RICE CULTIVATION DATE ESTIMATION USING PROGRESSIVE ITERATION APPROXIMATION TIME SERIES MODIS IMAGERY

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Abstract: In Thailand, rice is important to economy. Information relevant to rice is critical to the government policy in the field of rice cultivation. These data include area of rice cropping, start planting date and harvest date which can be monitored by remote sensing. Remote sensing technique is used to record real data and can monitor in the long time from the initial planting to harvest. Monitoring of rice cultivation date based on Normalized Difference Vegetation Index (NDVI) which is derived from Moderate Resolution Imaging Spectroradiometer (MODIS) is phenology detection for estimating date of start season and date of end season. This study used MOD13Q1 which is a product of MODIS 16-day composite for monitoring rice cultivation in Thailand to estimate period of cultivation date. Unfortunately, MODIS data is contaminated with noise, thus, preprocessing is required in order to increase the accuracy of rice cultivation date estimation. This research is proposed to create smooth curve for estimation date by Progressive Iteration Approximation (PIA) using Bezier curve. Smoothing signal with PIA using Bezier curve is a new method to smoothing time series of MODIS. The smoothed time series can provide more accurate date estimation. The estimation from smoothed time series can identify period of rice cultivation for estimation of volume of rice product.

KEY WORDS: Rice crop phenology, Terra MODIS, PIA, Bezier curve fitting

1. INTRODUCTION

Rice is important to Thailand's economy. Rice growing areas cover all regions of the country. The rice cultivation in Thailand has two categories, rainfed rice and irrigated rice. The rainfed rice can be cultivated only one time in a year. It is cultivated in rainy season and has long crop cycle about 180 days or 6 month. On the other hand, irrigated rice can be cultivated several times in a year and has crop cycle shorter than rainfed rice. The main regions for rice cultivation are in the central and northeastern region of Thailand. In the central, the area is low-land and flat. The risk of flooding is higher than the northeastern region. After flooding the government will make an evaluation of the damage in rice fields; the cultivation date can be used in estimating crop process as well as crop yield in an agriculture support system [1]. To help farmer, the government must have accurate and up-to-date rice cropping information. The estimation cultivations date using Normalized Difference Vegetation Index (NDVI) which is derived from Moderate Resolution Imaging Spectroradiometer (MODIS) can be used to monitor rice growth from initial plant to harvest by reflection of an object in crop cycle

[2]. The NDVI profile is shown in Figure 1, in the initial stage there is increase from bare soil reflection to the green leaves reflection. In the growing stage, the NDVI increase with surface of green leaves increment. In the harvest stage, NDVI drops from peak because NDVI is changing by chlorophyll of leaves. And in the end of season, NDVI comes from bare soil reflection again.

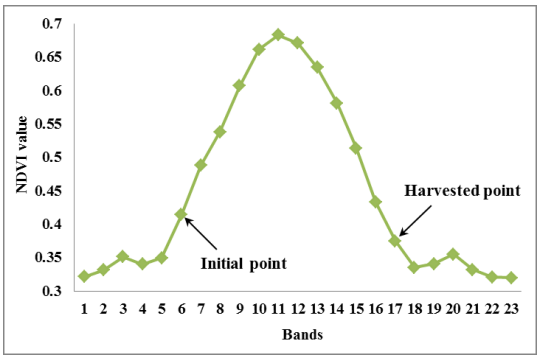

Figure 1: Phenology of rice from NDVI in rice crop season.

To use smooth NDVI time series to estimate period of rice cropping is not a new idea. This paper uses PIA by Bezier curve for smoothing NDVI data. The PIA is popular algorithm to curve fitting in computer graphic. This algorithm can smooth NDVI signal [3]. We use the smoothed time series to estimate cultivation date.

This paper uses smoothing NDVI 16-day composite at 250 meter of resolution to estimate and identify for initial date and harvested date by mean NDVI threshold. The NDVI time series is model as cosine function. We can use zero crossing point from mean value to identify initial date and harvest date of rice cropping.

2. STUDY AREA AND DATA DESCRIPTION

2.1 Study areas

In this study is focus on rice cropping area, the rainfed area and irrigated area in the central part of Thailand. Study areas is show in figure 2. The rectangle in figure is study area. The study area is located on the tropical grasslands, near the equator, with moderate rainfall, and occasional drought. Rainy season is during May to October to make enough water to grow for rice. In dry season, irrigation systems support cultivation that makes the area suitable for cultivation [4].

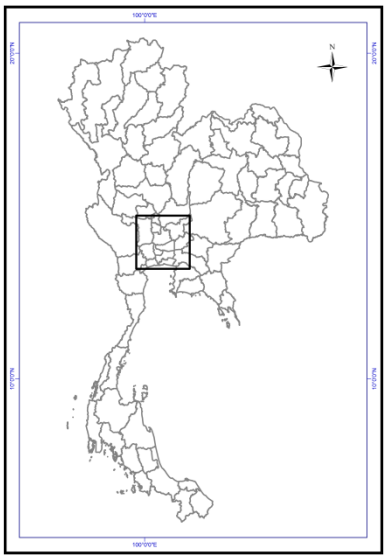

Figure 2: Study Area

2.2 Data Description

In this study, MOD13Q1 (Vegetation Indices) was used which is all about the vegetation index of the 16-day composite at resolution of 250 meters. The imagery covered a five-year time series, from 2006 to 2010 made to the phenology of the plant cover. The NDVI of MODIS is re-projected into Universal Transverse Mercator (UTM) Thailand in zone 47-48. The NDVI ratio is calculated by dividing the difference in the near-infrared (NIR) and red color bands by the sum of NIR and red color bands for each pixel in the image as follows:

$$NDVI = \frac{NIR\text{-}RED}{NIR+RED}$$

The NDVI data is dominant in vegetation. The NDVI Time series can show the dominant feature of signal illustrated in figure 3. Figure 3 showed signal of 115 NDVI data in one pixel from 1st January 2006 to 19th December 2010.

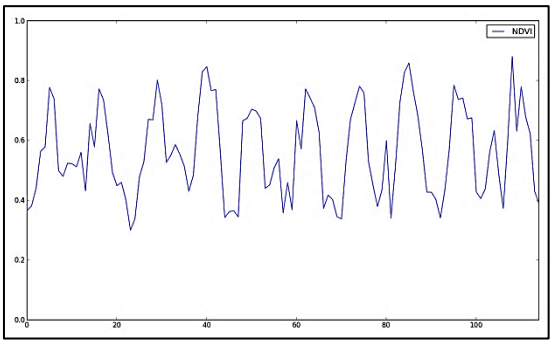

Figure 3: NDVI profile in one pixel from 2006 - 2010

2.3 Ground Truth

The rice growing data is derived from ground data of each province. This data showed the initial date and harvested date to compare with the estimated cultivation date with NDVI MODIS. The obtained data can be derived into 3 samples for rainfed and 2 samples for irrigated because the ground truth for comparison in period of study has five data. So we can compare data with ground truth for five samples only.

3. METHODOLOGIES

3.1 Progressive Iterative Approximation

Smoothing signal with Progressive Iterative Approximation by Bezier curve for rice phenology in Thailand with MODIS can smooth the signal. This signal can be used to estimate cultivation date by identifying initial date and harvest date. The PIA by Bezier curve is algorithm to curve fitting in computer graphic. The Bezier curve is from of parametric curve. A Bezier curve is defined by its control points and a Bernstein Polynomial. The Bezier curves can be represented by

$$B(t)= \sum_{i=0}^{n} c_i B_i^n(t)$$

where $\{c_i\}_{i=1}^{n}$ are control points and $B_i^n(t)$ is a Bernstein polynomial expressed as

$$B_i^n(t)= \binom{n}{i} t^i(1\text{-}t)^{n\text{-}i}$$

Progressive Iterative Approximation is a process of curve fitting. An approximated Bezier curve that fits a series of data can be obtained by using data point as control points [5]. The PIA has two set of control point, fixed and active control point [6]. The PIA by Bezier curve can calculate as follows

$$P^{k+1}(t)= \sum_{i=0}^{n} c_i^{k+1} \; B_i(t)$$

where updated control points are calculated from

$$c_i^{k+1}=c_i^k+\Delta_i^k$$

Difference vectors Δ_i^k are relative distances from sampling points to their corresponding updated control points, denoted by

$$\Delta_i^k=p_i - P^k(t_i)$$

where t_i is chosen as

$$t_i=\{0, \frac{1}{n\text{-}1}, \frac{2}{n\text{-}1}, \ldots, 1\}$$

Applying PIA by Bezier technique to the time-series data of rice cropping cycle can generate a parametric representation of rice cropping in Thailand which allows user to determine rice cropping situation in any specific of time.

3.2 Zero Crossing Method

Zero Crossing is commonly used term in electronics, mathematics, sound and image processing. The zero crossing is point where change sign of value from negative to positive or inverse, represented by a crossing of the axis (zero value). The mean value of NDVI can be used to detect crossing point from PIA smoothed signal. The position of crossing is identifying to initial date and the harvest date respectively.

4. RESULT AND DISCUSSION

This section shows the experimental result from applying the methodology to estimate cultivation date using NDVI time series. The NDVI time-series data which is smoothed by PIA by Bezier curve and NDVI raw data are plotted together in figure 4(A) for rainfed rice and in figure 4(B) for irrigated rice.

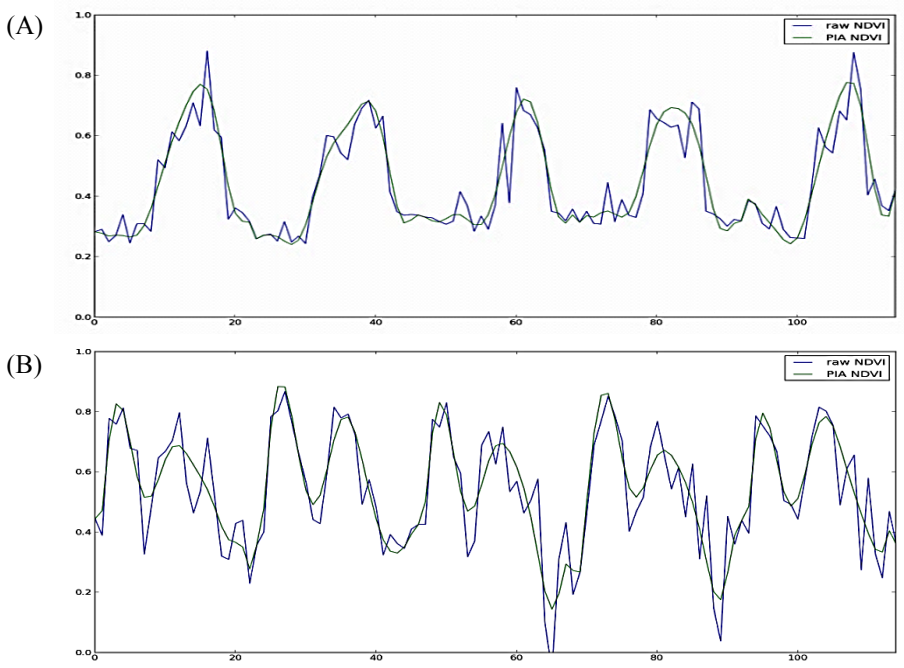

Figure 4: (A) Raw NDVI time series and PIA smoothed NDVI time series in rainfed rice from 2006 – 2010 (B) Raw NDVI time series and PIA smoothed NDVI time series in irrigated rice from 2006 - 2010

The raw NDVI data is very noisy. The PIA by Bezier curve smoothed NDVI data appears to be less noisy and smooth. In this work, we choose threshold from mean value of each pixel. Figure 5 showed the corresponding cultivation dates for rainfed rice and irrigated rice respectively.

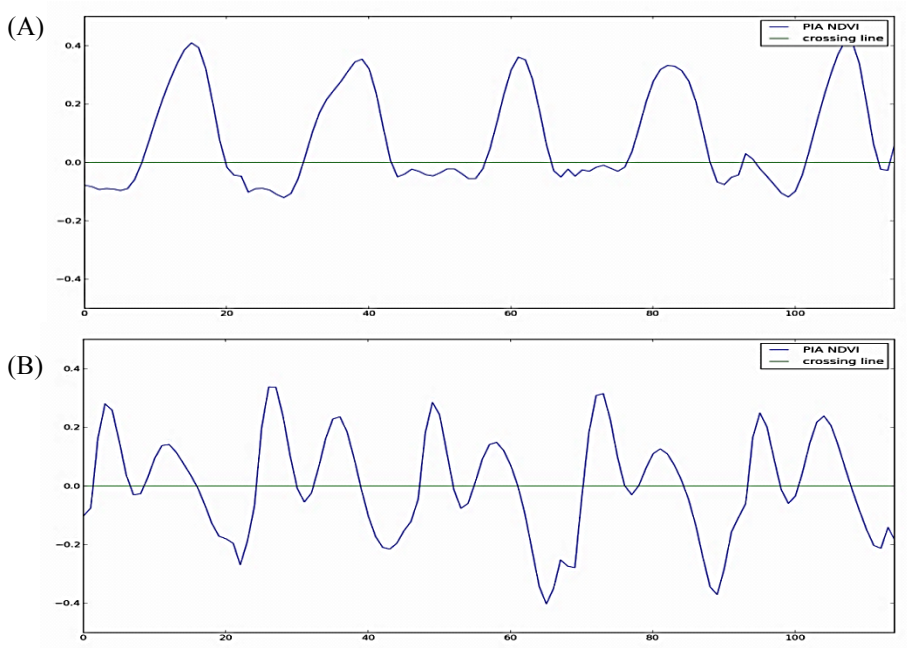

Figure 5: (A) PIA smoothed NDVI time series and crossing line with threshold by mean value and rainfed NDVI time series with estimated cultivation dates
(B) PIA smoothed NDVI time series and crossing line with threshold by mean value and irrigated NDVI time series with estimated cultivation dates

The result of comparing with ground truth and proposed methodology is shown in Table 1. The estimate cultivation date of ground truth and estimation result showed initial date and harvest date from 2006 to 2010. Smoothed NDVI by PIA to estimate cultivation date with mean value crossing has results which is close to ground truth. In the Table, test site no.1, 2 and 4 are rainfed rice area and test site no.3 and 5 are irrigated rice area. The errors are in 16 day because we used 16-day composite. The error is acceptable. In test site no.2, the initial date of estimation result was detected before ground truth 1 day. In test site no.3, the second cropping has error in harvested date of estimation result was detected before ground truth 10 day. In test site no.4, the harvested date of estimation result was detected before ground truth 12 day. In test site no.5, the cropping in 2008 has error in initial date of estimation result was detected before ground truth 9 day and harvested date of estimation result was detected before ground truth 2 day. The other estimation cultivation date using PIA smoothed NDVI was detected after ground truth date. One limitation of experimental result is frequency of data collection. The increase in accuracy may be obtained by more frequent data collection.

TABLE 1: COMPARING DETECTION INITIAL DATE AND HARVEST DATE BETWEEN PIA SMOOTHED SIGNAL NDVI AND GROUND TRUTH

Test site no.	Ground truth		Estimation result	
	Initial Date	Harvested Date	Initial Date	Harvested Date
1	05/05/2007	24/08/2007	09/05/2007	29/08/2007
2	23/03/2007	09/07/2007	22/03/2007	12/07/2007
3	22/01/2007	17/05/2007	02/02/2007	25/05/2007
	12/08/2007	27/11/2007	13/08/2007	17/11/2007
4	23/06/2008	11/10/2008	25/06/2008	29/09/2008
5	02/06/2008	30/08/2008	24/05/2008	28/08/2008
	03/01/2009	21/04/2009	17/01/2009	23/04/2009

5. CONCLUSION

In this study, how to estimate cultivation date from PIA smoothed NDVI time series on rainfed rice and irrigated rice has been purposed. PIA is algorithm for curve fitting in computer graphic. We use data from PIA smoothed NDVI time series for estimating cultivation date by mean value. The calculation of cosine function can detect the results by zero-crossing method. This process can apply to rainfed rice and irrigated rice. The experimental result showed that PIA smoothed NDVI time series can detect and identify cultivation date. The estimate cultivation date is closely characterized of cultivation in rice phenology stage. The error of estimation is problem from frequency of collection data. In the future, more frequent collection data may give better result to estimate cultivation date.

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