Food security monitoring using Japan's space technology

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ABSTRACT

On November 2011, the Group on Earth Observations (GEO) has announced that it is establishing a Global Agricultural Monitoring initiative to improve food security and market stability around the world, and particularly in vulnerable countries. The GEO Global Agricultural Monitoring initiative (GEO-GLAM) will bring together existing national and regional monitoring systems to establish a "system of systems" for monitoring global agricultural production and food security. GEO-GLAM will focus initially on four key crops – corn, rice, soybeans and wheat – that are widely traded and whose production is dominated by the world's main agricultural producers. Fluctuations in the annual production of these critical commodities can impact global food markets, cause price volatility and threaten food security in vulnerable countries. Since Asian countries are responsible for approximately 90% of the world rice production and consumptions, rice is the most significant cereal crop in Asia and Japan Aerospace Exploration Agency (JAXA) agreed to lead the development of Asia rice monitoring work plan for GEO-GLAM. In addition, JAXA works with Thai Geo-Informatics and Space Technology Development Agency (GISTDA) to develop a prototype system to provide crop anchorage and yield estimation by using space-based radar and other earth observation satellite based data with ground observation data and crop growth model for rain-fed type rice in Thailand. This paper describes the overview of Japan's activity for food security monitoring using Japan's earth observation satellite and early results of rice crop monitoring using space based radar under JAXA-GISTDA cooperation.

1. INTRODUCTION

Given the critical importance of studying food security issues in a increasingly inter-connected world, we need a global view of global croplands, their productivity, and their water use leading to food security analysis and action. In 2011, G20 agriculture ministers agreed to conduct GEO (Group on Earth Observations) to define and implement Global Agriculture Monitoring (GLAM) project. G20 GEO-GLAM work plan aimed to reinforce the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales. This will require creation of a framework of best practices that will lead to development of an advanced geospatial information system on croplands, their productivity, and their water use. Remote sensing is the only data type that makes such a complex agricultural monitoring system feasible that is globally consistent, repeatable, and scalable. As a part of G20 food security concern, since Asian countries are responsible for approximately 90% of the world rice production and consumptions, rice is the most significant cereal crop in Asia. Japan Aerospace Exploration Agency (JAXA) works with Thai Geo-Informatics and Space Technology Development Agency (GISTDA) to develop a prototype system to provide crop anchorage and yield estimation by using space-based radar and other earth observation satellite based data with ground observation data and crop growth model for rain-fed type rice in Thailand. This paper describes the overview of Japan's activity for food security monitoring using Japan's earth observation satellite and early results of rice crop monitoring using space based radar under JAXA-GISTDA cooperation.

2. Japan’s satellites for food security

2.1 Remote sensing for food security

Given the critical importance of studying food security issues in a increasingly inter-connected world, we need a global view of global croplands, their productivity, and their water use leading to food security analysis. This will require creation of a framework of best practices that will lead to development of an advanced geospatial information system on croplands, their productivity, and their water use. Such a system will be conceptualized to be global, consistent across nations and regions by providing information such as: (a) crop types, (b) precise location of crops, (c) cropping calendar, (d) watering methods (e.g., irrigated, supplemental irrigated, rainfed), (f) agro-meteorological information (e.g. precipitation, solar radiation, land surface temperature, snow cover and heat/cold wave) and terrain data (slope or aspect of land). Remote sensing is the only data type that makes a complex agricultural monitoring system feasible that is globally consistent, repeatable, and scalable. The specific remote sensing advances enabling global cropland mapping and generation of their statistics.

2.2 Japan’s satellites for food security

Opportunities to set-up such a global system are best achieved using fusion of advanced Earth Observing (EO) data from multiple remote sensing platforms (e.g., Landsat, ALOS-1/3, IRS Resourcesat, SPOT, MODIS, GCOM-C, and NPOESS VIIRS; active and passive microwave systems such as TRMM, AMSR-E, GCOM-W, ALOS-1/2, RADARSAT and ENVISAT ASAR ;, thermal infrared imagers; and commercial data from systems such as IKONOS, Quickbird, GEOEYE, Rapideye) in combination with national statistics, ancillary data / ground based observation (e.g., elevation, precipitation, temperature, soils), and systematic collection of field-plot data. Such a system, at global level, will be complex in data handling and processing and requires coordination between multiple agencies leading to development of a seamless, scalable, and repeatable methodology.

Way forward in cropland mapping will be to use high spatial resolution (30 m or better) that are multi-temporal (e.g., every 15 days during the crop growing period), multi-sensor data fusion (e.g., to increase richness of data to better characterize crops) along with automated cropland classification algorithms to produce cropland area statistics and crop productivity at pixel to various administrative units level routinely and rapidly. The overwhelming focus of a global cropland mapping should be on 18 major crops which occupy 85% of all global cropland areas. Japan’s ALOS-1 and 3 will provide such cropland area estimation information.

Cropland phenology, cropping intensity, and crop calendars are best studied using time-series remote sensing such as MODIS time series data. GCOM-C with VIIRS will provide continues MODIS type dataset as POST-MODIS. These data will help build the history of agricultural development by providing information on such factors as which areas have changed from rainfed to irrigated, non croplands to croplands croplands to non-croplands, single crop to double crop, double crop to single crop, or have remained double crop always, single crop always, or have supplemental irrigation.

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 vegetation growths. So far, these variables are 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 enables us to measure agro-meteorological variables globally and uniformly with a certain revisit time. These products are imperative for policy maker or scientists to understand current meteorological conditions that affect crop growths and yields. In addition, historical records of these products are useful to formulate relationships between climatic factors and annual crop yields. This kind of information will be useful information to predict future crop yields which will be affected by climate change. Hourly precipitation global data named GSMaP produced by multiple earth observation satellites including TRMM, NOAA, GCOM-W with geostationary meteorological satellites are available. In addition with precipitation, solar radiation, land surface temperature and soil moisture information are also provided by earth observation satellites, such as MODIS, GCOM-W, GCOM-C, VIIRS, SMOS, SMAP, etc.

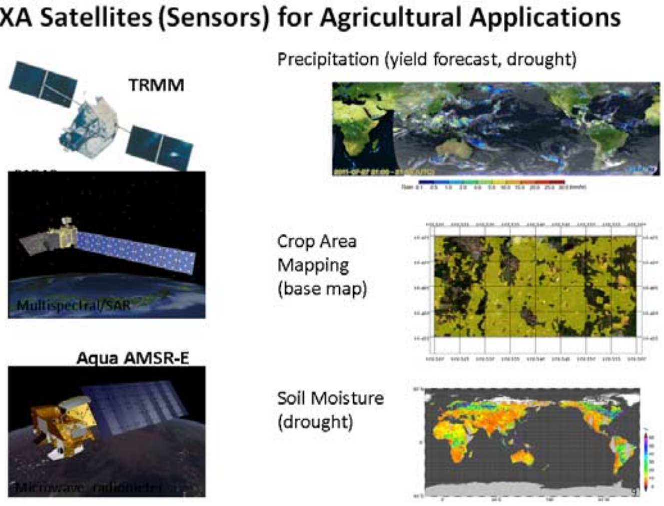


Figure 1. Japan's satellites for food security

3. JAXA-GISTDA RICE CROP MONITORING

3.1 Project overview

Figure 2 illustrates framework of a rice crop monitoring project in Kohn Kaen province in Thailand under the cooperation between JAXA and GISTDA. This project consists of paddy field mapping rice yield estimation by using observation data and crop growth model. First, paddy field are detected and mapped by using multiple season data of ALOS/ PALSAR and/or Radarsat. In dry season, optical sensors of THEOS and ALOS/AVNIR-2 have higher spatial resolution and useful for detailed mapping. However, in rain season for main rice crop in Thailand, it is sometimes difficult to estimate acreage by optical sensors because of cloud. In contrast, although PALSAR and Radarsat does not have higher spatial resolution as THEOS or AVNIR2, PALSAR and Radarsat are active microwave sensors (SAR sensors) and they can penetrate cloud and acquire land-surface information even if the area is covered by cloud. Therefore, SAR sensors are suitable for monitoring cloudy area such as tropics including Thailand. By integrating those SAR sensors data with ground observation data for agro meteorological information, we estimated rice crop acreage for entire Kohn Kaen province. In addition with acreage estimation by SAR data, we also studied the relationship between accumulated precipitation and transplanting ratio in Khon Kean since farmers in Kohn Kean decided rice seeding method with rain condition and their experience. There are two rice seeding method in Thailand. One is transplanting if there is enough precipitation in

the beginning of rainy season. Another is direct seeding with much seeds. In general, rice productivity with transplanting method is more than one with direct seeding. Thus, we applied satellite based precipitation map (GSMaP) to estimate the ratio of transplanting.
After estimation of rice crop acreage, through using the statistical information by the office of agriculture and economic (OAE), the accuracy of paddy field mapping by SAR data is validated Second, we applied rice crop growth model developed by Prof. Krik Pannangpetch in Khon Kaen University (KKU model) to estimate rice crop yield per unit, and we compare the yield per unit by KKU model with ground sampling data (crop cutting) and statistical information by office of agriculture and economy (OAE) in Thailand. Then, we have rice crop yield information by SAR and other data with the model.

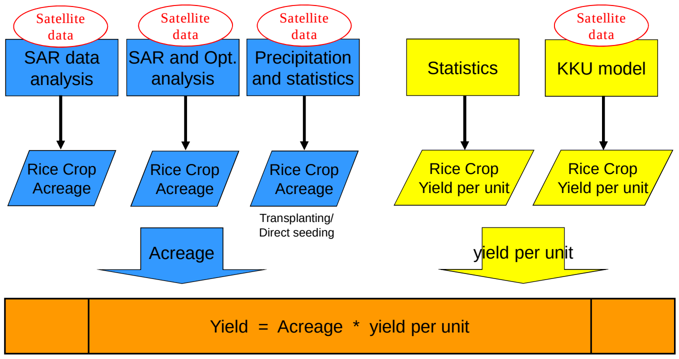


Figure 2. Framework of a rice crop monitoring project in Thailand

3.2 Methodology for Paddy field Mapping by SAR

It is difficult to differentiate paddy rice area from other crop areas, because they have similar spectral and scattering signatures in flowering stage. Xiao et al. [1] detected paddy field by using distinctive phenological stages, when the surface is flooded just before paddy rice is planted and when the surface is matured after planting by using MODIS data. In this project, seasonal characteristic of paddy field was retrieved from multiple SAR data. In flooding season, backscatter is quite low, because the flooding surface is so smooth that it causes specular reflection. In matured season, backscatter indicates the highest, because the surface of vegetated paddy field is so rough that it causes strong backscatter (Inoue et al., 2002). And, ALOS/PALSAR imagery enables us to detect the pixels that have flooded and flowering season easily, because even if the land-surface is covered by cloud, ALOS/PALSAR can monitor seasonal changes of backscatter.

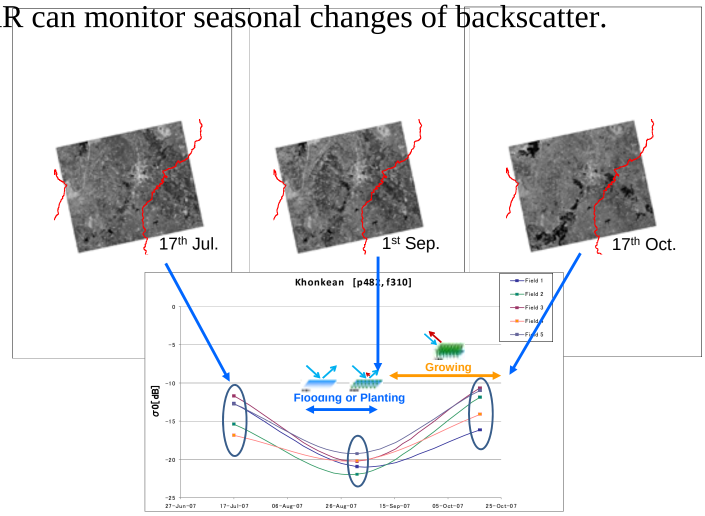


Figure 3. Backscattering change of rice crop phenology

3.3 Study results of rice crop yield estimation in Khon Kaen in Thailand

We applied the above proposed method to 2011 rainy crop season using SAR data with ground observation and we compared rice crop yield with field survey information through crop cutting. As a first step, we derived rice crop acreage by using SAR data with yield per unit information derived from Khon Kaen University crop growth model with satellite and ground based agro-weather information in GIS shown in figure 4.

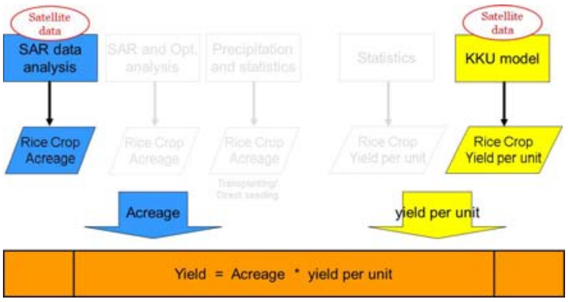
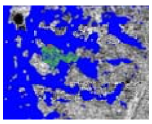


Figure 4. Rice crop yield estimation

By multiplying rice crop acreage information with yield per unit for each polygon, total rice crop yield for rain-fed type rice in Khon Kaen is estimated. To check the accuracy of this estimation, we use crop cutting information as yield per unit information and statistical information provided by OAE.

Table 1. Result of the study in Khon Kaen.

	Acreage [m2]	Yield per unit [g/m2]	Yield [ton]
Result of estimation	 164,405.99	Statistic information 203.96	Acreage*Yield per unit 33.53
Validation data by field survey	166,766.39	2.47 – 750.08	40.96
Accuracy	98.58%	–	81.87%

*Statistic information : Average of the past five years.

Table 1 shows the comparison between space based yield estimation information with field survey based yield estimation information with statistical information. The accuracy of acreage estimation is more than 98% and the accuracy of yield estimation is about 82%.

4. Conclusion

This paper reports earth observation satellite usefulness for food security and preliminary results of rice crop monitoring under GISTDA and JAXA joint research in Khon Kaen. We validated the usefulness of this study with field survey information and statistical information through cooperation with University of Tokyo and Khon Kaen University on GIS. However, to use rice crop acreage estimation for entire Thailand and further, we should improve KKU model to support irrigated rice. In addition, it is very important to monitor rice crop phenology since there are more than one rice crop growthing in Asian countries every years. In addition with them, we may consider to apply SAR data with optical sensors to improve rice crop acreage and apply more space based observation data to provide agro-weather information such as solar radiance, etc. To integrate those data, it is also very important to develop GIS with downscaling and/or upscaling technology to have uniform grid information from space based observation, ground based observation with statistical information.

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