Rice Crop Calendar Based on Phenology Analysis from Time-series Images

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***Abstract*—In 2012, GISTDA has launched a sensor network project for monitoring agricultural fields in every region of Thailand. Integration of digital camera and weather sensors, Field Server (FS) is used to collect two types of data; image and weather condition. In this study, time-series images acquired from the rice field are used for computing and understanding the rice crop calendar. A proposed diagram consists of rice field segmentation (A), phenological computation (B) and analysis (C), rice crop calendar (D). The proposed diagram can be used to classify single and double crop cycles, which are the major types of cultivated areas in Thailand. A significant information for yield estimation model, start and end of growing season (SOS, EOS), can also be determined by using our approach.**

***Keywords*—Phenology, Rice field, Crop calendar, ExG index, Field Server**

I. Introduction

In a recent year, an advanced agricultural system becomes an interesting research topic. The advanced system can be used for supporting several tasks such as *field monitoring, analyzing, yield prediction, etc.* It can also be used for different levels of users for example *farmer, farm manager, trader, policy maker, etc.* One of requirements for smart farming system is field monitoring which can be used to obtain and collect the information from the agricultural fields. Referring to existing systems, there are several systems that have been developed for monitoring in different objectives such as *climate change* [7], *forest observation* [5], [6], [8], *farm monitoring* [2], [6], [9].

Fig. 1. Field Server (FS) is installed in the rice field.

Geo-Informatics and Space Technology Development Agency (GISTDA) has launched a sensor network project [11]. The objective is to directly collect and record the data from agricultural fields for instance rice, cassava, sugar cane, para rubber, etc. Instead of field survey staffs, in figure 1, an equipment called Field Server (FS) is installed in the agricultural field for a very long period [10], [11]. As shown in figure 2, the data obtained from FS can be separated into two types 1) daily images 2) weather condition. The data is uploaded to central server which can be accessed and obtained via a web service. Until February 2014, there are twenty-four stations of FS installed in every region of Thailand. Referring to GISTDA's sensor network, 11 of 24 stations are used for monitoring in the rice fields. In this study, we focus on the daily images acquired from the rice fields. Regarding to the image processing techniques, the period of rice cultivation can be computed and obtained. Considering to the rice cultivation, it can be separated into single-crop and double-crops which mean 1 and 2 cycles per year, respectively. This is also known as rice crop phenology. In general, single-crop fields are cultivated in Northeast of Thailand and other non-irrigated areas. 2-crops fields are located in Central of Thailand, which are mostly supported by the irrigation system. As shown in figure 3, a simulation shows that the rice crop cycle can be explained by phenological vegetation.

The paper is organized as follows: Section 2 discusses about related work. Section 3 describes a diagram of rice crop calendar. Section 4 shows the experimental results. The types of cultivation and crop calendar can be determined. Section 5 provides the conclusions and future work.

II. Related Work

This section is separated into two parts. For the first part, existing camera networks used for acquiring the images from observed areas will be listed. For the second part, the phenological vegetation obtained from RGB images will be described.

A. Camera networks

Referring to near-surface remote sensing, digital camera can provide the ecological information. Camera networks are developed for obtaining the information in a wide region. A set of time-series images (or video sequences) is used for understanding the changes of observation area. Existing systems used to obtain the images are listed as follows:

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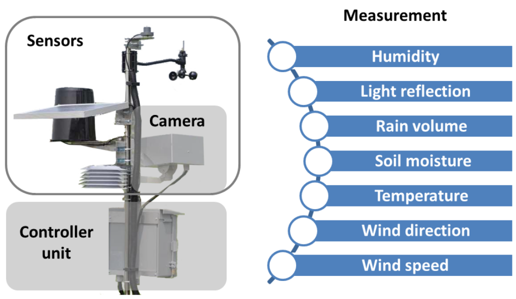
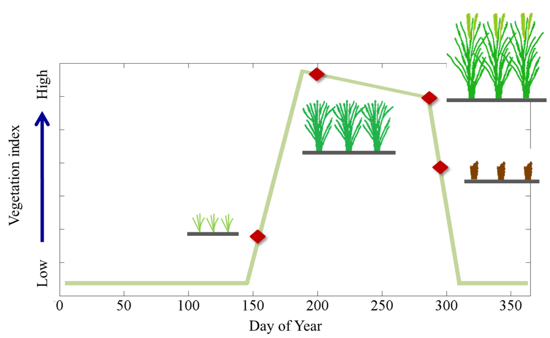
(a) Daily images acquired from the rice field.

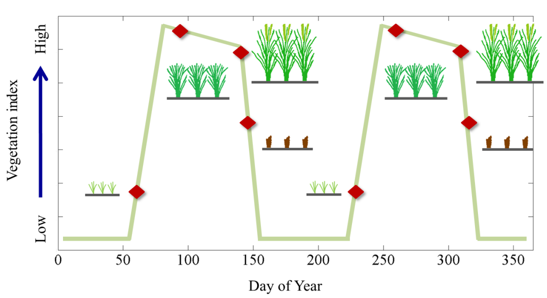


(b) Weather condition measurement

Fig. 2. Two types of data collected using FS.



(a) Single-crop per year



(b) Double-crops per year

Fig. 3. A simulation of rice crop cycle based on phenological vegetation.

- National Ecological Observatory Network: NEON or AmeriFlux http://ameriflux.ornl.gov/ (accessed May,15 2015)
- AsiaFlux [7] http://asiaflux.net/ (accessed May,15 2015)
- Phenological Eyes Network: PEN [6] http://phenocam.sr.unh.edu/webcam/ (accessed May,15 2015)
- Internet Nature Information System, Japan [1] http://www.sizenken.biodic.go.jp/ (accessed May,15 2015)
- Etc.

B. Phenology from RGB images

Given RGB images captured from the digital camera, it composed of red, green and blue channels. The phenology computed from RGB images were proposed in several literatures [2]–[4], [14], [16]. It is represented as the levels of vegetation index in a period. Comparison of three vegetation indices [10] shows that ExG index is more efficient in estimating the stages of rice field than the other two (NGRDI, ExGR). ExG index is calculated by using eq. 1.

$$ExG = 2 \cdot g - r - b \tag{1}$$

When r is a normalized of R component, $r = R/(R+G+B)$
g is a normalized of G component, $g = G/(R+G+B)$
b is a normalized of B component, $b = B/(R+G+B)$

Referring to recent works, image processing techniques are applied for the time-series images obtained from the rice field for example height measuring [13]. Rice growing stages are classified based on the phenological vegetation, which consist of seedling, tillering, heading and harvesting [10], [15]. The growing stages can also be determined and classified by using texture feature [12].

III. Rice Crop Calendar

As shown in figure 4, a diagram of rice crop calendar consists of AOI–rice field (A), Phenological computation (B), Phenological analysis (C) and Crop calendar (D).

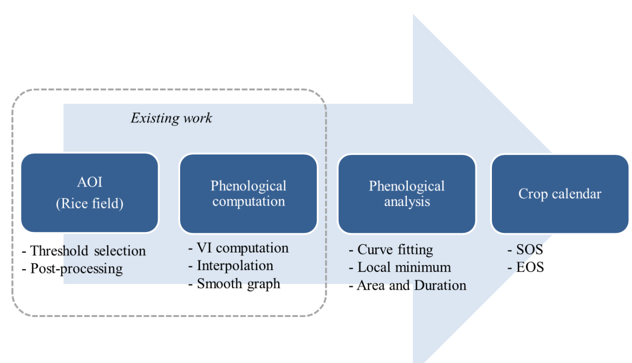


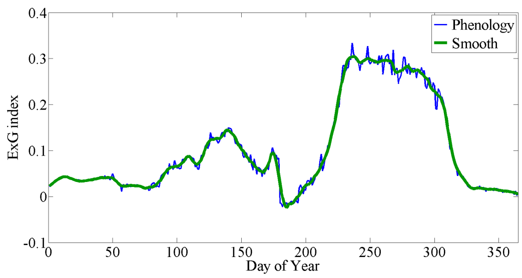
Fig. 4. A diagram of rice crop calendar modeling.

A. AOI–rice field

AOI (Area of Interest) is defined for the rice field region on each image. The rice field is detected and segmented by using an amount of green level, which is a type of threshold selection [10]. The binary mask is required for reducing noise by post-processing techniques (e.g. dilation, erosion, size filter). The result is shown in figure 5a.

Rice field image　　Result of rice field region

(a) AOI–rice field



(b) Phenological computation

Fig. 5. Phenology obtained from daily images [10].

B. Phenological computation

For the phenological computation, the vegetation index is preliminarily calculated on time-series images. Similar to the strategy of [10], ExG index is used as the vegetation index. As shown in figure 5b, the ExG values are plotted on temporal axis by referring to Day of Year (DOY).

C. Phenological analysis

The phenological analysis is used to separate the phenology curve into subcurves. Then, the phenology subcurves are classified between cultivated and non-cultivated periods. The analysis method consists of curve fitting, local minimum, area and duration.

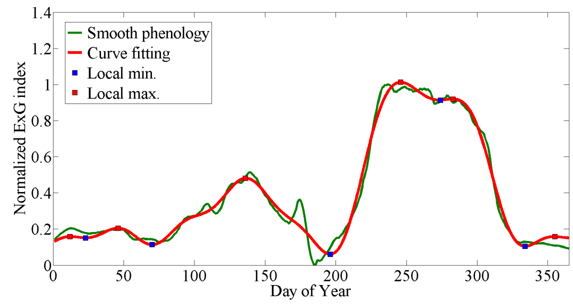
• *Curve fitting*: Fourier series with order 8 (given $N = 8$ in eq. 2) is used for fitting the phenology curve, which is efficient for 1 and 2 crop cycles. The number of order should be increased for 2.5 crop cycles or more.

$$f(t) = a_0 + \sum_{n=1}^{N} a_n \cdot cos(n \cdot \omega t) + \sum_{n=1}^{N} b_n \cdot sin(n \cdot \omega t) \quad (2)$$

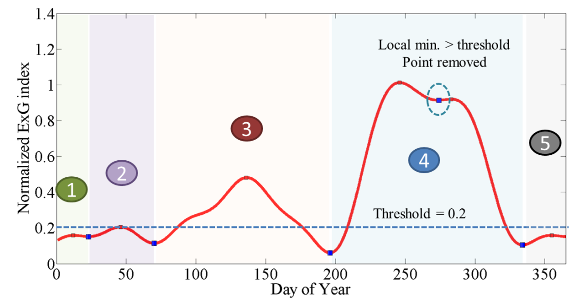
Where a_0, a_n, b_n are known as Fourier coefficients.

• *Local minimum*: The local minimum points are computed on the fitted curve. The points can be used to determine subcurves periods as shown in figure 6a. In order to obtain the complete subcurves, some points less than a threshold value are removed. As shown in figure 6b, the subcurves are separated into five periods.

• *Area and Duration*: To separate between cultivated and non-cultivated periods, area and duration of each subcurve are calculated and used for classification. For the cultivated period, high area and duration are found on the subcurves. The other characteristics are defined as the non-cultivated period. Comparison of five subcurves (#1 – #5) in figure 7, the subcurve #4 is classified to the cultivated period. The other ones are classified to the non-cultivated periods. The classification is based on the threshold selection technique. It should be noted that the subcurve #3 presents some computation area because of weed. This is also the non-cultivated period.



(a) Curve fitting and local minimum.



(b) Subcurves are determined by local minimum points.

Fig. 6. Phenological analysis

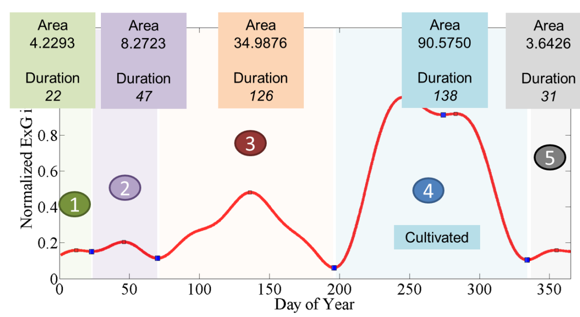


Fig. 7. Classification of cultivated subcurve.

D. Crop calendar

Crop calendar is an algorithm to determine the start and end of growing season (SOS and EOS) on each cultivated period. The subcurve is also fitted by using Fourier series in eq. 2 as shown in figure 8. This is a re-calculated process in order to obtain the accurate SOS and EOS. Then, accumulated area under the cultivated curve is computed for the crop calendar. Given a curve with normal distribution, the points at 5% and 95% of accumulated area are used as the SOS and EOS, respectively.

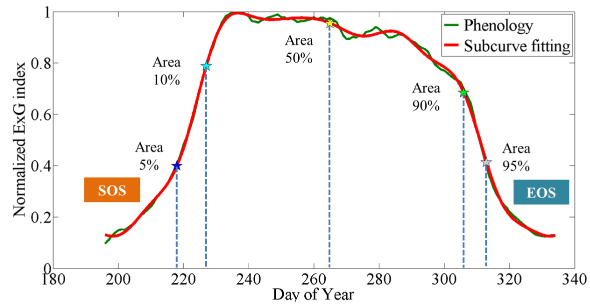
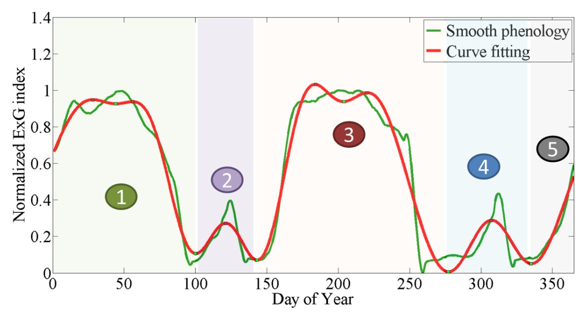


Fig. 8. SOS and EOS are 5 % and 95 % of accumulated area, respectively (see in Section IV, table I–Roi et).

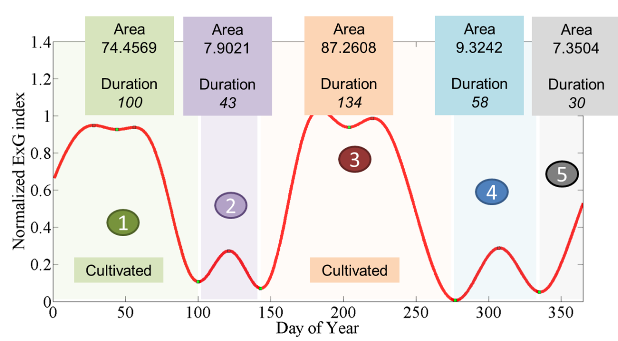
IV. Experiments

Given the phenology computed from daily images, in our study, the rice crop calendar can be separated into two types: single crop, double crops. Regarding to the FS stations, the images from 8 sample rice fields are used for the experiments. In table I, the SOS and EOS obtained from our approach are presented by referring to DOY.

For an example result of double crops, the phenological analysis is shown in figure 9. Based on our classification, subcurve #1 and #3 are defined as the cultivated periods. The calculation of SOS and EOS is shown in figure 10 (see also table I–Suphanburi #2). Weeds detected on subcurve #2 and #4 are classified to the non-cultivated periods. The weeds generally have low values of area and duration.



(a) Curve fitting and subcurve periods.



(b) Cultivated and non-cultivated subcurves.

Fig. 9. Phenological analysis–double crops

According to FS stations installed on the rice fields, a summary of rice crop calendar using the proposed method is shown in table I.

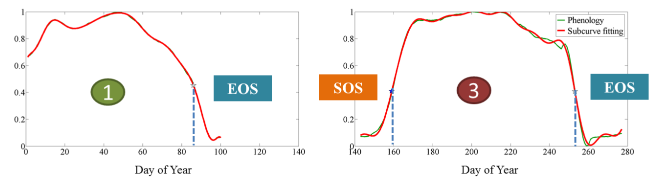


Fig. 10. SOS and EOS on the cultivated periods.

TABLE I. Rice crop calendar (in 2014) using our approach.

Station (Province)	Type	SOS-1	EOS-1	SOS-2	EOS-2
Suphanburi #1	double	77	146	220	340
Suphanburi #2	double	*N/A*	83	163	249
Roi et	single	218	312	–	–
Nan	double	*N/A*	110	189	285
Chiang rai	double	*N/A*	132	205	318
Ang thong	double	*N/A*	88	152	249
Ubon ratchathani	single	231	315	–	–
Rayong	double	72	158	242	317

Note: SOS and EOS are referring to DOY (1 = 1 Jan, 365 = 31 Dec 2014). *N/A* means that there is no information for estimating SOS.

V. Conclusions and Future Work

Referring to GISTDA's sensor network, the time-series images acquired from the rice fields can be computed for the crop calendar. It is a significant information for estimating yield. The proposed method is suitable for single and double-crops, which are the major types of cultivated areas in Thailand. Phenological computation is based on ExG (vegetation) index computed on rice field region. Phenology analysis is an algorithm to classify for the cultivated and non-cultivated periods. The analysis method consists of curve fitting with Fourier series, local minimum, area and duration. Given the phenology curve, the local minimum points are used for separating into subcurves. The area and duration are computed for detecting the cultivated curves. For each cultivated curve, it can be computed and determined for the SOS and EOS which are 5% and 95% of area under the curve, respectively.

For the future work, an advanced algorithm is still required to develop for supporting in several cases for example 2.5 or 3 crop cycles monitoring, crop calendar prediction, etc.

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