TIME SERIES ANALYSIS OF SPOT NDVI FOR IDENTIFYING IRRIGATION ACTIVITIES AT RICE CULTIVATION AREA IN SUPHANBURI PROVINCE, THAILAND

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Abstract: In this paper, the real scenario of water situation (e.g. water management, water availability and flooding) in an irrigated rice cultivation area in Suphanburi Province, Central-West Thailand is discussed together with the NDVI time series data. The result shown is derived by our classifier named "Peak Detector Algorithm (PDA)". The method discriminated 5 classes in terms of irrigation activities and cropping intensities, namely, Non-irrigated, Poorly irrigated – 1 crop/year, Irrigated – 2 crops/year, Irrigated - 3 crops/year and Others (no cultivation happens in a year or other land covers). The overall accuracy of all classified results (1999-2001) is around 77% against independent ground truth data (general activities or function of an area). In the classified results, spatial and temporal inconsistency appeared significantly in the Western and Southern areas of Suphanburi. The inconsistency resulted mainly by anomaly of rainfall pattern in 1999 and their temporal irrigation activity. The algorithm however, was proved that it could detect actual change of irrigation status in a year.

Keywords: SPOT NDVI time series, Irrigation activity, Irrigated rice cultivation, Suphanburi province.

1. Introduction

Rice, the most important cereal crop in Thailand and other Asian countries, has been grown covering the major areas of agricultural cropping and irrigation. It is important to know the actual irrigated area or where water is supplied to grow rice outside rainy season for a better understanding of current rice production and evaluation of scenarios of future demand and water development.

Our study dealt with rice cultivation practices in Suphanburi province - irrigated or non-irrigated, homogeneous or heterogeneous field configurations and numbers of crops grown per year were analyzed. A method for exclusively discriminating irrigated and non-irrigated (rainfed) rice (oryza savita) cultivation areas at provincial/regional scale named "Peak Detector Algorithm (PDA) was developed (Kamthonkiat et al., 2005, 2004 and 2003). The algorithm is mainly based on Normalized Difference Vegetation Index (NDVI) of SPOT-VGT and rainfall data which are easily available at low cost in most of the regions.

2. Study Area

Suphanburi province is located in the Central-West of Thailand (Figure 1) between 14° - 15° of North latitude and 99° - 100° of East longitudes and occupies an area of around 5,358 square kilometers. Suphanburi is a low flat province, except on the western side where its approaches the mountains of Kanchanaburi and Uthai Thani.

The hot season in the province occurs from February to May, with the highest temperatures reaching around 40.6 ^{0}C in April. The southwest wind prevails over Thailand, while the monsoon moves up and lies across Northern Thailand and bringing rains in Suphanburi at the end of May and which finish about June-July. The rainy season ends about October, giving an average annual rainfall of around 1,300 mm. The cool or dry season starts at the end of October and continues to mid February with the lowest temperature hovering around 17.7 ^{0}C in December.

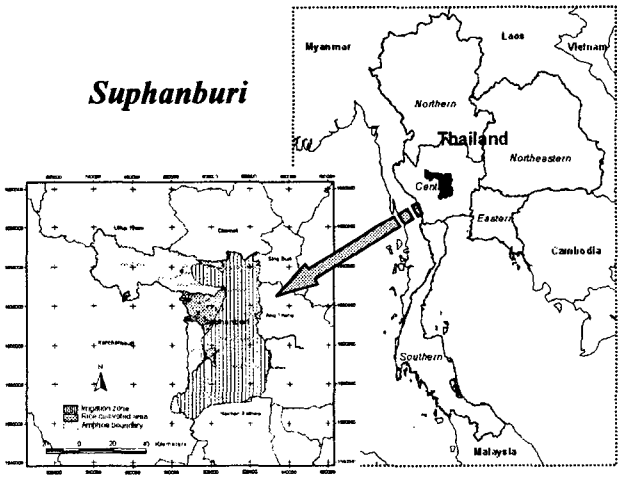

Figure 1 Study area – Suphanburi province, Thailand.

The dominant agricultural activity in this area is rice cultivation, both with and without irrigation. There are 2 major types of rice planted in Suphanburi province. The first type covers around 120 days per crop cycle, while the second covers around 110-115 days per crop cycle. Farmers generally plant the same type of rice in the same field. The shorter duration rice is popular for 2-3 crops grown per year in some irrigated areas in the central and parts of upper Suphanburi.

3. Data and Methodology

Based on SPOT-VGT; NDVI time series of Local Maximum Fitting – LMF (Sawada et al., 2000) processed data (1999-2001) and 10 years averaged rainfall data, PDA was developed to identify number of vegetative peaks (Reed et al., 1994) based on the relationship (time lag) between peak of rainfall and peak of NDVI. From our observation, the value of rice's peak (peak value of

NDVI) is always equal or higher than 0.55. Peaks lower than 0.55 hence are not considered or counted. There is a high correlation at a 40-50 day lag, between a peak rainfall and a 'single' peak NDVI of rainfed rice. In irrigated areas, there are multiple peaks, and multiple correlations with low values for at least 90 days after peak rainfall. This classifier algorithm was developed in Interactive Data Language (IDL) - Version 5.6. It was applied on yearly basis to SPOT NDVI time series data from 1999 to 2001 for discriminating 5 classes in terms of irrigation activities and cropping intensities, namely, Non-irrigated, Poorly irrigated – 1 crop/year, Irrigated – 2 crops/year, Irrigated - 3 crops/year and Others (no cultivation happens in a year or other land covers). The methodology currently uses a mask to remove un-cropped and non-rice areas, which is derived from existing Geographic Information Systems (GIS) data (Land use). The classified results are validated by using field survey data. Surveys include Global Positioning System (GPS) measurements, digital photographs of the land use and interviews with local officers and farmers to get more information about agricultural practices.

4. Results and Discussions

The classified results consist of 5 classes, Non-irrigated (CLASS 1), Poorly irrigated - 1 crop/year (CLASS 2), Irrigated - 2 crops/year (CLASS 3), Irrigated - 3 crops/year (CLASS 4), and Others (CLASS 5). Figure 2 shows the classified results of year 1999-2001 shown by overlaying boundary of Suphanburi province and the irrigation zone.

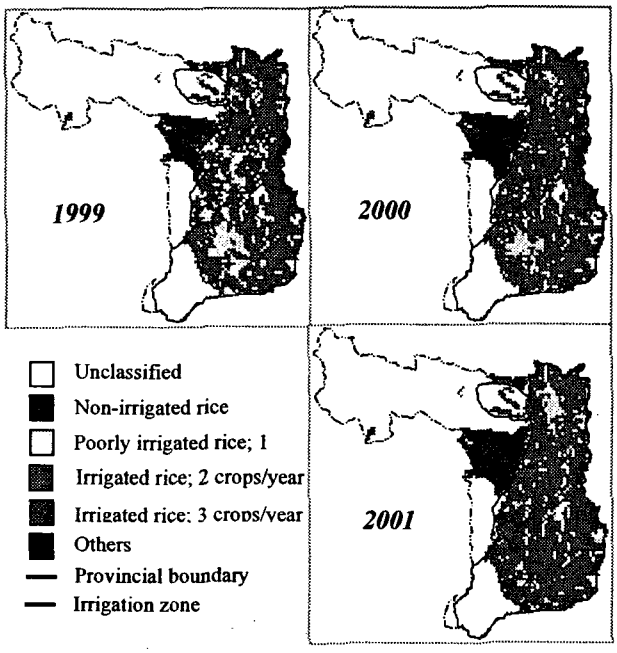

Figure 2 Classified results; 5 classes in 1999-2001

The validation was done by using 39 ground truth points (Non-irrigated rice = 13, Poorly irrigated rice = 3, Irrigated rice 2 crops/year = 12, Irrigated rice 3 crops/year = 8 and Others = 3). The accuracies of the classified results of years 1999-2001 are 64.1%, 79.5% and 87.2% as shown in Table 1-3.

Table 1 Result of the Validation in 1999

	1999					
Overall Accuracy	**64.1 %** (25/39)					
Kappa Coefficient	**0.53**					
Ground Truth (Percent)						
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	Total
non-irri rice	61.54	0	0	0	0	20.51
poorly irri rice	23.08	66.67	25	0	33.33	23.08
irri rice 2 crops	15.38	33.33	66.67	37.5	0	35.9
irri rice 3 crops	0	0	8.33	62.5	0	15.38
others	0	0	0	0	66.67	5.13
Total	100	100	100	100	100	100
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	
Commission (Percent)	0.00	77.78	42.86	16.67	0.00	
Omission (Percent)	38.46	33.33	33.33	37.50	33.33	

Table 2 Result of the Validation in 2000

	2000					
Overall Accuracy	**79.5 %** (31/39)					
Kappa Coefficient	**0.72**					
Ground Truth (Percent)						
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	Total
non-irri rice	84.62	0	0	0	0	28.21
poorly irri rice	0	33.33	0	0	0	2.56
irri rice 2 crops	15.38	66.67	83.33	25	0	41.03
irri rice 3 crops	0	0	8.33	75	0	17.95
others	0	0	8.33	0	100	10.26
Total	100	100	100	100	100	100
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	
Commission (Percent)	0.00	0.00	37.50	14.29	25.00	
Omission (Percent)	15.38	66.67	16.67	25.00	0.00	

Table 3 Result of the Validation in 2001

	2001					
Overall Accuracy	**87.2 %** (34/39)					
Kappa Coefficient	**0.83**					
Ground Truth (Percent)						
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	Total
non-irri rice	92.31	0	0	0	0	30.77
poorly irri rice	0	66.67	0	0	0	5.13
irri rice 2 crops	7.69	0	83.33	12.5	0	30.77
irri rice 3 crops	0	33.33	8.33	87.5	0	23.08
others	0	0	8.33	0	100	10.26
Total	100	100	100	100	100	100
Class	non-irri	poorly irri	irri 2 crops	irri 3 crops	others	
Commission (Percent)	0.00	0.00	16.67	22.22	25.00	
Omission (Percent)	7.69	33.33	16.67	12.50	0.00	

The highest omission of Non-irrigated rice in 1999 was found for Poorly irrigated rice (In a year 1 crop was grown in dry season or independent of rainfall) in the western Suphanburi where non-irrigated area is adjacent to the irrigated area. The anomalous pattern of rainfall in 1999 affected cropping activities in the area especially

planting period of Non-irrigated rice that absolutely depends on rainfall. Based on 10 years data (1993-2002) of Suphanburi that was used in this study (Figure 3), the total amount of rainfall in 1999 was the highest (1342.8 millimeters). Also its peak appeared in May (dry season) instead of the averaged time at the end of September (that represents pattern in this study) as shown in Figure 4.

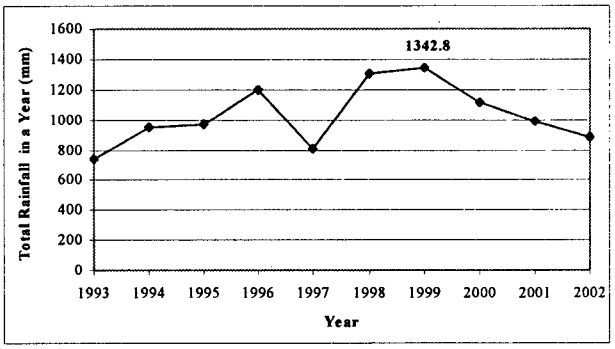

Figure 3 Total rainfall amount of Suphanburi province during 1993-2002.

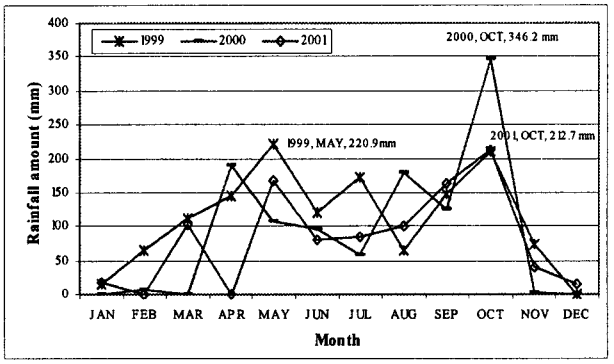

Figure 4 Monthly rainfall patterns of Suphanburi province during 1999-2001.

Some farmers grew up rice utilizing this unusual rainfall but skipped growing the second rice in wet season as the period of harvesting of the first crop in 1999 was overlapped the period of growing usual cropping season of non-irrigated rice (July-August). At some locations, two crops were taken in year 1999 because of availability of high amount of water due to anomalous rainfall pattern in the year.

Since 10 years averaged rainfall data was used for the classification in stead of rainfall data in each year, the time lag between the peak of rainfall and NDVI was not calculated correctly if farmers grew only one crop in earlier time (before the end of September) or if they grew two crops, NDVI fluctuation will have 2 peaks making the algorithm identify the class to be irrigated although the area was not irrigated.

The small areas of western Suphanburi and some of the adjacent areas in the north where water is transferred by underground and nearby irrigation facilities were classified as irrigated (2 crops per year) for three years (1999-2001).

High confusion among CLASS 2, CLASS 3 and CLASS 4 was found as number of crops grown varied from 1 to 3 crops per year in the irrigated area. Poorly irrigated rice (CLASS 2) was confused with Irrigated rice 2 crops per year (CLASS 3) in 1999-2000 while confused with Irrigated rice 3 crops per year (CLASS 4) in 2001. The Poorly irrigated rice was found at the low flat terrain in the southern Suphanburi as flooding always occurs in this area in wet season resulting in low density (not growing in full extent) or no cultivations during wet season.

Figure 5 presents the variations of 1-2 cropping grew per year in the Middle-Southern of Suphanburi, the low flat terrain where flooding often occurred in wet season. Based on the interviews with farmers, the second crop in this area was damaged by flood or skipped. The NDVI fluctuation curve shows variation of single to two peaks in a year. The small peak in 2000 reflects the lower density cultivation (the cultivation was not covered to full extent) or flooding in the rice fields.

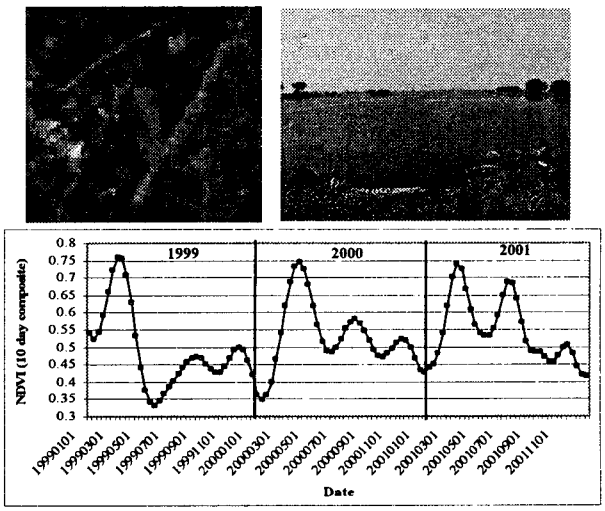

Figure 5 Irrigated rice cultivation; 1-2 crops in a year

Some locations in the southern Suphanburi, which are located at the tail of irrigation system, were identified as non-irrigated rice cultivation areas because of water scarcity and delayed delivery of water hinders farmer from growing dry season crop (the first crop).

The mixed cultivation of rice and horticultures (vegetables flowers, etc.,) in small patchy (heterogeneous) fields of Irrigated rice (2-3 crops per year) showed lower amplitude of curve having peak value less than 0.55 in some cases

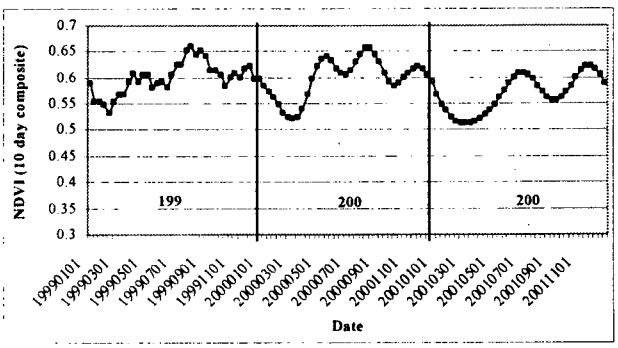

Figure 6 Irrigated rice cultivation; 2-3 crops in a year

In Figure 6 the shape of NDVI curve of 2-3 rice crops and mixed cultivations in the heterogeneous fields appears to be small and incomplete because of the overlapping cropping seasons (growth stages) in the area.

The omission of the class 'Others' (the areas not corresponding to the criteria of PDA) occurred in 1999, one pixel of Others was classified as Poorly irrigated. While the commission occurred in 2000 and 2001, one pixel of Irrigated rice 2 crops per year of both years was classified as Others. Figure 7 shows the locations of Others for three years where the area of rice cultivation has been invaded by fisheries. The NDVI fluctuation curve of non-rice or mixed land uses is less than 0.55 thus no peak was detected by PDA.

5. Conclusions

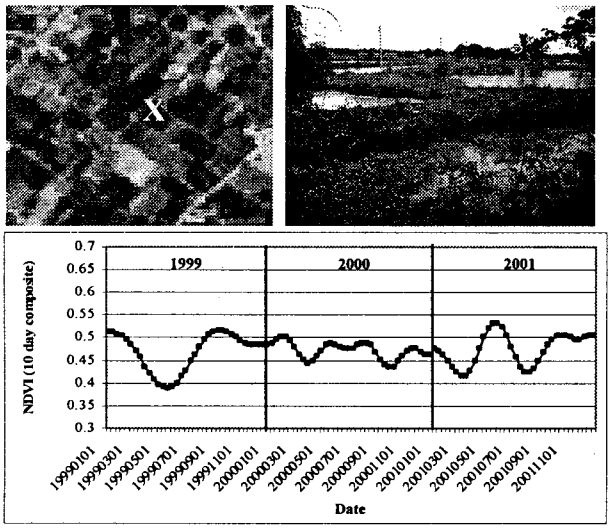

Figure 7 Class 'Others', the mixing of rice cultivation and fishery areas

Peak Detector Algorithm is found to be promising for applications at provincial scale to discriminate the crops. It performed good classification within rice crops in Suphanburi province. The overall accuracy of all classified results (1999-2001) is around 77% against independent ground truth data (general activities or function of an area). Although, non-rice crop appeared in the classification process, it showed less effect to the accuracy of results as PDA could identify 'Others' from rice. The NDVI fluctuation curve of non-rice or mixed land uses is less than 0.55 thus no peak was detected by PDA.

PDA, however, faced difficulties in identifying irrigated and non-irrigated rice when an anomalous rainfall occurs during the period of observation years. The algorithm was proved that it could detect actual change of irrigation status in a year. Crop diversification in rice-based systems (other crops are cultivated in the rice fields) also affects the shape of NDVI curve, the occurrence of irregular shape and small peak value with less than 0.55. Among the diversified crops grown, upland crops are predominant and contributory to about 40 percent of the total cropped area. Soybean, mungbean, groundnut, taro and vegetables are the popular cash crops grown in the Central Plain after rice cropping in a year.

6. Recommendations

This methodology still uses a mask to remove un-cropped and non-rice areas, which is derived from existing GIS. Regionally available data such as Global Land cover Data (GLC2001 or more up to date versions) and monthly rainfall data should be replaced to local land use and daily (10 day aggregated) rainfall data for developing the methodology towards regional/global scale applications.

7. Acknowledgement

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