DETECTING DEFORESTATION IN THE TROPICS USING CHANGE VECTOR ANALYSIS WITH PATTERN DECOMPOSITION COEFFICIENTS

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ABSTRACT

Brightness value of a pixel is composed of three basic types of land cover on the Earth surface i.e. soil, vegetation and water. Pattern decomposition analysis (PDA) decomposes the value into the soil, water and vegetation coefficients. In this study, multi-sensor data of Landsat-TM and MSS are used. The three common bands of the sensors are used in the PDA. Relative radiometric normalization to one reference image is implemented to remove the temporal fluctuation of the spectral shape patterns. The tasseled cap transformation's brightness and greenness are the most widely used variables in change vector analysis (CVA). Instead, the pattern decomposition (PD) coefficients of the soil and vegetation are employed in the CVA. The usefulness of the algorithm for the deforestation detection is investigated at three test sites at Kinabalu area, Sabah, Malaysia. The CVA with the PD coefficients is found superior than image differencing techniques using the NDVI, a widely used detection algorithm. The algorithm is then used to

detect the deforestation of the whole study area in two change periods i.e. 1: 1973-1991 and 2: 1991-1996. In short, the CVA with the PD coefficients is a useful algorithm for deforestation detection in the tropic as well as other area.

1. INTRODUCTION

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Deforestation is a type of change can be detected using satellite remote sensing. The deforestation has been one of the most important issues in the world especially in the tropics over the twentieth century. The basic premise in using remote sensing data for detection of deforestation is that changes in the forest cover will result in changes in radiance values that are separable from changes caused by other factors, such as differences in atmospheric conditions, illumination and viewing angle, soil moisture etc. It may further be necessary to require that changes of interest be separable from expected or uninteresting events, such as seasonal, weather, tidal or diurnal effects. The existing algorithms are well documented in Singh (1989). The change detection, in most cases, relies on indices that indicate the basic land cover types i.e. water; soil and vegetation. The widely recognized ones are normalized differenced vegetation index (NDVI), tasseled cap transformation and components of the principal components analysis. Likewise, the PD coefficients (Muramatsu *et al*., 2000) are the recent example of the land cover indices but its applicability in change detection application is not well examined. The objective of this study is to examine the usefulness of the CVA with the PD coefficients for deforestation detection in a tropical area. It is also intended to detect the deforestation at the Kinabalu area, Sabah, Malaysia.

2. METHODS

The study area, Kinabalu area, is located at the Northwestern part of Sabah, Malaysia, between 116° 15' and 116° 45' and between 6° and 6° 30'. It is a suburb area to the northeast of Kota Kinabalu, the capital of Sabah, Malaysia. The distinctive topographic features are narrow coastal plains and high mountain ranges. In 1964, Kinabalu Park (753.7km^2) was established as the first protected area in the state. The satellite images acquired are Landsat-MSS data on January 12th, 1973 (MSS73) and Landsat-TM data on June 14th, 1991 (TM91) and on April 8th, 1996 (TM96). The three common bands of the green, red and near infrared of the two sensors i.e. band 1, 2, and 4 for Landsat-MSS and band 2, 3 and 4 for Landsat-TM, are employed. Histogram matching is carried out to correct minor striping effect of the MSS73. The TM96 is first geo-referenced then the MSS73 and TM91 are co-registered to the TM96 where the RMSE of the registration are within one pixel. In this study, relative radiometric normalization to one reference image based on pseudo-invariant features (Schott *et al*., 1988) is adopted to remove at once all the inter-scene radiance variability due to factors mentioned, including atmospheric factors.

The basic premise of the PDA is a pixel can be decomposed into three components i.e. water, vegetation and soil, if and only if they exhibit distinctive patterns which are called spectral shape patterns. Thus, regardless the number of spectral bands, the PDA can be performed as long as the three distinctive patterns can be defined. Procedure of the PDA involves image endmember selection, within-scene normalization to spectral response patterns, derive standard spectral shape patterns, and decompose the spectral response patterns into the three components using the standard spectral shape patterns (Muramatsu *et al*., 2000). To extract the shape of the spectral response patterns, image endmembers have to be selected. For the water endmember, pixels of calm water at bay area are selected while pixels in the Kinabalu Park are selected for vegetation endmember. Bare sand, road and exposed granite rock surfaces are used. The relative radiometric normalization is strongly recommended as it greatly reduces the temporal fluctuation of the spectral shape patterns.

The CVA uses any number of spectral bands from multi -date satellite data to produce change images that yield information about both the magnitude and direction of differences in pixel values (which are proportional to radiance) (Michalek *et. al*, 1993). The magnitude of change is shown by the length of the vector, while the direction of change is shown by the angle. The CVA computes the total change magnitude per pixel by determining the Euclidean distance between the end points through n-dimensional space. An advantage of CVA is its ability to process any number of spectral bands desired. This is important because not all changes are easily identi fied in any single band or spectral feature. The CVA is applicable to any number of spectral bands, whether original scaled radiance, calibrated radiance or transformed variables. Transformation of the multisepctral data to some indices which represent vegetation and bare soil components is widely used in the CVA. The typical one is analyzing change vector within the plane of vegetation, defined by the greenness and brightness of the tasseled cap transformation (Kauth and Thomas, 1976). The vegetation and soil coefficients derived with the PDA are representative of the vegetation and bare soil required to detect changes over time. Instead of the tasseled cap transformation's brightness and greenness, the PD coefficients of soil and vegetation are employed in the CVA. Besides, the PD coeffcients of soil and vegetation are used in the image differencing techniques to examine the change detection power of the individual coefficient. The NDVI image differencing algorithm, a widely recognized algorithm, is also employed to serve as a comparison to the PD-coefficient-based algorithms.

3. RESULTS AND DISCUSSION

Selection of the best algorithm is carried out by assessing the performance of the four algorithms to detect changes between 1973 and 1996 at three test sites covered with aerial photographs. Each of the three sites is divided into 300m quadrates where a point is systematically placed at each quadrate. A series of thresholds are tested for the change detection accuracy at the three sites until the threshold with maximum khat accuracy is found for each algorithm. In total, there are 331 points for the image differencing algorithms and 176 points for the CVA as only change sector of clearing is assessed. Table 1 compiles the accuracy measures of the best two algorithms i.e. the NDVI image differencing and the CVA. Im general, the accuracy between the two algorithms is almost indifferent. However, the producer's accuracy of the NDVI image differencing is comparatively low compared to that of the CVA. Thus, the CVA is accepted as the best algorithm for deforestation detection.

For the whole study area, the CVA is used to detect the deforestation in two change periods i.e. 1: 1973-1991 and 2: 1991-1996. Although harvest at paddy fields is also detected, it is easily removed with the availability of a land use map in 1984 because the use of land for paddy cultivation has not been changed. In total, 2939 ha forest, which is

		NDVI	CVA
Khat Accuracy		67.89	67.35
Overall Accuracy		94.26	90.34
User's Accuracy	Change	100	88.46
	No Change	93.83	90.67
Producer's Accuracy	Change	54.76	62.16
	No Change	100	97.84

Table 1. Accuracy of the NDVI image differencing and the CVA Algorithms for Change Detection between 1973 and 1996

1.11% area of the study area, is cleared from 1973-1996 and most of them are deforested in the period 1 (2569ha) (Table 2). While the multi-sensor approach gives the deforestation estimate, the types, distribution and causes have to be investigated. The relatively large-scale deforestation occurs on well-stocked forest and is due to copper mining and commercial agricultural development. In fact, the copper mine is established at a-$25km^2$-forest excised from the Kinabalu Park in 1974. Both the mining and commercial agricultural activities concentrate at the areas near the southern part of the park. On the other hand, the small-scale ones are mainly on degraded forest or shrub and are due to slash-and-burn agriculture. The traditional practice scatters over the study area.

1973-1991	Change (ha)	2982.51
	No Change (ha)	262453.41
	% Change	1.12%
1973-1991 (False change pixels on paddy area removed)	Change (ha)	2569.05
	No Change (ha)	262866.87
	% Change	0.97%
1991-1996	Change (ha)	369.45
	No Change (ha)	265066.47
	% Change	0.14%
	Total Area (ha)	265435.92

Table 2. Deforestation at Kinabalu area in the Two Change Periods

4. CONCLUSION

The usefulness of the CVA with PD coefficients of soil and vegetation is examined rigorously in this study. It is revealed that the algorithm is superior to the other algorithms for deforestation detection. The PD coefficient can replace the greeness and brightness for the CVA for deforestation detection using a multi-sensor remote sensing approach. The deforestation at the Kinabalu Area from 1973 to 1996 is successfully detected using the algorithm. It is conceived that this algorithm is useful to deforestation detection in the tropics as well as other region.

5. REFERENCE

Kauth, R. J. and Thomas, G. S., 1976. The tasseled cap-A graphic description of spectral-temporal development of agricultural crops as seen by Landsat. Proceedings, 2nd. International Symposium on Machine Processing of Remotely-sensed Data, Purdue University, West Lafayette.

Michalek, J., Wagner, T., Luczkovich, J. and Stoffle, R., 1993. Multispectral change vector analysis for monitoring coastal marine environments. Photogrammetric Engineering and Remote Sensing, 59 (3), pp. 381-384.

Muramatsu, K., Furumi, S., Fujiwara, N., Hayashi, A., Daigo, M. and Ochiai, F., 2000. Pattern decomposition method in the albedo space for Lansat-TM and MSS data analysis. International Journal of Remote Sensing, 21 (1), pp. 99-119.

Schott, J., Salvaggio, C., and Volchok, W., 1988. Radiometric scene normalization using pseudoinvariant features. Remote Sensing of Environment, 26, pp. 1–16.

Singh, A., 1989. Digital change detection techniques using remotely sensed data. International Journal of

Remote

Sensing, 10 (6), pp. 989-1003.