A COMPARISON OF GROUND AND SATELLITE BASED PHENOLOGIES FOR MONITORING RICE FIELD

Narut Soontranon, Siam Lawawirojwong, Kulsawasd Jitkajornwanich, Panu Srestasathiern, and Preesan Rakwatin
Geo-Informatics and Space Technology Development Agency (GISTDA)
120 The Government Complex, Ratthaprasasanabhakti Building
6–7th Floor, Chaeng Wattana Road, Lak Si, Bangkok, Thailand 10210
E-mail: {narut, siam, kulsawasj, panu, preesan}@gistda.or.th

KEY WORDS: Phenology, Comparison, Field Server, Landsat-8, Excessive Green (ExG), Normalized Difference Vegetation Index (NDVI), Rice Field

ABSTRACT: In this paper, ground and satellite based phenologies are compared and evaluated. Based on time-series images taken from a still camera, the ground-based phenology is computed from agricultural fields. The equipment used to acquire the images is known as Field Servers, which have 24 stations covering entire Thailand (e.g. rice, cassava, sugarcane). We initially focus on the rice fields. Using Landsat-8, the satellite phenology is derived from vegetation index computation. Since the temporal resolution of ground-based images (daily) and satellite images (16-day) are not comparable, the interpolation procedure is required for normalization purposes. Comparison results are performed on the 2014 datasets to identify previously-undiscovered relationships, which will be used for monitoring rice fields in a wide region. To enable the rice fields tracking, two main parameters (SOS: start of growing season and EOS: end of growing season) are extracted from the phenology.

1. Introduction

Precision agriculture or smart farming becomes an interesting topic for research and development. According to Earth Observation System, satellite images cover a wide region which can be computed for estimating agricultural areas. In general, the time-series images are used as an input data for implementing several applications such as cultivation area monitoring, yield estimation and prediction. However, to obtain the accurate results, ground-based data is still required for validation process. For monitoring and tracking the growing stages, vegetation index is a useful parameter to indicate the green levels of agricultural areas. Using color feature of the image, the vegetation index is computed and observed for a period known as "Phenology". Referring to two vegetation indices (NDVI: Normalized Difference Vegetation Index) and (ExG: Excessive Green), they will be used for comparing between the satellite and ground based phenologies. In order to obtain the crop calendar, the dates of start and end of growing season are two main parameters extracted from the phenology curve.

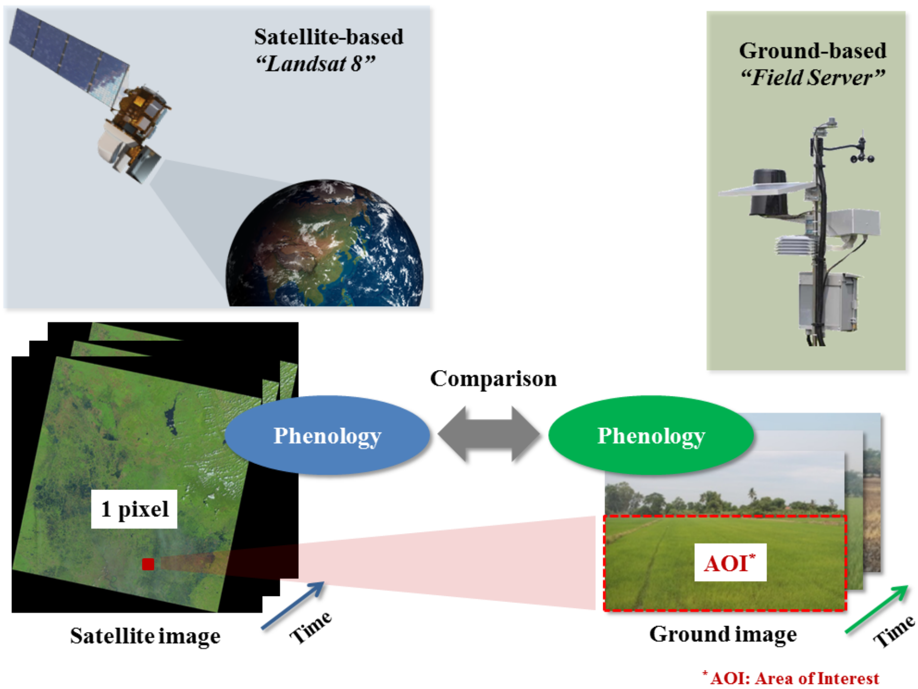


Figure 1: A comparison between satellite and ground phenologies by given the time-series images.

Discussing about the ground and satellite images used in the experiments, the ground-based images are obtained from Agriculture Monitoring System (AMS-Thailand) and the satellite images are retrieved from Landsat-8 (LS-8). AMS-Thailand project was launched in 2012 by Geo-Informatics and Space Technology Development Agency (GISTDA), 24 field server stations were installed for acquiring the images and recording the weather conditions [Soontranon et al., 2015b, Soontranon et al., 2014]. Several plants have been observed including rice, cassava, sugarcane, etc. In this study, we initially focus on the rice fields. The images obtained from field server will be used as the ground-based images since they have been captured daily. The ground-based images "near surface" can be observed for more accurate information comparing with the satellite images [Fisher et al., 2006, Soontranon et al., 2015a]. In the experiments, the ground-based images will be used as the ground truth information. For the corresponding area, a pixel of LS-8 image is selected by referring to the ground-based image acquisition (latitude/longitude of rice fields). Relying on the phenologies obtained from the ground and satellite platforms as shown in figure 1, the results will be compared and evaluated.

The rest of the paper is organized as follows. Section 2 describes the methods used for computing the phenology and extracting the crop calendar. Section 3 demonstrates the experimental results. Section 4 concludes and discusses about the comparison of ground and satellite based phenologies and future work.

2. Methods

Given a set of time-series images, phenology can be computed and extracted for the crop calendar. SOS and EOS are two parameters used to define the start and end of growing season, respectively. Based on the ground-based platform [Richardson et al., 2009, Ide and Oguma, 2010], the daily images provide the phenology which is able to understand the stages of cultivation (rice) field. The stages of the rice field are separated into seedling, tillering, heading and harvesting [Soontranon et al., 2014]. In order to obtain the crop calendar (SOS and EOS), the phenology curve will be processed and analyzed. The method used for extracting SOS and EOS is described in [Soontranon et al., 2015b]. Considering to the satellite platform, similar to the ground-based platform, the phenology is also used for monitoring the rice field. Generally, the satellite images provide less spatial and temporal resolutions than the ground-based images. Also, the satellite images consist of noise signals generated from atmospheric interferences, cloud, rain, shadow, etc. The method of phenology computation is required some initial steps for reducing noise signals. The following sub-sections describe the methods used for computing the phenology and the crop calendar on each platform. The ground-based images are acquired from the field server installed in the rice fields [Soontranon et al., 2014, Soontranon et al., 2015b]. The satellite images are retrieved from LS-8 [Landsat-8, 2013].

2.1. Ground based image

The ground-based images captured by the camera, which are recorded in Red, Green and Blue (RGB) components. The image resolution is 720×480 pixels which covers approximately 100×100 m^2 of rice field. The method used to extract the crop calendar is shown in figure 2. It consists of the following steps.

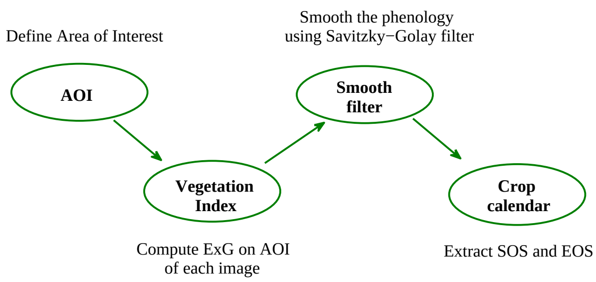


Figure 2: Crop calendar obtained from the ground-based images [Soontranon et al., 2015b]

- Area of Interest (AOI) is defined on the rice field.

- Vegetation Index is computed on each image. Based on RGB components, the vegetation index is referred to ExG (ExG = 2g - r - b; when r,g,b is known as RGB normalized) [Woebbecke et al., 1995, Soontranon et al., 2014, Soontranon et al., 2015b].

- Smooth filter is a tool for computing the smooth phenology. The phenology computed from the vegetation index is generally included with noise signals because of cloud, rain, shadow, etc. A well-known approach, Savitzky-Golay filter [Savitzky and Golay, 1964], is used for smoothing the phenology.

• Crop calendar is a method to determine the dates of start and end of season. The cultivation periods are separated into sub-curves for analysis. Then, each (cultivation) sub-curve will be computed for extracting the crop calendar represented by SOS and EOS. 5 % and 95 % of area under the sub-curve are determined for SOS and EOS, respectively. Moreover, the dates of SOS and EOS must have the vegetation index greater than 40 % of the maximum level [Soontranon et al., 2015b].

2.2. Satellite based image

Referring to LS-8 images, the characteristics are 16-day (temporal) and 30 meter (spatial) resolutions. To compare with the ground-based phenology, the satellite images will be considered in the similar area. Using geographical location (latitude/longitude), the corresponding pixel is selected for computing the phenology. According to LS-8 data, it should be noted that the components (bands) of LS-8 used to obtain the phenology are not only RGB but also included with near infrared (NIR). Given NIR and R components, a well-known vegetation index "NDVI" can also be computed. Based on LS-8 images, the method used to extract the crop calendar is shown in figure 3. It consists of the following steps.

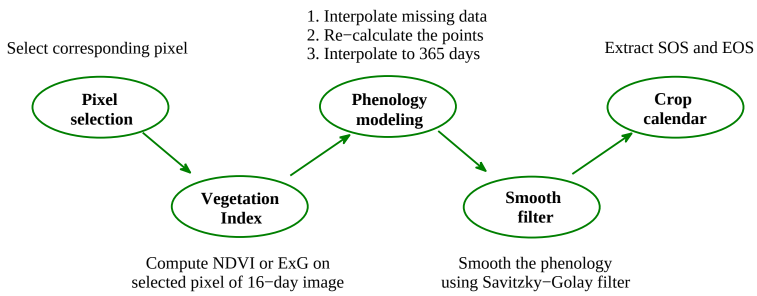


Figure 3: Crop calendar obtained from LS-8 images.

• Pixel selection is referred to the geographic location. For LS-8 images, the corresponding pixel of rice field will be considered.

• Vegetation index is initially computed on the selected pixel (time-series images). Regarding to RGB and NIR components obtained from LS-8, the vegetation indices are available for both NDVI and ExG.

• As shown in figure 4, phenology modeling consists of three sub-steps as follows.

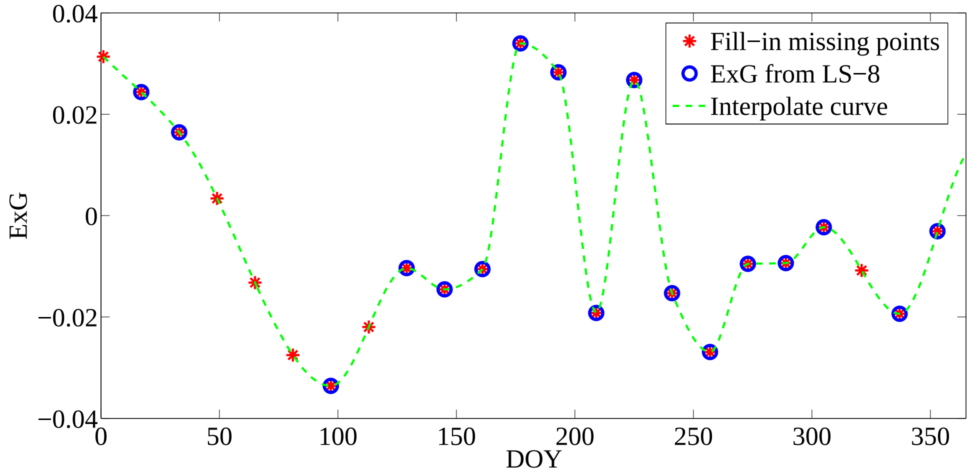
1. Interpolation is a method for estimating data on the phenology curve, since the images of LS-8 are not available for every 16 days. The images were not provided on the website [Landsat-8, 2013]. In figure 4–1, the red markers ($\star$) represent for an estimated data. On the other hand, the blue markers ($\circ$) represent vegetation index levels computed from LS-8 images.

2. After the interpolation was computed, the phenology curve is processed to re-calculate the points (vegetation index) because of the atmospheric interferences, bad weather conditions (e.g. cloud, shadow, rain). These points provide the low/high intensity values, which should be adjusted [Soontranon et al., 2015a]. The re-calculated phenology is presented by the pink line as shown in figure 4–2.

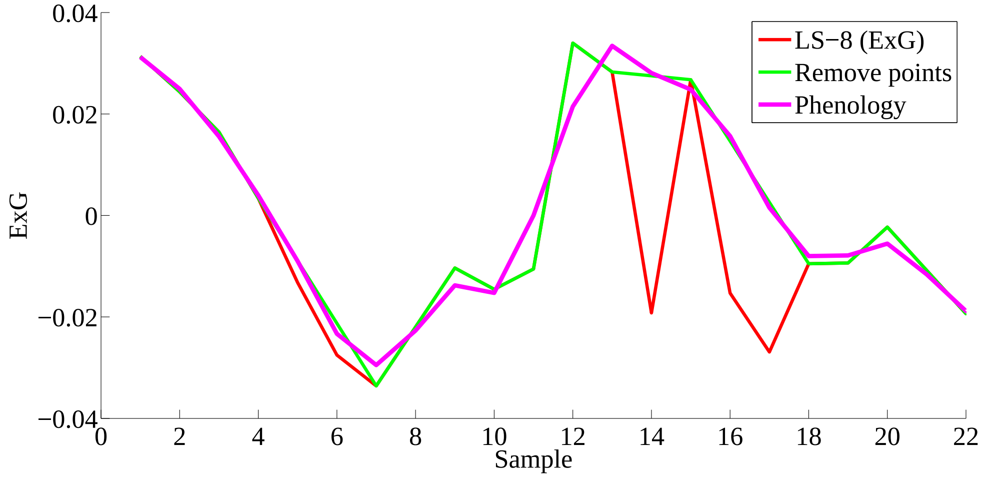
3. In general, the LS-8 phenology is less temporal resolution (16-day) than the ground-based phenology. In figure 4–3, cubic interpolation is the algorithm used for estimating the phenology curve from 22 samples (365/16 days) to 365 days, which is corresponding to the ground-based phenology.

• Smooth filter is relied on Savitzky-Golay approach [Savitzky and Golay, 1964], which is similar to the strategy of ground-based phenology.

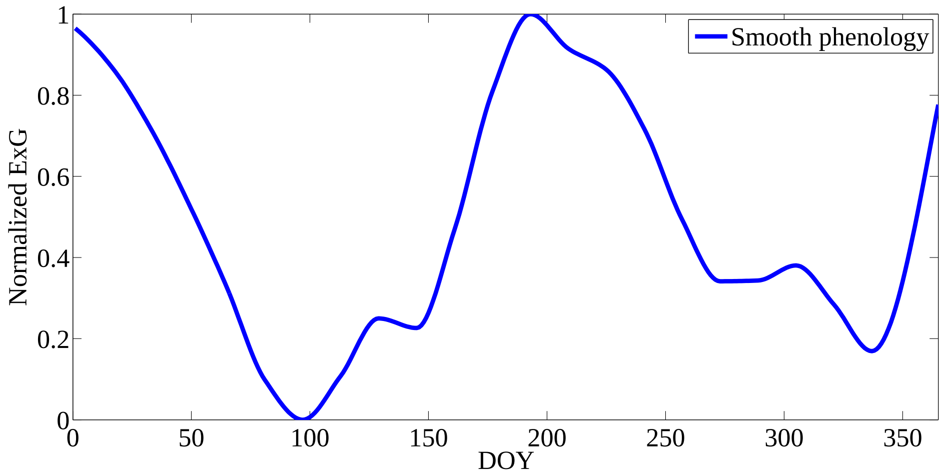
• Crop calendar is extracted on the cultivation sub-curve of the phenology. The strategy of SOS and EOS extraction is similar to the ground-based platform.



1. Interpolate missing data



2. Re-calculate and remove the noisy points



3. Interpolate from 22 samples to 365 days and smooth the phenology.

Figure 4: Phenology modeling

To compare characteristics of the ground and satellite based platforms, they are summarized in table 1. The ground-based images are obtained from the DSLR camera installed in Field Server. The daily images have spatial resolution at approximately 100×100 m^2 covered the rice field. The camera perspective is side view with 2 meters

Table 1: Comparative characteristics between the ground and satellite based platforms are summarized.

	Ground	**Satellite**
Platform	Field Server	Landsat-8
Spatial resolution	100×100 m^2 (1-2 fields per image)	30×30 m^2 per pixel
Temporal resolution	Daily	16-day
Image view	Side view (2 m. height from ground)	Top view
Component (band)	RGB	RGB and NIR
Vegetation index	ExG	ExG and NDVI
Interpolation (365 days)	–	Cubic
Filtering	Savitzky-Golay	
Plant	Rice (single and double crop cycle)	
Period	In 2014	
Crop calendar (SOS and EOS)	• 5% and 95% of area under cultivation period. • 40% of normalized vegetation index (greater than).	
Advantage	High spatial and temporal Res.	Wide area coverage
Disadvantage	Small area (1-2 rice fields)	Low spatial and temporal Res.

height above the ground. Based on RGB images, the vegetation index is referred to ExG. On the other hand, LS-8 images have spatial resolution at 30×30 m^2 per pixel and temporal resolution at 16-day. The camera perspective is approximately top view (satellite view). Using RGB and NIR components, the vegetation indices are computed to ExG and NDVI. For LS-8, in order to compare with the ground-based phenology, cubic interpolation is used for estimating the phenology curve (365 days). The observation period is in 2014. For both platforms, the phenologies are filtering by using Savitzky-Golay approach. SOS and EOS can be determined by computing the area under the cultivation curve and the vegetation index level. The advantage and disadvantage of each platform is also described in the table 1.

3. Results

Given the ground and satellite images obtained in 2014, comparative results were performed on the rice fields which are single and double crop cycle. Regarding to the rice field in Suphanburi province (Suphan #2: double crop), using ExG index computed from LS-8, the phenologies of the ground and satellite based platforms are plotted in figure 5. It can be observed that there are two cultivation periods (DOY: 1-100 and DOY: 150-250). Referring to SOS and EOS, the crop calendar is estimated as shown in figure 6. In table 2, the comparison of estimated SOS and EOS on three rice fields is evaluated. The phenology computed from field server is used as the ground truth. Two phenologies, based on ExG and NDVI, obtained from LS-8 are observed for shifting DOYs. According to the comparative results, our approach can be used to define the cultivation periods (crop cycle) from LS-8 phenology. The approach is able to compute for obtaining SOS and EOS. Using LS-8 phenologies computed from ExG and NDVI, the DOYs shifting of ExG phenology are more efficient than NDVI phenology.

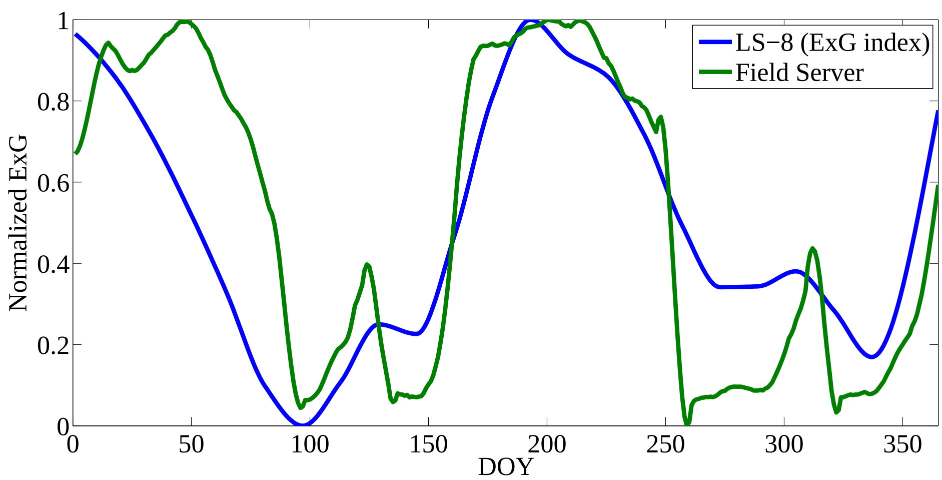
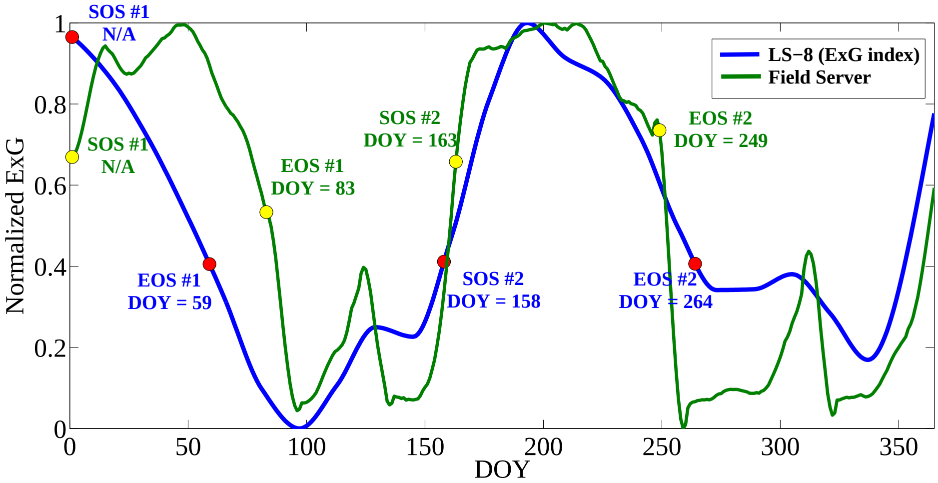
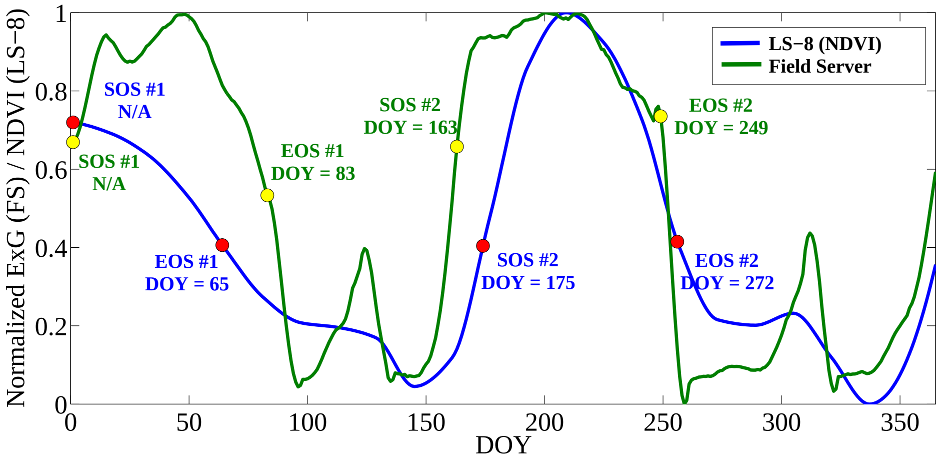


Figure 5: Based on ExG index (Suphan #2), phenologies between LS-8 and field server are compared.



1. Ground-based phenology and LS-8 with ExG index



2. Ground-based phenology and LS-8 with NDVI

Figure 6: Comparing with the ground-based (Suphan #2), crop calendars obtained from LS-8 with ExG index (above) and LS-8 with NDVI (below) are compared and evaluated.

Table 2: Crop calendars (SOS, EOS) obtained from field server and LS-8 phenologies are compared.

Rice field	**Type**	**Platform**	**SOS #1**	**EOS #1**	**SOS #2**	**EOS #2**
Suphan #1	Double	Field Server	77	146	220	340
		LS-8: ExG	87	170	223	293
		Day shift: ExG	+10	+24	+3	-47
		LS-8: NDVI	65	176	232	310
		Day shift: NDVI	-12	+30	+12	-30
Suphan #2	Double	Field Server	N/A	83	163	249
		LS-8: ExG	N/A	59	158	264
		Day shift: ExG	N/A	-24	-5	+15
		LS-8: NDVI	N/A	65	175	272
		Day shift: NDVI	N/A	-18	+17	+23
Roi Et	Single	Field Server	218	312	–	–
		LS-8: ExG	223	349	–	–
		Day shift: ExG	+5	+37	–	–
		LS-8: NDVI	244	342	–	–
		Day shift: NDVI	+26	+30	–	–

"+/-" means the DOY of LS-8 started or ended before/after the DOY of field server.

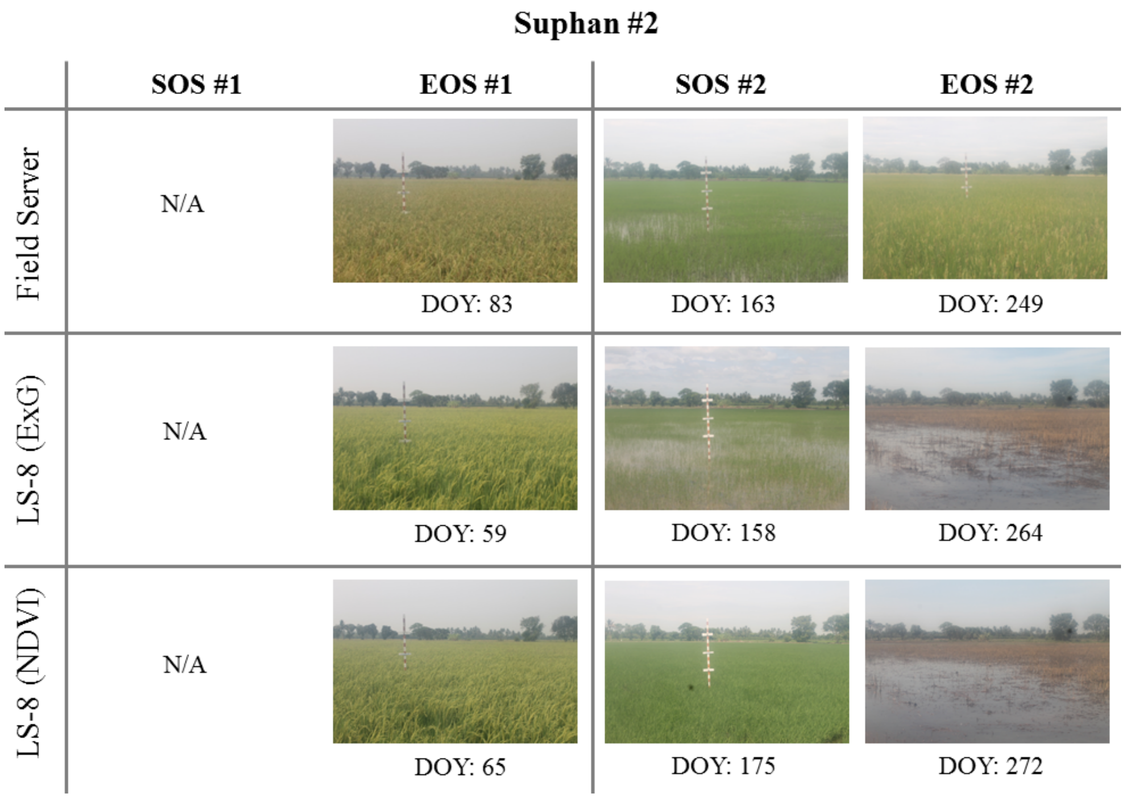


Figure 7: Referring to figure 6, the field server images of corresponding SOS and EOS obtained from each platform are presented (filed server: top, LS-8 (ExG): middle, and LS-8 (NDVI): low).

Referring to the results in table 2, the day shift of Suphan #2 has the maximum value at 24 days (EOS #1). It is generally acceptable for 16-day of LS-8. For the crop calendar obtained from Suphan #1, the day shift of EOS #2 is high value because the harvesting date was rescheduled. The phenology curves obtained from LS-8 and field server are not the same pattern (see also figure 8). Then, the method used to extract the crop calendar provides the high value of day shift (EOS #2: -47 days). For the single crop (Roi Et), the day shift of SOS #1 obtained from LS-8: ExG (5 days) index more efficient than LS-8: NDVI (26 days). However, the day shift of EOS #1 is approximately 30 days which is required to improve in the future. For the status on the rice field, referring to Suphan #2, the corresponding dates of SOS and EOS extracted from each platform are presented by the field server images as shown in figure 7. For more results of the other rice fields (Suphan #1, Roi Et), they are shown in Appendix A.

4. Conclusions and Future Work

In this paper, the phenologies between ground (field server) and satellite (LS-8) platforms are compared and evaluated. Due to the temporal resolution of field server images (daily) and LS-8 images (16-day) are not comparable, the cubic interpolation procedure is performed for normalization purposes. Three rice fields (double and single crop cycle) were observed for the experiments. Using our approach, the numbers of crop cycle can be determined by using the phenology of LS-8 images. Referring to SOS and EOS parameters, the crop calendar are extracted from LS-8 comparing with the field server phenology. According to the results, observing the dates of SOS and EOS, LS-8 computed from ExG is more efficient than NDVI. However, the accurate SOS and EOS parameters are still required to improve by using an efficient model. For the future works, the development is not only to improve the model of crop calendar extraction but also to include with the other satellite data such as MODIS (Moderate Resolution Imaging Spectroradiometer) [MODIS, 1999]. The phenology computed from the satellite images will be more accurate and useful. For the crop calendar modeling, the day shift (error) between the ground and satellite platforms should be reduced.

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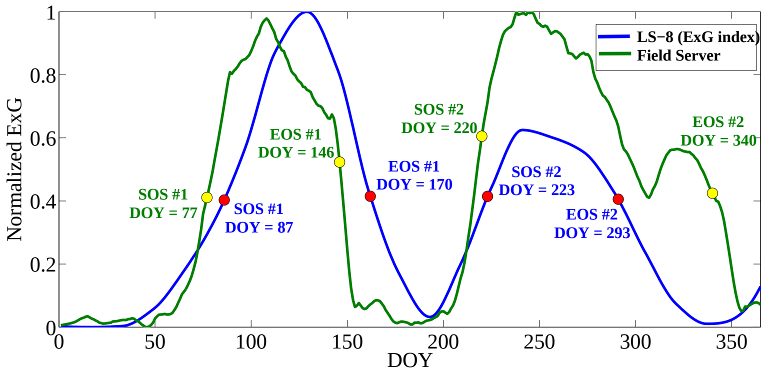
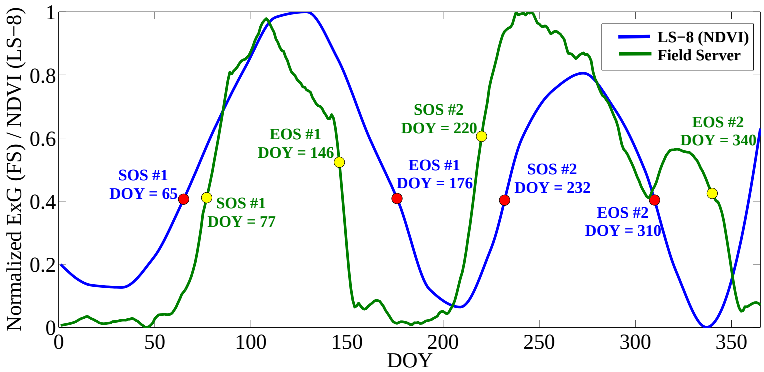
A. More Results (Suphan #1, Roi Et)

• Suphan #1: Comparative results between field server and LS-8 phenologies are presented in figure 8. Referring to the crop calendar extracted from each platform, the images from the rice field are shown in figure 9.



1. Ground-based phenology and LS-8 with ExG index



2. Ground-based phenology and LS-8 with NDVI

Figure 8: Comparing with the ground-based (Suphan #1), crop calendars obtained from LS-8 with ExG index (above) and LS-8 with NDVI (below) are compared and evaluated.

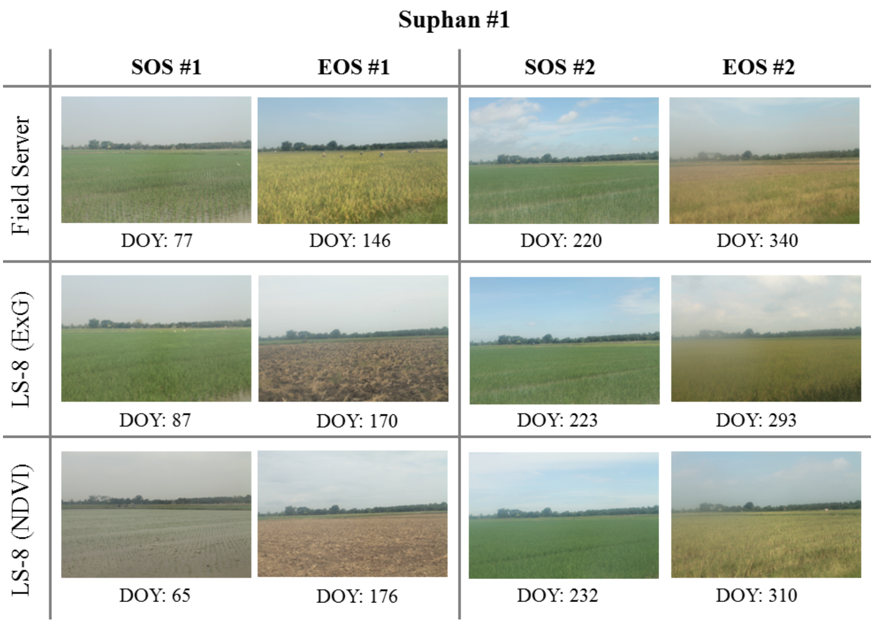
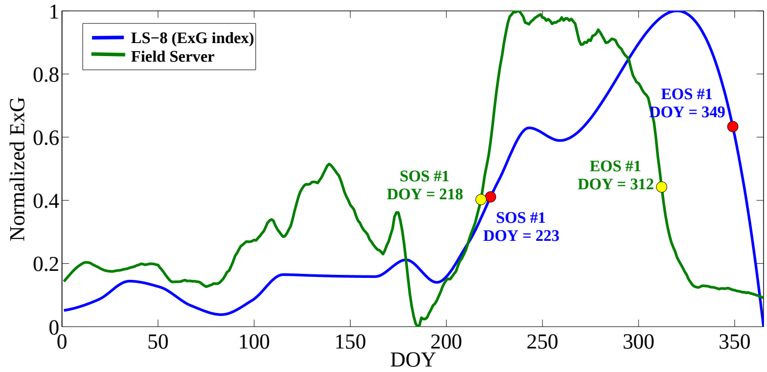
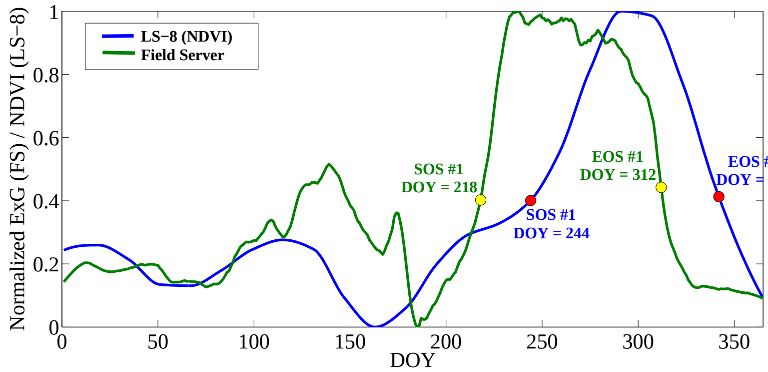


Figure 9: Referring to figure 8, the field server images of corresponding SOS and EOS obtained from each platform are presented (filed server: top, LS-8 (ExG): middle, and LS-8 (NDVI): low).

• Roi Et: Comparative results between field server and LS-8 phenologies are presented in figure 10. Referring to the crop calendar extracted from each platform, the images from the rice field are shown in figure 11.



1. Ground-based phenology and LS-8 with ExG index



2. Ground-based phenology and LS-8 with NDVI

Figure 10: Comparing with the ground-based (Roi Et), crop calendars obtained from LS-8 with ExG index (above) and LS-8 with NDVI (below) are compared and evaluated.

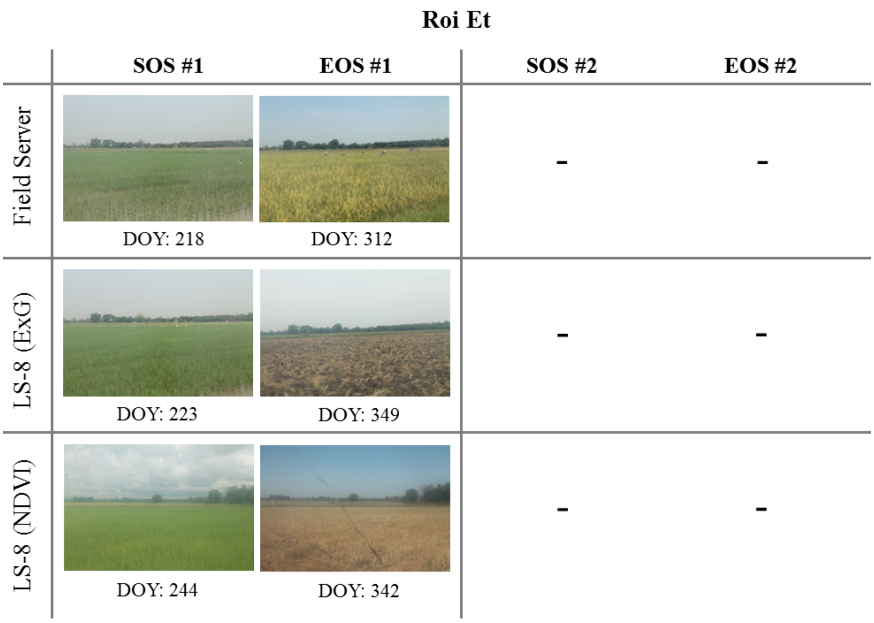


Figure 11: Referring to figure 10, the field server images of corresponding SOS and EOS obtained from each platform are presented (filed server: top, LS-8 (ExG): middle, and LS-8 (NDVI): low).