# Agricultural Monitoring by Earth Observation Satellites

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**KEY WORDS**: Food security, GEOGLAM, Rice yield estimate, Crop phenology, Agro-meteorological

**ABSTRACT:** Since Asian countries are responsible for approximately 90% of the world's rice production and consumption, rice is the most significant cereal crop in the Asian region. Therefore, Asian countries are expected to contribute Group on Earth Observations (GEO) Global Agricultural Geo-Monitoring (GLAM) through the development of an Asia-Rice Crop Estimation & Monitoring (Asia-RiCE) component. This paper presents rice yield estimate, crop phonology monitoring in Thailand and agro-meteorological monitoring by using Earth Observation (EO) data.

## 1. INTRODUCTION

Food security is one of the critical issues for the international community. In June 2011, the meeting of G20 agriculture ministers was held to discuss global food security and they agreed on an "Action Plan on Food Price Volatility and Agriculture" (Meeting of G20 Agriculture Ministers, 2011). This plan includes a Group on Earth Observations (GEO) Global Agricultural Geo-Monitoring (GLAM) initiative utilizing remote sensing to improve projections of crop production and weather forecasting. Hence, satellite remote sensing is expected to contribute national, regional and global food security through the systematic and efficient collection of food security related information such as agro-meteorological condition, crop growth or yield estimation. Food security related information is utilized to take mitigation strategies or policies to manage food shortages or trading, and ensure food security. Especially in Asia, rice is the most important cereal crop because Asian countries are responsible for approximately 90% of the world rice productions and consumptions. Therefore, Asian countries are expected to contribute GEOGLAM through the construction of rice crop monitoring component. Japan Aerospace Exploration Agency (JAXA) is working for the development of an Asia-Rice Crop Estimation & Monitoring (Asia-RiCE) component for the GEOGLAM initiative with broad range of stakeholders in Asia.This paper presents the overview of our activities for agriculture monitoring including the estimation of rice production, the crop phenology monitoring, and agro-meteorological monitoring system on the WWW.

## 2. Rice Crop Monitoring in Thailand

### 2.1. Rice Yield Estimate

JAXA is working with the Thailand Geo-informatics and Space Technology Development Agency (GISTDA) to develop a prototype system designed to provide paddy rice area and yield estimation. Generally, crop yield estimate consists of two components, estimation of cultivated area and yield per area. And we developed the prototype software to estimate cultivated area from satellite data and yield per area from a biophysical crop model. Cultivated paddy field is detected by using the seasonal signature of SAR data over paddy field, that is weak backscatter just before planting and strong backscatter from dense vegetation in growing season (Toan et al., 1989, Inoue et al., 2002). Figure 1 shows the overview of paddy field mapping by using seasonal characteristics of paddy rice. In this research, the paddy filed map was derived from time-series Advanced Land Observation Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) data with a simple thresholding method.

Then, to estimate rice yield per unit, we applied a rice crop model developed by Khon Kaen University, Thailand, which is a simple biophysical model. The input data to the model are physical and chemical properties of the soil, physiological crop characteristics, and daily weather such as photosynthetic active radiation (PAR), precipitation, wind velocity and humidity. Precipitation and parameters were acquired by satellite observations and

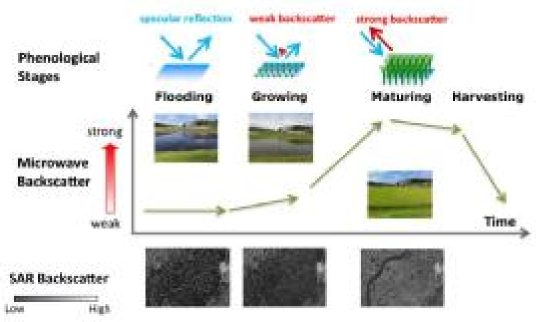



Figure 1. Seasonal changes of backscattering coefficients over paddy field.

Table 1. Results of rice yield estimation of the study area located at Khon Kaen, Thailand in 2011. Validation data of yield per unit (YPU) meansKh average YPU of direct seeding (230g/m$^2$) and that of transplanting area (280g/m$^2$).

| | Acreage ($m^2$) | Yield per Unit ($g/m^2$) | Yield ($t$) |
|---|---|---|---|
| Estimation | 164,406 | 203.96 | 33.53 |
| Validation | 166,766 | 230/280 | 40.96 |
| Accuracy | 98.6% | - | 81.9% |

others were obtained by in-situ measurements. Table 1 shows the result of rice yield estimate of the pilot study area (217 parcels of paddy field) located at Khon Kaen province, northeastern part of Thailand in 2011. The results were highly consistent with the validation data obtained by in-situ measurements including crop cutting. The accuracies of paddy acreage and rice yield estimates were 98.6% and 81.9%, respectively. At the moment, we are trying to expand the developed system to whole Thailand.

### 2.2. Crop Phenology Monitoring

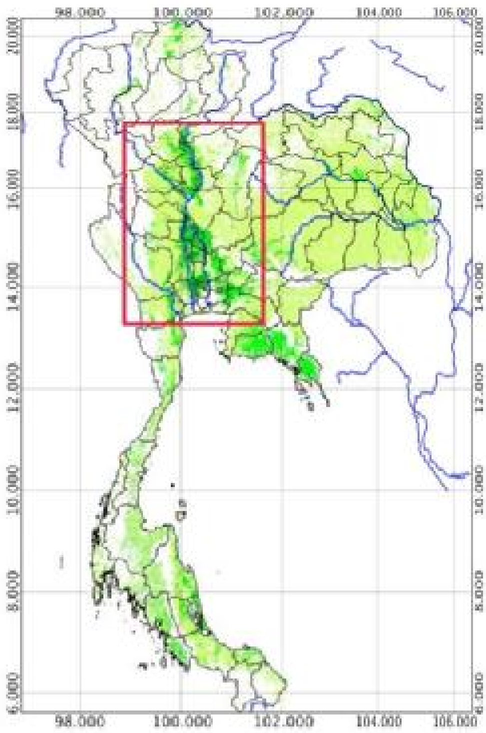
The prototype system to estimate rice yield have been developed only for the small pilot area. To expand the system to the whole country, crop calendar indicating the timing of planting, growing or harvesting of each area is indispensable to estimate yield per area. Because the Asian region, especially Southeast Asia has large variety of the crop calendars such as single, double and sometimes triple cropping in a year, and the pattern mostly relies on the water availability. To derive the crop calendar of each pixel, MODIS NDVI is useful because of its high temporal resolution (Sakamoto et al., 2005). In this study, Discrete Fourier Transform (DFT) was applied to 16-day MODIS NDVI data (MOD13) observed during 2001 - 2011.

Figure 2 shows the cropping cycle in Thailand and Chao Phraya River basin. Maximum frequency of each pixel derived from DFT analysis can indicate how many times the area is cultivated in a year. Average cropping cycle of a year at each pixel was calculated by dividing the derived frequency by the years of analysis and mapped over Thailand. Double or triple cropping area is located along the Chao Phraya River because paddy fields along the river are irrigated and a large amount of water is available. On the other hand, most of the paddy fields in the northeastern part of Thailand are in rain-red cultivation area and crop is harvested only once a year. Although further validations of the derived map against in-situ data or national agricultural statistics are needed, this map derived from MODIS data seems to be able to capture actual cropping cycle based on the visual interpretation. The derived crop calendar will be useful to the determination of the observation timing of SAR or higher resolution satellites. In addition, it can be the input parameter for crop models to determine the planting or harvesting date.

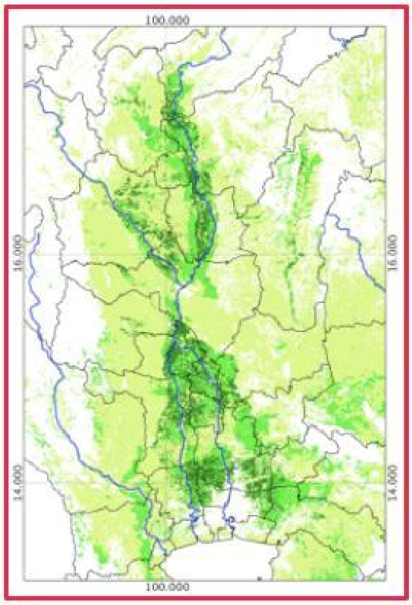
However, some areas of the derived cropping cycle map in the southern part of Thailand indicated extremely high-frequency more than 4-time per a year, this is because of the affect of cloud contamination. The smoothing algorithm, for example, Best Index Slope Extraction (BISE) algorithm can be useful to remove cloud contamination remained in MODIS product.

## 3. AGRO-METEOROLOGICAL MONITORING SYSTEM ON THE WWW

Agro-meteorological factors such as precipitation, solar radiation, land-surface temperature and soil moisture are imperative to predict crop yields, because these factors are one of the significant parameters to control crop growths. So far, these variables were mainly observed by ground-based measurements at weather stations. However, the data acquired at the stations are sparse and not distributed uniformly, and some variables can be missing. Remote sensing can measure agro-meteorological variables globally and uniformly with a certain revisit time. Figure 3 illustrates the examples of satellite-based global agro-meteorological products provided by JAXA. Figure 3 shows global hourly precipitation product (Fig.3-a), namely Global Satellite Mapping of Precipitation (GSMaP), derived from multiple microwave and RADAR satellites and geostationary satellites including TRMM PR/TMI, Aqua AMSR-E, DMSP SSM/I, MTSAT-2 and so on (Kubota et al, 2007). Photosynthetically Active Radiation (Fig.3-b) and Sea/Land Surface Temperature (Fig.3-c) are estimated from Terra/Aqua MODIS (Frouin et al., 2007, Saigusa et al., 2010), and soil moisture (Fig.3-d) is estimated from AMSR-E (Fujii et al. 2009). These products are provided via the internet for public use (http://sharaku.eorc.jaxa.jp/GSMaP/index.htm,




(a)




(b)

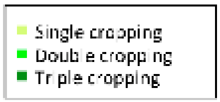
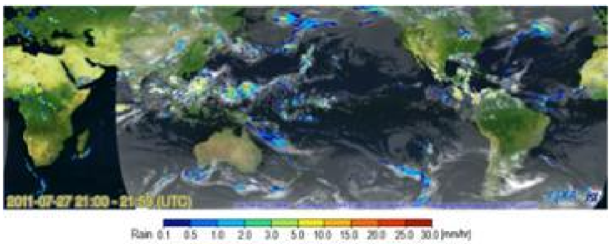
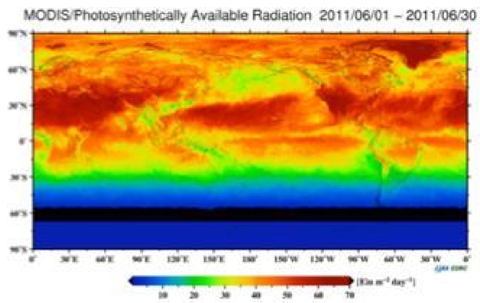


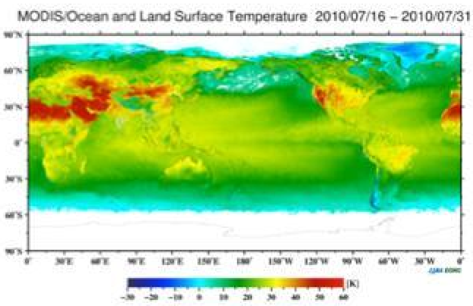

Figure 2. Crop calendar of the whole Thailand (a) and the Chao Phraya River basin (b). Croplands were defined as Croplands, Permanent wetlands and Cropland/Natural Vegetation of the MODIS landcover map (MCD12).



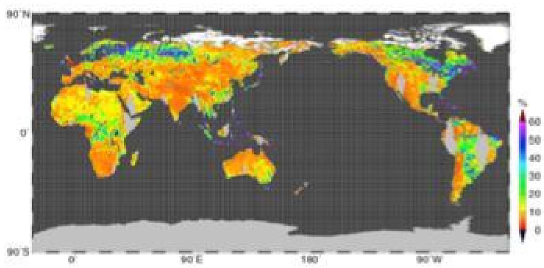

(a) Precipitation




(b) Photosynthetically Active Radiation (PAR)




(c) Sea/Land Surface Temperature




(d) Soil Moisture

Figure 3. Global agro-meteorological products derived from various satellite data.
(http://sharaku.eorc.jaxa.jp/GSMaP/index.htm, http://kuroshio.eorc.jaxa.jp/JASMES/index.html)

http://kuroshio.eorc.jaxa.jp/JASMES/index.html).

These products are imperative as input parameters for crop models to estimate crop yield. In addition, historical records of these products are useful to formulate the relationships between the climatic factors and the annual crop yields. This kind of knowledge will be useful information to predict future crop yields affected by climate change.

## 4. CONCLUSION

This paper presents the agricultural application of EO data including rice yield estimate, crop phonology monitoring in Thailand and agro-meteorological monitoring. Remote sensing is a useful tool to obtain the information on rice yield, crop phenology and agro-meteorological conditions in local- to global-scales, the systematic and accurate food security related information derived from EO data are indispensable to national and global food security policy. Further research will be needed to estimate rice crop yield over the whole country with acceptable precision. We would like continue the development of an Asia-RiCE component for the GEOGLAM initiative in cooperation with broad range of stakeholders in Asia.

## ACKNOWLEDGEMENTS

The MODIS data were obtained from Earth Observing System Clearing House (ECHO)/Warehouse Inventory Search Tool (WIST) at Goddard Space Flight Center (GSFC), National Aeronautics and Space Administration (NASA). The authors wish to express their gratitude to Prof. Masaru Mizoguchi, The University of Tokyo, Dr. Homma, Kyoto University for the field survey in Thailand and other all participants in GISTDA-JAXA collaborative project.

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