A Study of Rice Phenological Development Stages Estimation from Field Server Images

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***Abstract*—The accurate rice phenological development stages estimation is important for rice yield estimation, since each phenological developmental stage possesses different increase rates of biomass and leaf area. This paper presents a method to estimate the rice phenological development stages: seedling, tillering, heading, and harvest. This method uses a vegetation index, i.e. Excessive Green (ExG) integration to classify the phenological development stages. The ExG can be calculated from the intensity of different wavelengths in the field server images. The estimated phenological development stages is observed from ExG. Our method is compared to those from KKU rice model simulation and validated with the data obtained in 2013 during the wet season in Roi-Et and during the dry season in irrigated area in Suphanburi. The results show that the estimated phenological development stages obtained from the vegetation index ExG agree well with simulated values from KKU rice model simulation and field observation.**

I. Introduction

This article presents the estimation to rice phonological development stages via RGB images obtained from field servers. The results from estimation can be applied to improve the rice yield prediction, which is important to the economic plan for agricultural countries, such as Thailand.

Rice is a major economic crop of Thailand, for internal consumption and as well as for export. Due to its high production-related income, its importance to Thai's economic and agricultural sections is undeniable. Therefore, the estimation of the rice phenological development in each year (or in each crop cycle) is related to government whose major concern is to manage the economy of countries which have economic condition bound with agricultural market. Since the yield prediction needs to consider the rate of biomass and leaf area increases, both of which depend on each phonological development stage, the knowledge about rice phenological development stages estimation will raise the accuracy of the rice yield prediction, which is directly involved with the government's plan to improve the agricultural section. The accurate rice yield prediction is important to predict the production of rice, the stable food widely consumed by world's population, especially Asian. Generally, the estimation is involved with the rice phenological development separated into four main stages: seedling, tillering, heading, and harvest.

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In the recent years, the use of images for estimating the growth of crops, in the view of rice growth, were proposed in [1] - [4]. The difference among these methods is the use of different features for representing the phenology extracted from remote sensing modules. For example, rice phenology is represented by Enhance Vegetation Index (EVI) extracted from satellite images of Multi-temporal Moderate Resolution Imaging Spectroradiometer (MODIS) [1]; meanwhile the use of satellite images from MODIS is replaced by the images obtained from X-band [2] and C-band [3] from Synthetic Aperture Radar (SAR) systems. The use of Excessive Green (ExG) from field servers is proposed in [4]. The ExG is an efficient vegetation index, which was first proposed in [5]. Moreover, this vegetation index was used in several researches on agricultural area [6] - [7]. In this work, we will focus on improving the method from [4], which estimates the rice growth using the analysis of ExG graph. Our objective is to show the estimation of the rice development stage resulting from our method in comparison with the estimation from KKU rice model [8], [9] and the actual data measured from rice field. Additionally, our study will provide understanding about relation between the ExG value obtained from RGB images and the rice phonological development stages during the wet season and also during the dry season.

This article is organized as follows: Our analysis on the relation between information from RGB images obtained from field server in correlation to the rice phonological development stage is provided, and this leads to the development of our method in Section II; we, then, analyze the result obtained from KKU model in Section III; we compare the estimate obtained from our method and KKU model with the actual data from wet season rice field at Roi-Et province and dry season rice field at Suphanburi province, Thailand, in Section IV; and, finally, we provide conclusions for our experimentation and future works in Section V.

II. Rice Phenological Development Stages Estimation from Field Server Images

Our organization, the Geo-Informatics and Space Technology Development Agency or GISTDA, has installed equipments to observe crop fields, called field server [10]. Several crop types: rice, cassava, sugar cane, maize, tamarind, and asparagus, are observed. Weather data, which consist of temperature, humidity, light density, rain volume, wind speed, and wind direction, are recorded from the field servers. Moreover, the field servers can take images daily in order to observe the changing of the crop fields. The obtained images are RGB with resolution 720×480 pixels and recorded as jpeg files. In this work, we calculate the Excessive Green vegetation index or ExG from the RGB light intensity of rice fields as in [4]

$$ExG = \frac{2G - R - B}{R + G + B} \tag{1}$$

where R, G, and B are the average light intensity of red, green, and blue, respectively. The calculated vegetation index ExG is plotted on the y-axis and the day of year (DOY) is plotted on the x-axis of graph. The start and end points of a considered period are the points before the ExG value rapidly increases and after the ExG value rapidly decreases, respectively, as shown in Figure 1. The graph of vegetation index ExG is analyzed to estimate the rice phenological development stages. Let us define the area between the start point to a given specific date in the growth period as the area of partial accumulate ExG. Then, the ratio accumulate ExG (ratio ACC ExG) is the proportion between the area of partial accumulate ExG to the total area of the ExG graph as in Figure 2. The four phenological development stages are classified by using the ratio ACC ExG values from the experimental test, which equal to 0.0%, 14%, 86%, and 100% to define the start dates of seedling, tillering, heading, and harvest stages, respectively. In Section IV, this obtained start date of each stage from the ratio ACC ExG value is verified with the real start date of each stage from the field observation.

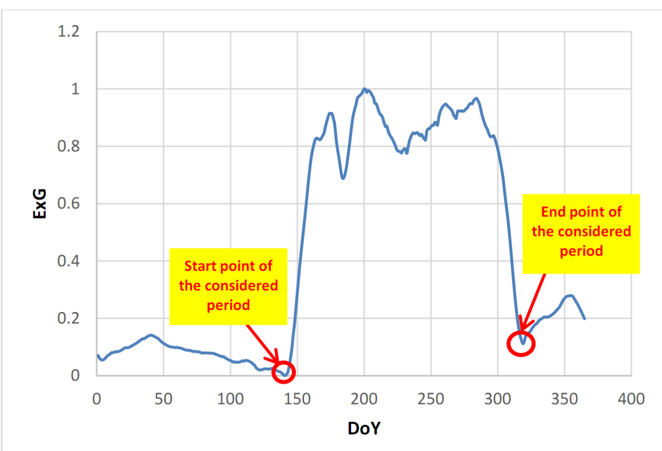

Fig. 1. An example of the vegetation index ExG graph with start and end points of the considered period to analyze the phenological development stages

III. Rice Phenological Development Stages Estimation from KKU Rice Model

This paper studies a rice yield prediction model called KKU rice model, which was proposed in [8]. This rice model can also provide the phenological development stages of rice by considering the phonology value and the crop and panicle weight increment, which are outputs of the model. The KKU rice model needs some input parameters, such as, temperature, soil moisture, light intensity, and some parameters depending on rice and soil types in the computation process. Field servers or some observing satellites can provide these input parameters to the model in order to validate the output of estimation yield model. For the yield prediction, we should use some input parameters obtained from climate prediction models. The model simulation provides phenology, weight of crop, weight of panicle, and leaf area index. The different phenological development stages can be classified by considering these outputs. The tillering stage starts when the phenology value equals 0.25. The heading stage starts, when the panicle weight increases. The harvest date is the date whose the phenology value equal to 1. An example of the start date of the tillering stage obtained from the KKU rice model is illustrated in Figure 3. This figure shows the phenology value of the photosensitive rice. The phenology value increases during the seedling stages and does not change so much until the day with optimal day-length, in which the rice panicle will be produced. The graphs of crop weight and panicle weight per an area unit is shown in Figure 4. We can obtain the start date of the heading stage and harvest date from these two graphs. In the next section, these results will be compared to the phenological development stages estimated from the vegetation index ExG of the field server images (Section II) and also the real stages from field observation.

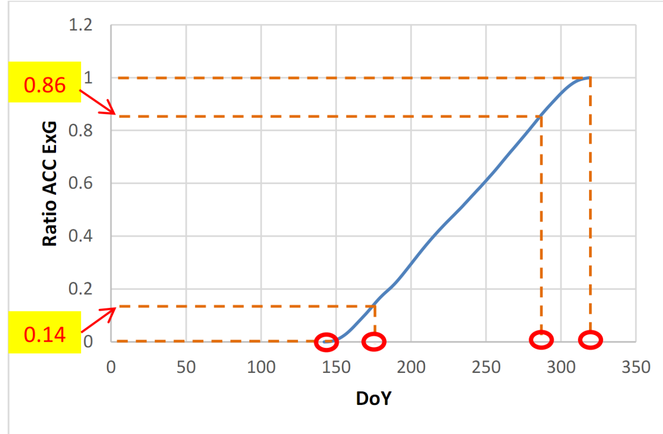

Fig. 2. An example of the ratio ACC ExG and the start dates of the phenological development stages

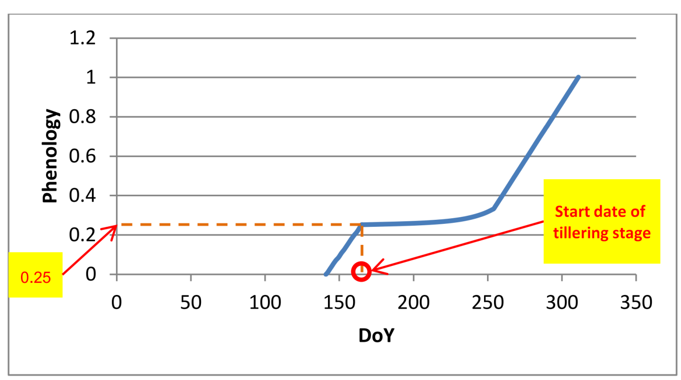

Fig. 3. An example of the rice phenology obtained from rice yield estimation model called KKU rice model

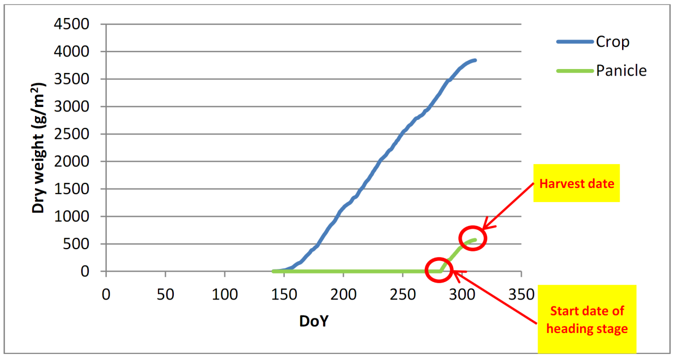

Fig. 4. An example of the crop weight and panicle weight per a unit of crop area from rice yield estimation model (KKU rice model)

IV. Experimental Results

As in Section II, the rice phenological development stages can be estimated by considering the area under the curve of the vegetation index called Excessive Green or ExG from field server images. In this work, the 2013 data from two crop areas: a wet season rice field in Roi-Et and an irrigated dry season rice field in Suphanburi, are used in experiment. The obtained phenological development stages from the field server images are compared to the phenological development stages from the KKU rice model and also compared to the real stages from the paddy fields.

We set the start date of the seedling stage, which is an initial state of the KKU rice model, as the one obtained from the field server. The phenplogical stage of KKU model is obtained from the accumulation of the daily changes of crop weight, panicle weigh, and leaf area index. However, the crop weight accumulated, since the start date, includes the dead leaf and dead cell. Hence, it is necessary to limit the leaf area index to 4.5. Especially, for wet-season rice which has long duration from seedling stage to harvest stage, the accumulation of total crop weight will be greatly compensated by limiting the leaf area index. This limitation helps control KKU model's parameters, leading to better approximation for realistic situation.

In our experiment, we consider the two common types of rice production in Thailand: wet-season rice and irrigated dry-season rice production. The wet-season rice in Roi-Et usually requires an entire year for the production; meanwhile, the irrigated dry-season rice in Suphanburi can be produced more than once a year. The results of two experimented areas, which are in the wet-season and the irrigated dry-season, are demonstrated in Figure 5 and 6, respectively. In each figure, the first two graphs show the ExG and the Ratio ACC ExG from the field server images. The other two graphs are the graph of the phonology value and the graph of the dry weight per area unit of crop and panicle obtained from KKU rice model. In Figure 5, one crop is active during an entire year for the wet-season area; however, two crops are active in the irrigated dry-season area, as in Figure 6. The comparison of the start date of phenological development stages from the field server images, the KKU rice model, and the observation fields are shown in Table I and II for one crop of the wet-season area and two crops of the irrigated dry-season area, respectively.

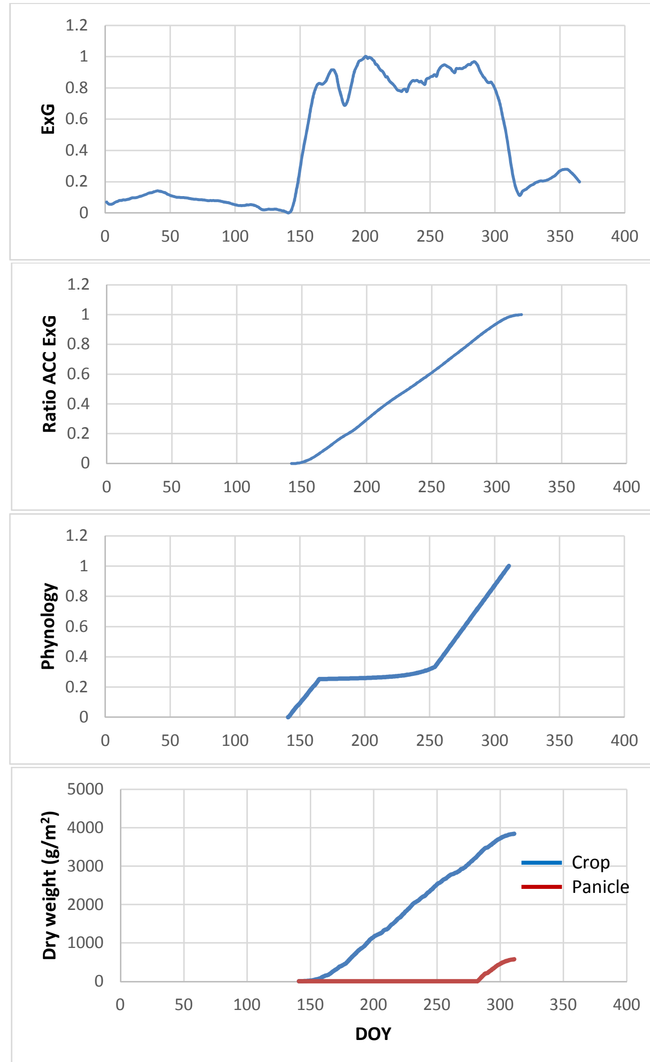

Fig. 5. Vegetation index-ExG, ratio of area under the curve, phenology value, and dry weights of crop and panicle from the field server image and KKU rice model of the wet-season area in Roi-Et province

TABLE I. Start date of each phenological development stage obtained from the field server-ExG, KKU rice model, and paddy field observation of the wet-season area (Roi-Et province)

Stage	Start Date of Stage		
	Field Server	KKU model	Observation
Seedling	141	141	145
Tillering	175	165	-
Heading	287	283	286
Harvest	319	311	313

The experimental results of both the wet-season and irrigated dry-season areas show that the start date of the phenological development stages, which consist of seedling, tillering, heading, and harvest, can be obtained by considering the area under the curve of the vegetation index called Excessive Green or ExG from the field server images. Moreover, these results are close to the start date of each phenological development stage obtained from the rice yield estimation model called KKU rice model and the real paddy field observation. It should be noted that the stage changing from seedling to tillering

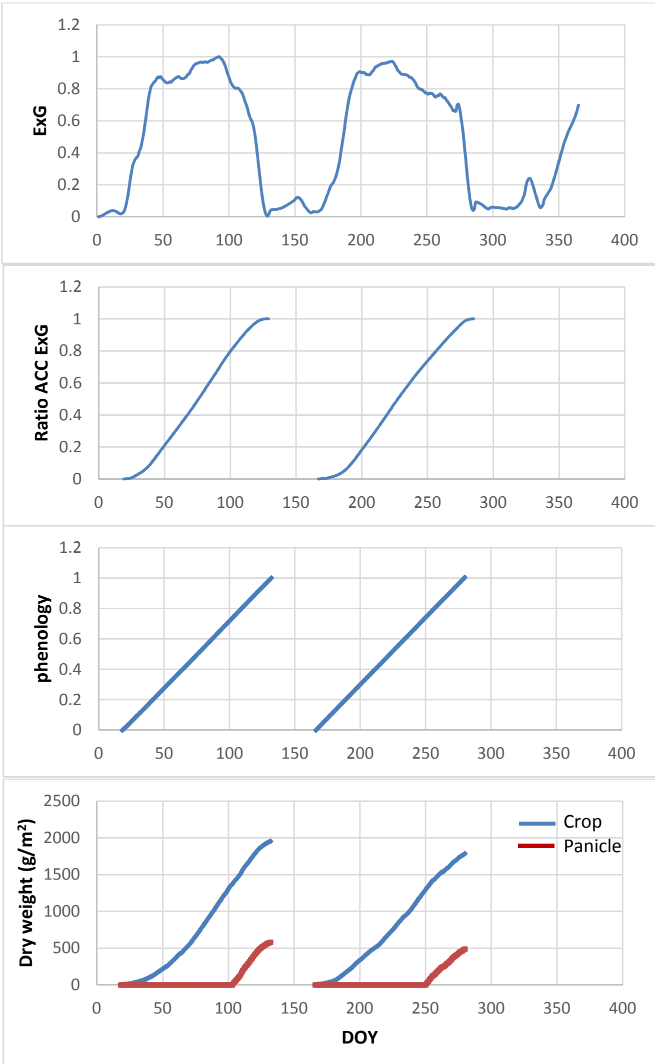

Fig. 6. Vegetation index-ExG, ratio of area under the curve, phenology value, and dry weights of crop and panicle from the field server image and KKU rice model of the irrigated dry-season area in Suphanburi province

TABLE II. START DATE OF EACH PHENOLOGICAL DEVELOPMENT STAGE OBTAINED FROM THE FIELD SERVER-EXG, KKU RICE MODEL, AND PADDY FIELD OBSERVATION OF THE IRRIGATED DRY-SEASON (SUPHANBURI PROVINCE)

	Stage	Start Date of Stage		
		Field Server	KKU model	Observation
1^{st} crop	Seedling	18	18	22
	Tillering	44	47	-
	Heading	107	104	99
	Harvest	129	132	124
2^{nd} crop	Seedling	166	166	172
	Tillering	197	195	-
	Heading	264	251	245
	Harvest	285	280	280

stages cannot be classified by visualization; therefore, the start date of the tillering stage cannot be obtained from the real observation.

V. CONCLUSIONS AND FUTURE WORKS

This article proposes the phenological development stages estimation by considering the area under the curve of the vegetation index called Excessive Green (ExG) from the field server images. The phenological development is classified in four main stages in this work, which are seedling, tillering, heading, and harvest. The proposed method is experimented in the wet-season area and the irrigated dry-season area and using the data in 2013. One crop in Roi-Et is tested for the wet-season area; two crops in Suphanburi are tested for the irrigated dry-season area. The experimental results show that the phenological development stages obtained from the vegetation index-ExG is similar to the phenological development stages obtained from the rice yield estimation model (KKU rice model) and from the real observation. Therefore, the vegetation index from the field server images can be used to classify the phenological development stages with the acceptable accuracy.

For future works, we plan to validate this proposed method in more different study areas, soil, and rice types for guarantee the accuracy. Moreover, the different methods and parameters will be tested in order to improve the strategy for classifying the phenological development stages of rice.

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