Rice Growing Stage Monitoring in Small-scale Region Using ExG Vegetation Index

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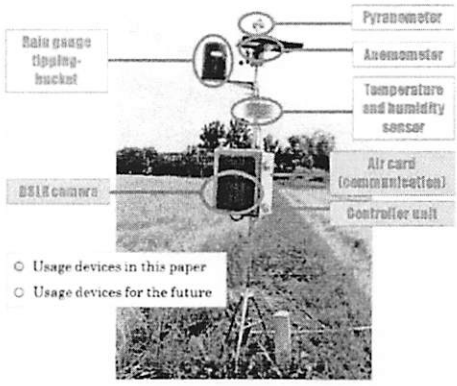
***Abstract*—In this paper, a software program is developed to monitor rice growing stages. Images are required as input data for the software. Using field server equipment, the images are obtained from two rice fields located in Suphanburi and Roi Et provinces, Thailand. Each daily image covers approximately 100×100 m^2 recorded by 720×480 pixels. Typically, a rice growing cycle is separated by three stages; seedling, tillering and heading. To define each stage, vegetation index is used for monitoring and analysing. In the prototype software, the vegetation index is computed from visible RGB channels. Our proposed diagram is described by three steps. a) Rice field segmentation is an initial step used to segment rice field region from the other regions (landscape, sky). b) Vegetation index computation is a measurement, which measures the levels of live green plants on the rice field region. c) Graph analysis is an algorithm used to determine and separate the rice growing stages. The experiments compared three vegetation indices; ExG–Excessive Green, NGRDI–Normalized Green Red Difference Index and ExGR–difference of ExG and ExR (Excessive Red). Relying on the images obtained from the field server, we found that the rice growing stages are able to monitor by using ExG index which is more efficient than the other two.**

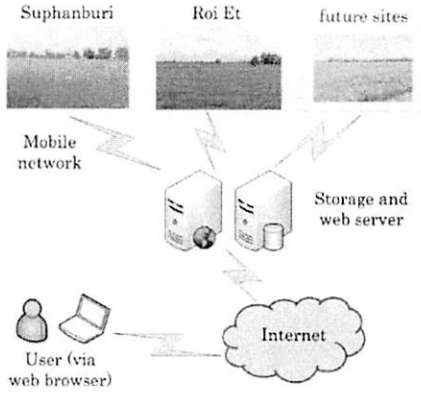
I. Introduction

Nowadays, agricultural products are very importance. Rice is one of the most significant (food) resources for the people around the world. The requirement for rice productions has been speedily increased. Thailand is one of the biggest suppliers who provides approximately 5,920,000 metric tons in 2013 (http://www.thairiceexporters.or.th/statistic_2013.html). To maintain and improve the quality of rice production in Thailand, rice growing process is necessarily required to monitor and analyze by using information from rice field.

Recently, image processing techniques are increasingly progressed in the field of agricultural applications. In this work, we have applied the image processing techniques for monitoring the rice growing cycle. The results were computed from two rice fields located in Suphanburi and Roi Et provinces, Thailand. Acquisition device used to obtain images and other data from the observed fields is called field server. Implementation of the field server is referred to [3]–[6], which provides the information from the observed field via web service. With the similar concept, the field server used in our work initially acquires images from the studied areas. It approximately costs $1,500 per site which composes of a DSLR camera, communication system and controller unit



(a) Field server installation at a rice field.



(b) Network configuration of rice field monitoring system

Fig. 1. Field server equipment and network configuration [13].

as shown in figure 1(a). The controller unit commands the camera to capture daily images two times per day (morning–10:00 / afternoon–02:00) reserved as spare images for each day. The communication system via mobile network is an air card attached in the field server case. It is able to upload the captured images into our central system. Moreover, the data obtained from the tested sites is not only the images but also weather information, which is measured by pyranometer,

anemoneter, humidity sensor, etc. The weather information will be used to process in the future. The daily data has been automatically acquired and recorded into the central system. Using the configuration in figure 1(b), users are able to obtain the data via the website (http://agritronics.nstda.or.th), which is developed by National Electronics and Computer Technology Center (NECTEC), Thailand.

The paper is organized as follows: Section 2 provides related work. Section 3 describes our system diagram for rice field monitoring which composes of a) rice field segmentation, b) vegetation index computation and c) graph analysis. Section 4 shows the experimental results. The rice growing cycles in 2013 were monitored and compared by using three vegetation indices. Section 5 concludes the paper and discusses about perspective of this work.

II. Related Work

Large-scale rice field monitoring is referred to [1], [2], [17], [18] using large-scale images obtained from satellite, airplane or UAV (Unmanned Aerial Vehicle). An example of satellite images acquired by Moderate Resolution Imaging Spectro-radiometer (MODIS) sensor [1], [2], [17], [18] is covered approximately 250×250 m^2 per image pixel. In this work, we have processed images acquired by the fixed camera installed in the parallel direction of rice stem. The capture images cover a part of rice field, which is less than 100×100 m^2 recorded by 720×480 pixels in JPEG format. Our system is a type of small-scale rice field monitoring. Comparing with the large-scale system, it is required different methods for monitoring and analysing. Although the large-scale system can be used for wide areas but the small-scale system is able to monitor specific areas with high accurate results. As summarized in table I, the benefits of small-scale system are also lower cost and less atmospheric interferences than the large-scale system. An application of small-scale system uses the images from the field server to measure the height of rice stem [13].

TABLE I. Comparison between large-scale and small-scale rice field monitoring system.

Type	Image	Characteristic
Large-scale	Satellite or aerial image	Large area, high cost, high atmospheric interferences (cloud, rain), obtained data with delay time (comm. via satellite)
Small-scale	Close view image (field sever, robot)	Small area, low cost, less atmospheric interferences (more accuracy), obtained data close to real time (comm. via mobile), weather measurement is possible.

In the following sections, we separate to two parts; rice growing stages and vegetation indices computed from visible RGB channels.

A. Rice Growing Stage

Considering a rice growing cycle, it consists of three stages [15]; seedling, tillering and heading as shown in figure 2. To define each stage, it can be separated by using the height of rice stem [13], texture, color feature, etc. In this paper, we will observe the rice growing based on the color intensity which is an efficient feature used in several literatures [8], [12], [14].

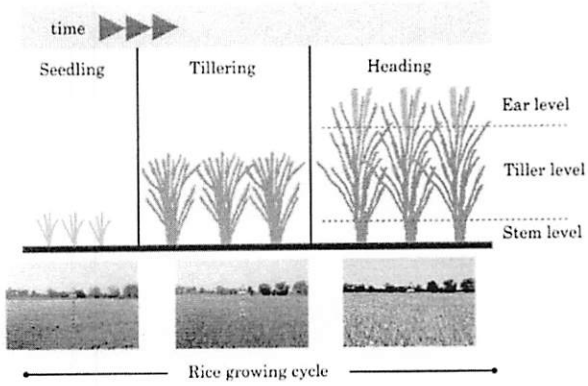


Fig. 2. Three stages of rice growing cycle [15]: seedling, tillering and heading.

B. Vegetation Index

The plant (rice) growing is observed and monitored by using Vegetation Index (VI). Normalized Difference Vegetation Index (NDVI) is one of the popular and efficient indices used in literatures [2], [17], [18]. Unfortunately, the NDVI index requires near-infrared channel that is not included in our prototype software. The software is primarily developed to monitor rice growing cycle based on (visible) RGB channels. Given RGB intensity values, (some popular) vegetation indices are listed as follows.

- *Excessive Green* (*ExG*) was proposed by [16]. It has been widely used in agricultural research (e.g. [8], [9]).

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

- *Normalized Green-Red Difference Index* (*NGRDI*) is referred to [7], [12], [14].

$$NGRDI = \frac{g - r}{g + r} \tag{2}$$

- *ExGR* [11] is a difference of *ExG* and *ExR*. When $ExR = 1.4 \cdot r - g$ and it stands for *Excessive Red* [10].

$$ExGR = ExG - ExR \tag{3}$$

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, $b = B/(R+G+B)$

III. Our Approach

As shown in figure 3, overview diagram composes of three parts; a) rice field segmentation b) vegetation index computation and c) graph analysis (vegetation index).

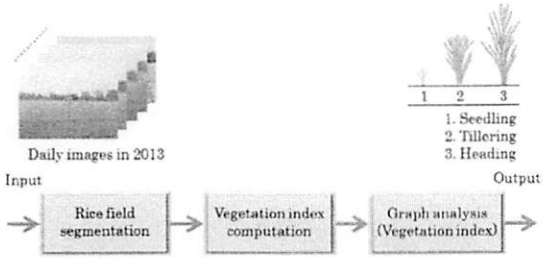


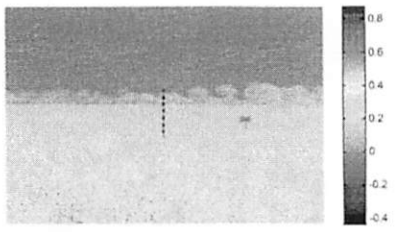
Fig. 3. Overview diagram of rice field monitoring system.

A. Rice Field Segmentation

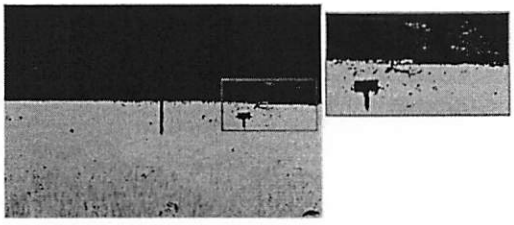
Rice field segmentation is an initial step in the diagram used to segment rice field region from the other regions. Given an image, ExG index is computed for each pixel. Referring to the ExG index shown in figure 4(a), pixels located on the rice field region are more or equal than 0.2 (ExG range is varied between $[-2, 2]$). We note that this is a suitable value for the images captured during the tillering stage. As shown in figure 4(b), we initially compute rice field mask using eq. 4.

$$Mask_{Rice\ field}(i,j) = \begin{cases} 1, & \text{if } ExG(i,j) \geq 0.2 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

When $ExG(i,j)$ is an ExG index of image pixel (i,j).
$Mask_{Rice\ field}$ is a binary mask of rice field region.



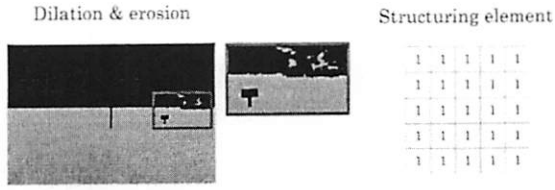
(a) ExG index of Suphanburi in figure 1(b).



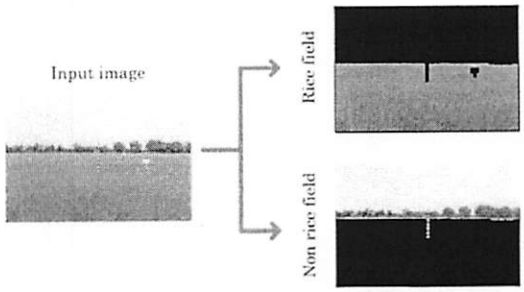
(b) Initial rice field mask.

Fig. 4. ExG index of Suphanburi and initial rice field mask.

However, to remove noise for the final results of the mask, post-processing is required. It consists of image processing techniques as follows; dilation & erosion as shown figure 5(a), labeling, maximum region selection (assuming the rice field is the max. region comparing with noise regions of the captured scene). In figure 5(b), the result shows that the image was segmented into two main regions; rice field and non rice field (landscape and sky).



(a) Dilation and erosion using a 5×5 square structuring element.



(b) Result of segmentation (rice and non rice regions).

Fig. 5. Some parts of post-processing and result of segmentation.

B. Vegetation Index Computation

After the segmentation was done, the rice field region is defined. The second step focuses on vegetation index computation. For each daily image, relying on eq. 5, pixels located on the rice field region are computed for an average of vegetation indices (ExG, NGRDI, ExGR). In small-scale system, the vegetation indices based on the region (pixels on the rice field) are more accurate and efficient than the pixel (only a pixel) as the strategy used in large-scale system.

$$\overline{VI} = \frac{1}{N}\sum_{n=1}^{N} VI(n) \quad (5)$$

When VI is a vegetation index (ExG, NGRDI, ExGR) for each pixel.
N is a number of pixels on rice region.
$\overline{VI}$ is an average of vegetation index on rice region in a day.

In a growing cycle (double crops per year), an example index, ExG is plotted and shown in figure 6. During the seedling stage, the ExG index increases to the maximum value at the tillering stage. Then, it slightly decreases during the heading stage. Finally, it rapidly drops on the harvest day.

C. Graph Analysis

To automatically separate each stage of a rice growing cycle, an algorithm is developed to analyse the vegetation index graph and monitor the rice growing stages. Given the ExG graph, low pass filter is used to obtain smooth ExG graph as shown in figure 7. In order to determine the stages of rice growing, the ExG graph is normalized to $[0, 1]$. As shown in figure 8, each growing stage is defined as follows; seedling

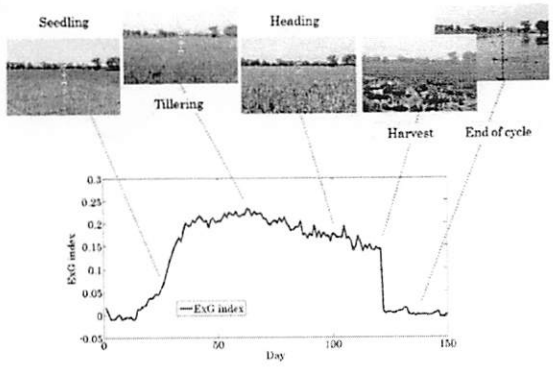


Fig. 6. Relation between rice growing stage (double-crop) and ExG index.

is 10 % of ExG max. (increasing function), tillering is 90 % of ExG max. (increasing function), heading is 90 % of ExG max. (decreasing function) and harvest is 10 % of ExG max. (decreasing function). The day and period of growing stages are also summarized in table II.

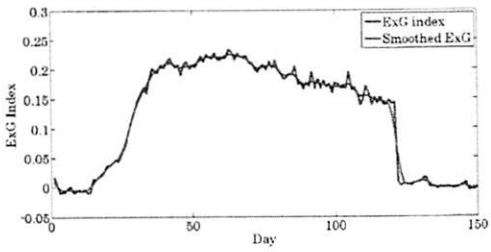


Fig. 7. Smoothed ExG (red) is obtained by using low pass filter.

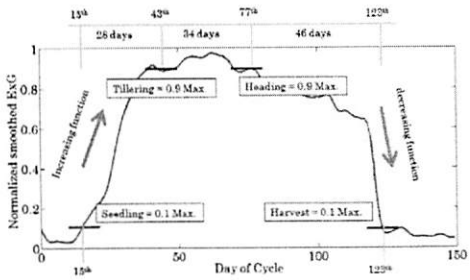


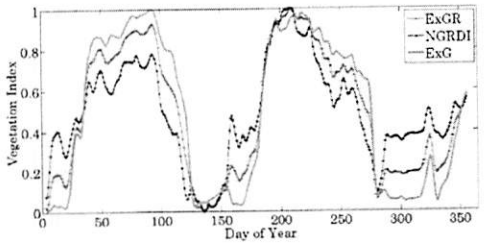
Fig. 8. Rice growing stages are defined on normalized smooth ExG.

TABLE II. ANALYSIS OF RICE GROWING STAGES USING NORMALIZED SMOOTH EXG.

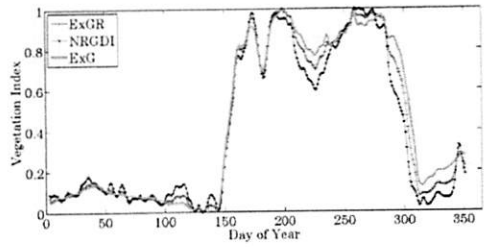
Stage	Day	Period (days)
Seedling	15	–
Tillering	43	28
Heading	77	34
Harvest	123	46

IV. EXPERIMENTS

The daily images in 2013 obtained from the field server were used to process in order to know the stages of rice growing. Two rice fields located in Suphanburi and Roi Et were tested for the results. According to vegetation indices used for monitoring, we initially compared the results on three vegetation indices (ExG, NGRDI, ExGR). In figure 9, a comparison of three indices shows that there are two types of cycle; Suphanburi (double-crop) and Roi Et (in-season). Based on subjective test, comparative results show that the ExG index is more stable and efficient to explain the stages of growing than the other two. In the comparison, the tested indices are normalized to $[0, 1]$ and smoothed by using low pass filtering.



(a) Suphanburi (double-crop)



(b) Roi Et (in-season)

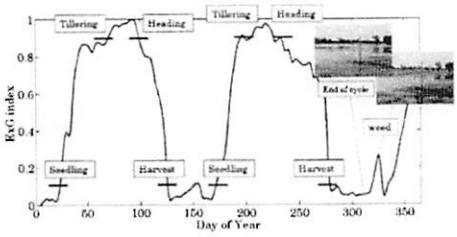
Fig. 9. Comparative results of three vegeation indices (ExG, NGRDI, ExGR); a) Suphanburi and b) Roi Et.

TABLE III. ANALYSIS OF RICE GROWING STAGES IN SUPHANBURI AND ROI ET PROVINCES, THAILAND.

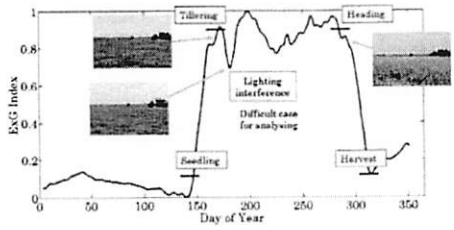
Suphanburi (double-crop)		
Stage	Day 1st, 2nd crop	Period (days) 1st, 2nd crop
Seedling	28, 176	–, –
Tillering	75, 204	47, 28
Heading	104, 238	29, 34
Harvest	130, 284	26, 46

Roi Et (in-season)		
Stage	Day	Period (days)
Seedling	152	–
Tillering	176	24
Heading	290	114
Harvest	320	30

To know the stages of rice growing, the ExG graph analysis was used to determine the growing periods as summarized in figure 10 and table III. It should be noted that the algorithm of graph analysis used in the prototype software is a basic algorithm, which may provide in-accurate results in some difficult cases (see also figure 10b). To handle several cases, the algorithm is still required to improve.



(a) Suphanburi: ExG graph analysis.



(b) Roi Et: ExG graph analysis.

Fig. 10. Analysis of rice growing stages using ExG index; a) Suphanburi and b) Roi Et.

V. Conclusion

In this work, a software program has developed to monitor the rice growing stages. The study aims to use image processing techniques on daily images obtained from the field server equipment. The RGB images (in 2013) were obtained from two rice fields located in Suphanburi and Roi Et provinces, Thailand. Our strategy is based on a vegetation index computation, which measures the levels of green rice region on the images. Using the vegetation index, the rice growing stages are separated to; seedling, tillering, heading and harvest. In the experiments, we also compared three vegetation indices (ExG, NGRDI, ExGR) which are based on the (visible) RGB channels. Comparative results show that ExG index is more efficient to interpret than the other two.

In the future, in order to obtain more accurate results, not only RGB images but also other information (such as near-infrared image, weather information) will be able to integrate and use in the software. The near-infrared image can be used to compute for the NDVI. Given a set of captured images, the weather information for example lighting will be considered for radiometric correction.

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