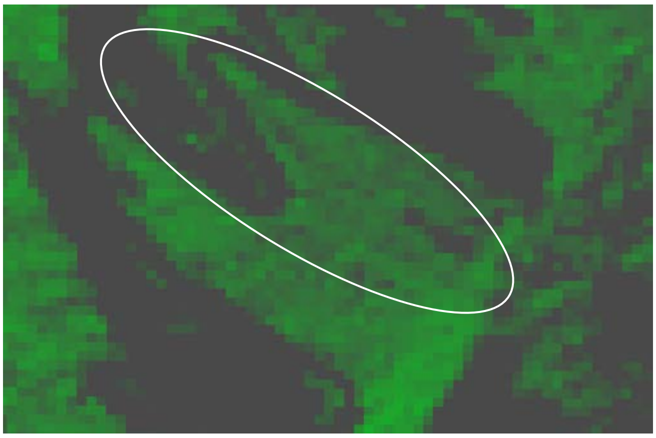

Fig. 4. Preimage green coverage in the variation area.

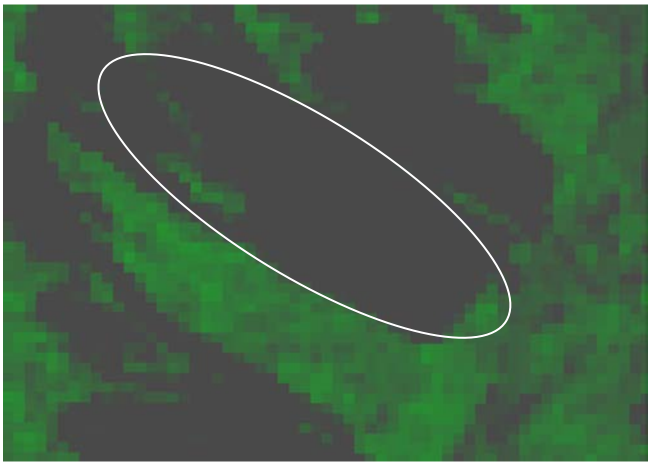

Fig. 5. Postimage non-green coverage in the variation area.

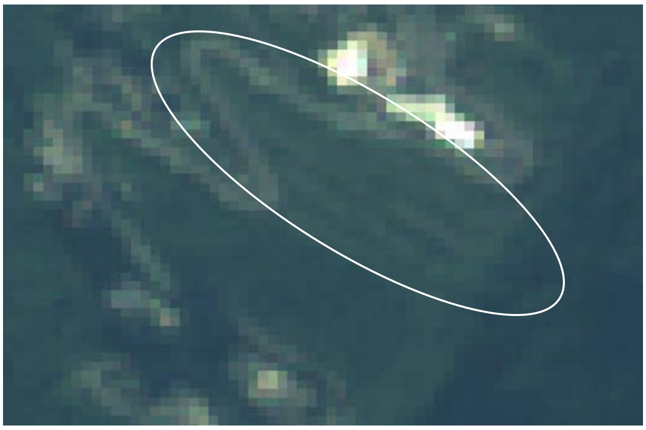

Fig. 6. Satellite preimage in the variation area.

IV. RESULT AND DISCUSSION

From Fig. 4, in the preimage, most water conservation areas in the catchment area were covered in green, but, from Fig. 5, green cover was reduced or even eliminated in the postimage due to land development. The satellite imagery confirmed these findings. In Fig. 6 (the preimage), green cover is clearly visible, but the illegal use of land in the later stage leads to a decrease in green coverage, which can be viewed as surface soil in Fig. 7 (the postimage).

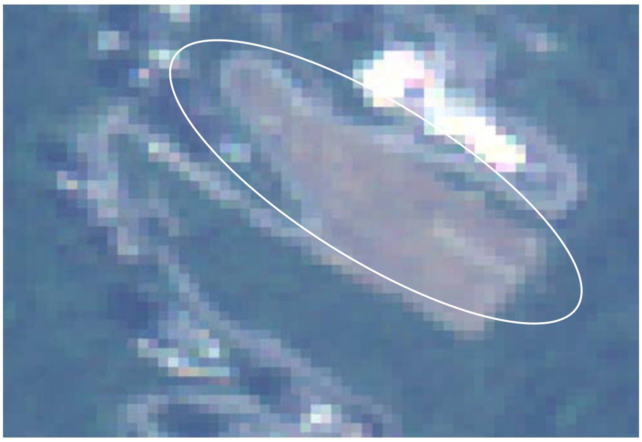

Fig. 7. Satellite postimage in the variation area.

According to the preliminary case analysis results, the NDVI can be effectively applied to interpretation of landform variation in a target catchment area. In addition to using satellite telemetry image data to calculate the NDVI of surface topography, multispectral cameras and lenses on unmanned aerial vehicles will be used in a follow-up experiment to take detailed photographs of the selected variation points for automatic interpretation. In addition to recording the variation points, multispectral images will also be recorded. Multispectral images can be used to calculate a more detailed NDVI for the site, which could enhance the reliability of the data and help in monitoring and tracking the degree of restoration in the region.

Previously, automatic interpretation technology often required manual intervention to help confirm interpretation results. Moreover, these technologies required more manpower to confirm landform variation, which made them impractical for frequent use. Therefore, the introduction of artificial intelligence to assist in land use interpretation will enhance the ability to search for variation points. Recent developments in computing power have led to the expansion of deep learning technology and application of neural networks, especially in terms of image recognition based on convolutional neural networks.

V. CONCLUSION

Application of satellite imagery to large-scale water conservation in catchment areas has become increasingly common, and it is now feasible to monitor and manage water resources using satellite remote sensing. By applying various analytical methods, the relationship between spectral data and land use can be established to evaluate abnormal land use in water resource conservation areas. This study established a monitoring process for the relationship between vegetation and satellite spectra. The satellite spectral values were converted to monitoring data according to the transformation relationship. With the calculated NDVI, the vegetation location can be determined. In this study, the threshold of the NDVI for green and non-green coverage was 0.05. This value was further used to automatically generate images with a NDVI greater or less than the threshold. The green parts of the image were vegetation areas and the dark gray parts were places where the landscape changed. Through image transformation, the algorithm automatically compared the pre- and postimages and selected the landscape variation points based on the change from the original green space to non-green space. The algorithm employed in this paper demonstrates that the NDVI can be used to judge the scale of landscape change. Patrol personnel may be unable to judge illegal use of catchment areas, and therefore, the use of hyperspectral remote sensing data to judge illegal development zones can further protection and management of water resources. Intelligent image interpretation technology combined with image data acquisition and interpretation can help water resources protection and land use management in catchment areas by revealing illegal exploitation.

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