

Mapping Paddy Rice Using Multi-Temporal MODIS Images

Chi-Farn Chen, Qing Chen, Li-Yu Chang, Chu-Yen Chen
Center for Space and Remote Sensing Research, National Central University
Jhongli City, TAIWAN.

Tel: (886)-3-422-7151 ext 57659 Fax: (886)-3-426-4301

E-mail: cfchen@csrsr.ncu.edu.tw, 92207439@nccu.edu.tw, lychang@csrsr.ncu.edu.tw,
annechen@csrsr.ncu.edu.tw

KEY WORDS: MODIS, EMD, Paddy rice

ABSTRACT

In this study, temporal MODIS data are used to classify double rice crops in Taitung, Taiwan. Empirical Mode Decomposition (EMD) is applied for data noise filtering. Three similar assessments, including minimum squared Euclidean distance (MSED), cosine similarity, and correlation coefficient methods, are utilized in the classification of double crops. The accuracy assessment of the double crops classification was evaluated. The results indicate that EMD is able to filter out the noises of the time series data and successfully preserve the temporal and spectral patterns for rice paddies classification.

1. INTRODUCTION

Remote sensing of the extent and distribution of individual crop types has proven useful to a wide range of end-users, including governments, farmers, and scientists. In recent years, a number of studies have been carried out using temporal MODIS data to identify crop patterns and to classify cropland areas. Because the noises generated by clouds, atmospheric effects and the sensors can degrade the spectral qualities of a time series images, several studies have been used to reduce the spectral noises in a time series images. For example, a procedure was developed by generating various masks for clouds, snow cover, water bodies, and forest cover in an effort to minimize their potential impacts. It utilizes a priori knowledge of the system's seasonality in order to mask the noise (Xiao *et al*, 2005). The frequency analysis studies have used the Fourier transform for separating the high-frequency components of noise and the low-frequency components of seasonal changes of VI. Because using series of annual harmonics can create spurious oscillations in a curve fit, it fails to remove high frequency noise caused by the long rainy season. (Galford *et al*, 2005). A wavelet-based filter method has been used to identify crop pattern across Japan. (Sakamoto *et al*, 2005). However, application of the wavelet filter can create distortion around the edges of the time series data, when the wavelet basis functions were used to reconstruct a signal (Sakamoto *et al.*, 2005). In

this study, Empirical Mode Decomposition (EMD) technique proposed by Huang et al. (1998) is used to perform the noise reduction for a time series of MODIS images. Because EMD can decompose a nonlinear and non-stationary time series data into intrinsic mode functions (IMFs), consequently, the noises and the significant information can be separately discovered in different IMFs. Then the rejection of the noisy IMFs will leave the significant IMF for further analysis. In this study, one of the main objectives is to decompose a time series of MODIS images and discover the spectral pattern of the double rice crops from the significant IMF. Another objective is to categorize the double rice crops by classifying the significant IMFs.

2. THE STUDY AREA AND THE GROUND TRUTH

The study site with area of 3,515 km² is located in Taitung County in Eastern Taiwan, between Carp Mountain, and the Pacific Ocean (Figure 1a). The positions of double rice, generated from aerial photographs, are used as the training data and the ground truth. In order to evaluate the accuracy of the proposed method, the double rice data is converted into the grid map with a 500 m spatial resolution (the pixel size of MODIS images). Figure 1b shows the ground truth map of the double rice paddy.

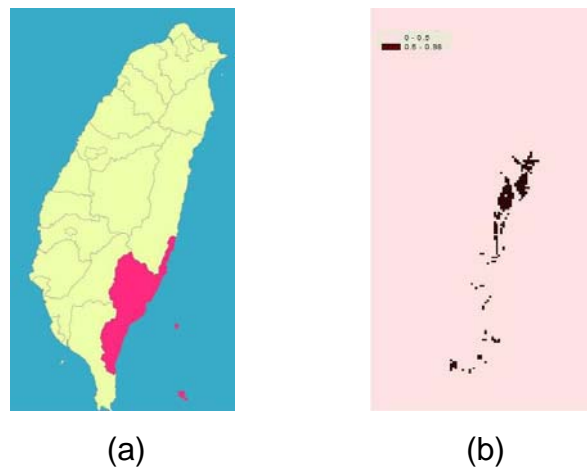


Figure 1. (a) Study area (red area) (b) ground truth of double rice

3. METHODOLOGY

Figure 2 shows a schematic presentation of the method used in this study. Basically EMD is utilized for noise filtering and the three similarity measurements are used for double rice crop classification.

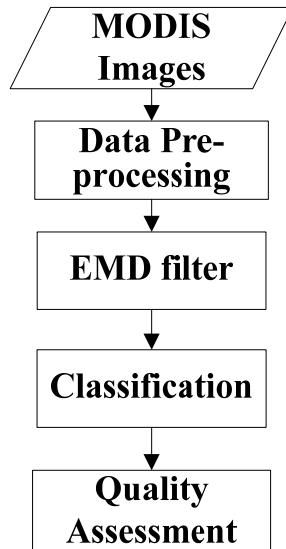


Figure 2. Schematic representation of the study method

3.1 Data Preprocessing

This study uses MODIS Surface Reflectance (MOD09A1) as the testing data. The data contains seven spectral bands at 500-meter resolution in an 8-day period. For the year 2007, there are forty-six MODIS data with image size of 200×100 pixels covered the study area. These MODIS images are then computed for Normalized Difference Vegetation Index (NDVI) and created a time series data for further analysis.

3.2 EMD Filter

In this step, errors of the time series data are reduced in order to reveal the information of the double rice crops. In general, such errors can come from noise recorded by the sensor, which is caused by the radiance absorption or emission of atmospheric particles during the energy transportation process. For the purpose of reducing the inherent noise, EMD-based noise filtering preprocessing of the images is proposed. EMD is an adaptive decomposition technique by which any complicated signal can be decomposed into a definite number of high frequency and low frequency components by means of a process called sifting. These components are called Intrinsic Mode Functions (IMF). These IMFs have well-behaved Hilbert transforms and can be defined as functions which: (1) have the same number of zero-crossings and extremes; and (2) the mean value of the upper and the lower envelopes is equal to zero. The decomposition of the signal into IMFs becomes a monotonic function until the final residual component when no more IMFs can be extracted. Then, after the investigation and evaluation of each mode, the significant information of double rice crops will be revealed. The EMD method is applied to smooth the NDVI profile for each pixel. Figure 3 shows an example of how the EMD is performed for a sample pixel. It is to detect the pattern of the double rice

crops from the smoothed NDVI profile (Figure 3b).

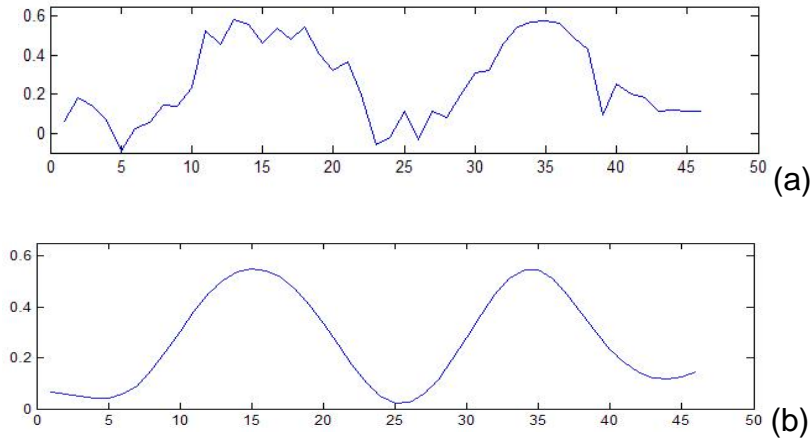


Figure 3. (a) Original time series of NDVI profile; (b) filtered NDVI profile by EMD

3.3 Classification

The similarity assessment process involves measuring the similarity of the time series data. In this study, we adopt three similarity assessments discussed below.

3.3.1 Minimum squared Euclidean distance (MSED)

MSED is a criterion used to describe the similarity of the pixels in a time series. The MSED value is calculated by considering the distance for each point in the curve. The squared Euclidean distance between X_i and Y_i is calculated with equation (1) utilizing a threshold determined from the rice paddy training data. If the unknown pixel in the time series is smaller than the threshold, it is identified as paddy rice

$$Similarity(X, Y) = \sum_i (X_i - Y_i)^2 . \quad (1)$$

3.3.2 Cosine similarity

Cosine Similarity is another method used for the classification of time series data. We consider the feature vectors for the pixels in the time series. We can calculate the cosine distance for the curves as shown in Equation (2). Therefore, the similarity between the two curves X_i and Y_i can be calculated as a combination of the cosine distances

$$Similarity(x, y) = \frac{\sum X_i Y_i}{\sqrt{\sum X_i^2 \sum Y_i^2}} . \quad (2)$$

3.3.3 Correlation coefficient

The correlation coefficient is a number between 0 and 1. The value can be calculated

with equation (3). If there is no relationship between X_i and Y_i , the correlation coefficient is 0

$$\rho_{XY} = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}} \quad (3)$$

After the similarity assessment process, the intensity image was generated. From the intensity image, each pixel in the image is compared with threshold which was determined by the training data of the double rice. Therefore, the threshold process can discriminate the double rice from other classes.

4. EXPERIMENTAL RESULTS

4.1 Classification of Rice-crop Area

Firstly, 50 of 250 pixels of the ground truth are selected as the training data of the double rice. The averages of NDVI of all 50 pixels are then calculated to characterize the time series pattern of the double rice. Three proposed similarity assessments are hence utilized to discriminate the double rice from other classes. The spatial distribution is showed of the double rice crop as derived from the MSED (Figure 4a), cosine similarity (Figure 4b) and correlation coefficient (Figure 4c) algorithms.

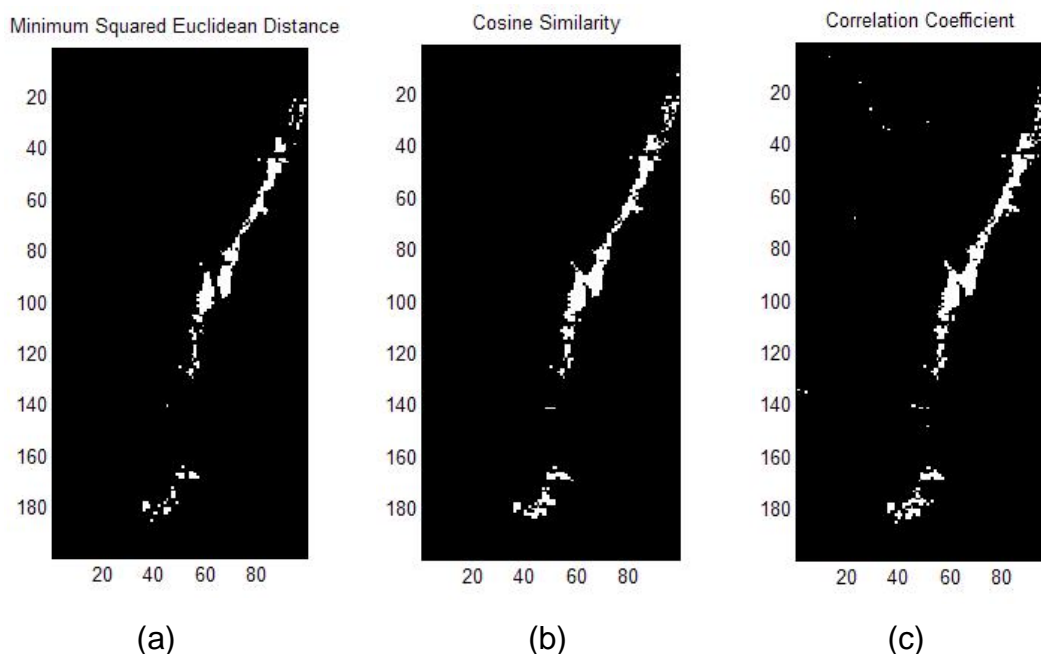


Figure 4. The spatial distribution of double rice classified by: (a) MSED; (b) Cosine Similarity; (c) Correlation Coefficient

4.2 Accuracy Assessment

The results of the classification are examined with the ground truth map (Figure 1(b)).

Table 1 shows the results of the accuracy assessment from three classification algorithms. It reveals that overall accuracy is 86% for MSED, 89% for cosine similarity and 90% for correlation coefficient, and the kappa coefficients are all above 0.7 for three algorithms.

Table 1. Accuracy assessment for the classification of the double rice

Similarity Algorithm	Producer accuracy (%)	User accuracy (%)	Overall accuracy (%)	Kappa
MSED	74.51	98.06	86.25	0.73
Cosine	79.9	97.6	89.0	0.78
Correlation	81.37	97.65	90.0	0.79

5. CONCLUSION

This study develops a two-step method for rice crop classification using 500-m temporal MODIS images. The method firstly requires a preprocessing operation to filter out noisy signals in a time series data. The EMD is used in the study to decompose the time series data into the noisy and significant IMFs. Then the spectral pattern of the double rice in a time series data is obtained from the significant IMF. Secondly, the similarity measurements are employed to compare the pattern of the double rice with the patterns of MODIS images. As a result, it is able to produce the double rice map from a time series of MODIS images. The comparison with the ground truth indicates that the overall accuracy is greater than 85% for the proposed method. It is anticipated that the study can be applied to assess the rice phenology at a large scale area.

REFERENCE

- Galford, G.L., Mustard, J.F., Melillo, J., Gendrin, A., Cerri, C.C., and Cerri, C.P., 2006. Wavelet analysis of MODIS time series to detect expansion and intensification of row-crop agriculture in Brazil, *Remote Sensing of Environment*, 112(2008):576-587.
- Huang, N.E., Shen, Z., Long S. R., Wu, M. C., Shih, H. H., Zheng, Q., Yen N. C., Tung, C. C., and Liu, H. H., 1998. The Empirical Mode Decomposition and The Hilbert Spectrum for Nonlinear and Non-stationary Time Series Analysis, *Proceedings of Royal Society of London, Series A* 454, pp903-995.
- Sakamoto, T., Yokozawa, M., Toritani, H., Shibayama, M., Ishitsuka, N., and Ohno, H., 2005. A crop phenology detection method using time-series MODIS data, *Remote Sensing of Environment*, 96 (2005): 366 – 374.
- Xiao, X. M., Boles, S., Liu, J., Zhuang, D., Frohling, S., Li, C. S., and Salas, W., 2005. Mapping paddy rice agriculture in southern China using multi-temporal MODIS images, *Remote Sensing of Environment*, 95(2005):480-492.