RICE MAPPING USING SENTINEL-1 SAR IMAGERY IN AYUTTHAYA PROVINCE, CENTRAL THAILAND

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ABSTRACT: Rice is the most important staple food in Thailand, and an economically important export crop. Thailand is one of the largest rice producers and exporters in the world. In Thailand, rice planting season is also the rainy season, and cloudy weather is therefore very common. In recent years, Synthetic Aperture Radar (SAR) imagery is playing a more important role in rice crop mapping because of its advantage of using microwave that can penetrate clouds. The aim of this study is to map the rice area in Ayutthaya province, Thailand using Sentinel-1 SAR images during the wet-season (May-August) in 2015. The Ayutthaya province, located in the central area of Thailand, is one of the important rice production areas in the country. Three essential steps are required to conduct the study: (1) image pre-processing, including radiometric correction, geometric correction, and speckle noise removal; (2) rice area mapping, including Normalized Difference Sigma-0 Index (NDSI) calculation and NDSI thresholding; and (3) assessing mapping accuracy, by comparing with ground truth data. This study shows the applicability of Sentinel-1 SAR imagery for rice crop mapping during the cloudy wet-season in Thailand.

1. INTRODUCTION

Rice is one of the most widely grown crops in the world, and it is by far the most important food crop for the poor. More than 3.5 billion people depend on it worldwide. In most Asian countries, rice availability is equated with food security (RIICE, 2012). Also, rice is a staple food for many countries in Asia including Thailand. It has been Thailand’s traditional food crop and an economically important export product. In 2015, the rice product was approximately 23.5 million tons and exported around 9.8 million tons (OAE, 2015). In some regions of Thailand, rice can be planted and harvested more than once a year and has a complicated crop calendar. Thus, earth observation satellites play an important role in estimating rice-planted areas in a timely, efficient, accurate, and objective manner (Oyoshi et al., 2015).

Following the rice crop calendar, there are two rice seasons (the wet-season and dry-season) in Ayutthaya province. In this study, we focused on the wet-season (May-August) which is the main season for planting rice. During this time of the year, it is rainy season and there is a high cloud density limiting the optical sensors usually affected by cloud cover. The Synthetic Aperture Radar (SAR) can detect target objects on the ground even though they are covered by cloud because it uses microwaves to penetrate through clouds in all weather conditions. Therefore, the advantage of SAR has been widely demonstrated in rice monitoring data such as rice area mapping (Shao et al., 2000; Chen et al., 2015). However, the SAR imagery is costly and the careful planning is needed to make sure that the acquired images cover the studied area. Since April 2014, the European Space Agency (ESA) has launched the Sentinel-1 satellite providing freely SAR imagery covering the entire world’s region and having a short revisit time. For this reason, the Sentinel-1 would greatly advance users’ capabilities and provide data routinely and systematically for land and marine monitoring, as well as for climate change and security (ESA, 2013).

Normalized Difference Sigma Naught Index (NDSI) is the index that derives normalized value of difference of sigma naught value between two images. In the SAR imagery, the digital number data can be converted to sigma naught value in order to analyze differences of two SAR images (Furuta and Tomiyama, 2008). NDSI value takes a value from -1 to 1. If the NDSI value is close to -1 or 1, it means that the targets are changed. On the other hand, if the NDSI value is close to 0, it means that the targets are not changed during that period of time.

The main objective of this study is to show the applicability of VH polarization from Sentinel-1 SAR imagery for rice crop mapping in Ayutthaya province, Thailand during the wet-season (May-August) in 2015. The NDSI value was calculated to prove alteration of the targets between the two images. The NDSI threshold was also determined to identify rice and non-rice production areas.

2. STUDY AREA AND DATA

2.1 Study Area

The study area is in Ayutthaya province located in the central region of Thailand and in Chao Phraya river flat plain (Figure 1). It is one of the important rice production areas in the country. The province is subdivided into 16 districts, with a total area of 2,557 square kilometers and a total population about 808,360 people. Most of the areas are paddy fields. The average annual temperature is 29.1 degrees Celsius and the average annual rainfall is about 1152.7 millimeters with 95 rainy days (Ayutthaya Meteorological Station, 2016). The total rice area in Ayutthaya province was approximately 1,518 square kilometers or almost 60% of the total area (DOAE, 2015). Thus, rice is the main agricultural food in Ayutthaya province. During the wet-season (May-August), the rice phonological stages in this study area are almost the same and can be divided into three stages. Most of the rice plants are sowing in May, growing from May to July, and harvesting in August.

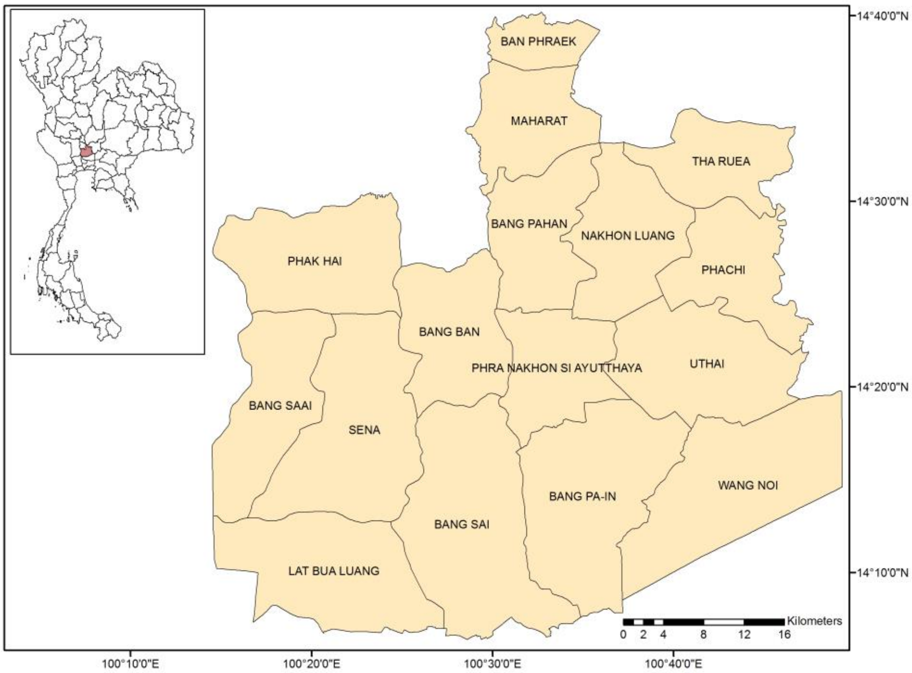


Figure 1. Location of the study area in Ayutthaya province, Central Thailand

2.2 Data

Sentinel-1 is the European Space Agency (ESA) radar satellite launched in April 2014. The satellite provides C-band SAR imagery operating in four imaging modes with different resolution: Strip Map Mode, Interferometric Wide Swath Mode, Extra-Wide Swath Mode, and Wave-Mode. It provides dual polarization capability with a 12 days repeat cycle (ESA, 2013). In this study, the VH polarization images of Interferometric Wide Swath with 35-40 degrees incidence angle were used. The image acquired on May 25, 2015, was selected as the sowing phase while the image obtained on August 29, 2015, was selected as the heading phase based on the rice crop calendar.

The maps of rice-growing areas of Ayutthaya province from May to August 2015 were collected from rice production monitoring system processed by Geo-Informatics and Space Technology Development Agency (GISTDA). The data were converted to raster map (10 m resolution) and used as ground reference data to assess the accuracy of the rice mapping result. The rice maps also provide the estimated rice areas and it is also used for accuracy verification of the classification results.

3. METHODS

3.1 Image pre-processing

Sentinel-1 images were pre-processed by using the Sentinel Application Platform (SNAP), software provided by ESA. First, radiometric correction was done to correct the distortion from the system noise, sensor malfunction, and atmospheric interference. Next, geometric correction was done to remove the distortion from sensor geometry with the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global, 30 meters digital elevation model data. The digital number data were converted to sigma-naught (dB), and the data were resampled to a spatial resolution of 10 meters by applying the bilinear interpolation algorithm. Then, speckle noise filtering was done to reduce the speckle noise in the images by using Lee filter with a 5 x 5 window size. Lastly, the pre-processed SAR images were clipped to cover the study area.

3.2 Rice area mapping

The backscattering value of SAR image from the surface depends on the roughness of the surface. Rice paddy fields have distinctive characteristics that are different from other land cover types. Rice had a low backscatter value during the sowing stage because the paddy fields were filled with water. After that the backscatter value during growing stage was increased because the rice was growing, resulting in the increment of density, height, and biomass. The backscatter, nonetheless, was only increased during the growing state and become quite stable after heading stage (Toan et al., 1997). The result of the backscatter value changes of paddy field over time could be used to identify rice areas. Thus, Normalized Difference Sigma Naught Index (NDSI) was used in this study to analyze differences of the two images.

NDSI is the index deriving normalized value of difference of sigma naught value between the two images. In order to calculate the NDSI, the master image backscatter value is subtracted by the slave image backscatter value, and divided by the sum of the master image backscatter value and the slave image backscatter value (Furuta and Tomiyama, 2008). The equation can be expressed as follows:

$$\text{NDSI} = \frac{\sigma_0^m - \sigma_0^s}{\sigma_0^m + \sigma_0^s}$$

In this study, the image acquired on May 25, 2015, was selected as the slave image because of the sowing phase. The image obtained on August 29, 2015, was selected as the master image because of the heading phase. The Sentinel-1 NDSI map is illustrated in Figure 2.

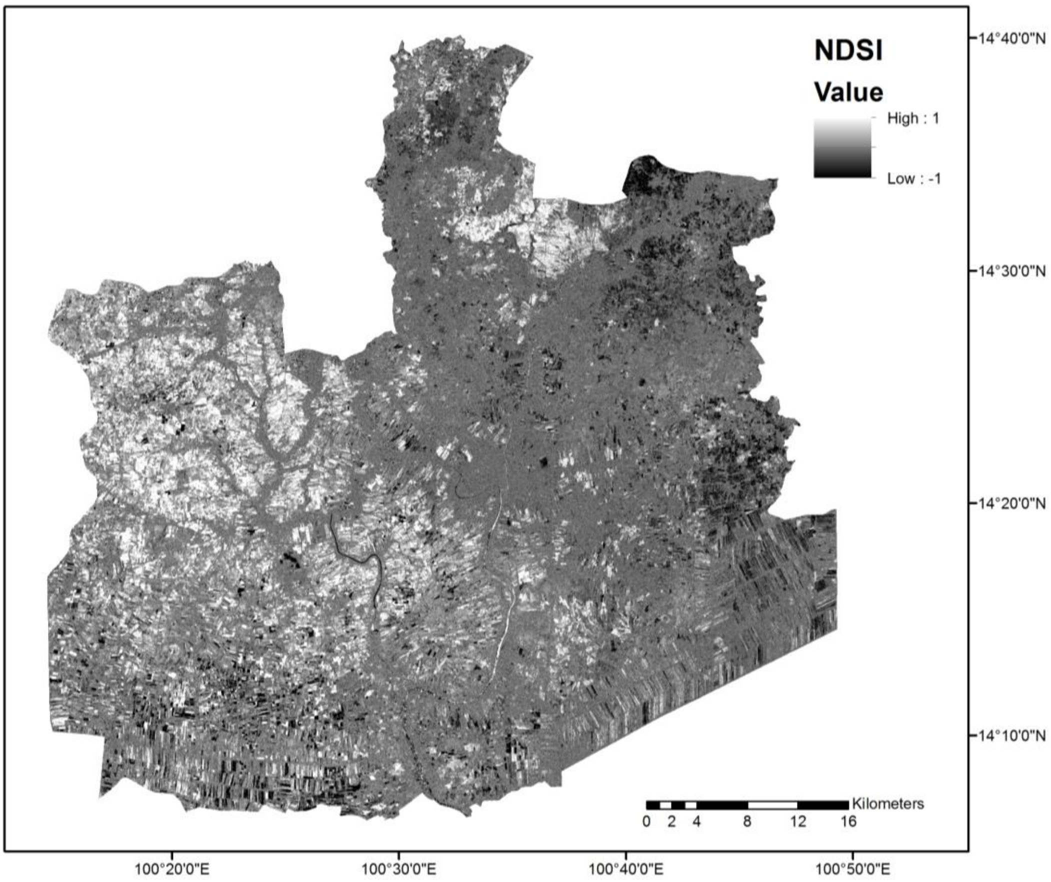


Figure 2. Sentinel-1 NDSI Map

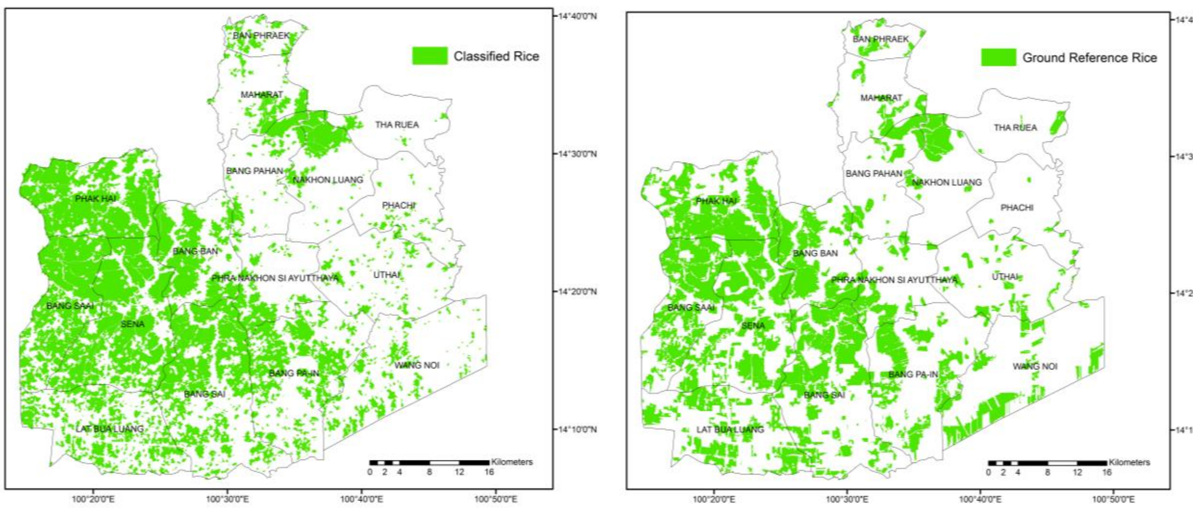
Traditional pixel-based analysis of remotely sensed data results in inaccurate identification of some crops due to pixel heterogeneity, mixed pixels, spectral similarity, and crop pattern variability. This problem can be overcome by using object-based image analysis (OBIA) techniques, which incorporate new spectral, textural and hierarchical features after segmentation of imagery (Peña-Barragán et al., 2011).The object-based identification algorithm using segmentation of each parcel in the image may be useful in reducing misclassifications induced by speckle noise (Oyoshi et al., 2015). Segmentation is the dividing of an image into separated patches. It groups pixels to spatial clusters which meet certain criteria of homogeneity and heterogeneity (eCognition User Guide 4, 2004). Hence, we applied the object-based identification algorithm in the study. The NDSI images were segmented by using eCognition, software provided by Trimble. The software can use different segmentation scale parameter and the composition of homogeneity criterion, shape and compactness, for creating the patch objects from the image. In this study, we set the segmentation scale parameter as 15. For the composition of homogeneity criterion, we set shape equal to 0.2 and compactness equal to 0.8 because the patch fits the rice paddy field visually after the segmentation process. Then, the threshold was determined to classify rice and non-rice areas, which are the trial and error threshold based on the NDSI value of the image.

3.3 Accuracy assessment

To assess the accuracy of the rice classification result, the land covers were classified into two land cover types which are rice area and non-rice area. For each land cover type, 1,000 pixels were randomly generated from the ground reference data and compared with the classification result. The overall accuracy and kappa coefficient value of the rice and non-rice areas was calculated using confusion matrix to assess the classification accuracy. Also, comparing the rice area at district level between the Sentinel-1 derived rice area and GISTDA's rice area assessed the consistency of the classification result.

4. RESULTS AND DISCUSSION

The rice area map was created using the NDSI threshold value of 0.03 for the Sentinel-1 NDSI map. The classified rice map generated using VH polarization data from NDSI calculation and segmentation with the setting threshold is illustrated in Figure 3(a). The classification result showed spatial distributions of rice-growing patterns in Ayutthaya province during wet-season in 2015. The rice areas were clustered at the western part of the study area from May to August, which including Phak Hai, Bang Saai, Sena, Bang Ban, Lat Bua Luang, and Bang sai districts. Generally, the rice areas are widely distributed around Ayutthaya province, but the result shows only the western part because of the late growing rice in the eastern part of the province. The classification result was compared with the ground reference data by randomly generated 2,000 pixels, 1,000 pixels for each rice area and non-rice area. The overall accuracy and kappa coefficient were 85.2% and 0.7, respectively. Table 1 shows the accuracy assessment of the classification result. The producer accuracy of the rice area was 83.2% while that of the non-rice area was 87.2%, which mean that the rice and non-rice area can be classified well.



(a) (b)

Figure 3(a). The classified rice map, (b). The ground reference rice map

Table 1. Accuracy assessment of the classification result

		Classification Result		
		Rice Area	Non-rice Area	Total
Ground Reference Data	Rice Area	832	168	1000
	Non-rice Area	128	872	1000
	Total	960	1040	2000
Producer Accuracy (%)		83.20	87.20	
User Accuracy (%)		86.67	83.85	
Overall Accuracy (%)		85.20		
Kappa Coefficient		0.704		

In addition to the accuracy assessment, the result of rice area derived from Sentinel-1 imagery was compared with the rice area derived from GISTDA at district level. The result showed that the classified rice area for each district was closely the GISTDA's rice area (Figure 4). However, there were some districts that the rice area was overestimated because other crops grown in their vicinity might have similar NDSI value as rice. So, after NDSI thresholding, the classification result was shown. The root mean square error (RMSE) between the classified rice area and the GISTDA's rice area was 15.18 square kilometers. Overall, the classification result from Sentinel-1 SAR imagery showed satisfactory results.

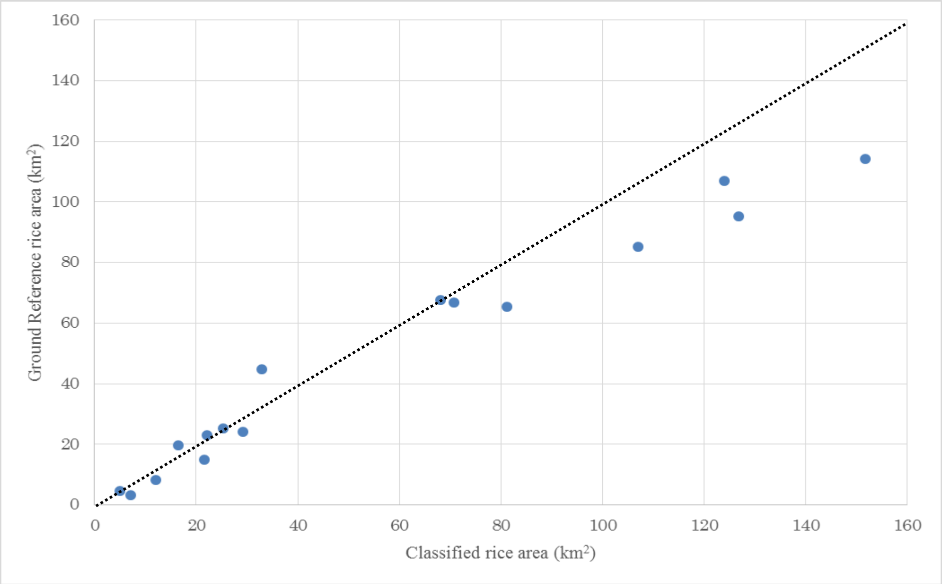


Figure 4. The consistency between Sentinel-1 derived rice area and GISTDA's rice area.

5. CONCLUSION

The changes of backscattering coefficient of Sentinel-1 SAR images acquired during the rice sowing and heading stages could be used to identify rice and non-rice area. The NDSI were used to analyze the differences of the two images and segmentation of each parcel in the image could help reducing misclassifications induced by speckle noise. The classified rice map compared with ground reference map indicated an overall accuracy of 85.2% and kappa coefficient of 0.7, respectively. The finding shows the potential of Sentinel-1 imagery and methodology for rice area mapping. Moreover, the Sentinel-1 provides SAR images at no cost, covering the entire world's region and having a short revisit time. It then advances user's capability to acquire the imagery readily to further study in many related fields. This study demonstrates the applicability of Sentinel-1 SAR imagery for rice area mapping using the NDSI calculation and threshold during the cloudy wet season in Thailand.

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