Int J Appl Earth Obs Geoinformation 69 (2018) 226–236

Contents lists available at ScienceDirect

Int J Appl Earth Obs Geoinformation

journal homepage: www.elsevier.com/locate/jag

Field-based rice classification in Wuhua county through integration of multi-temporal Sentinel-1A and Landsat-8 OLI data

Huijin Yang, Bin Pan*, Wenfu Wu, Jianhao Tai

School of Remote Sensing and Information Engineering, Wuhan University, China

ARTICLE INFO

Keywords:
Rice
Sentinel-1A
Landsat-8 OLI
Per-field approach
Time series SAR images

ABSTRACT

Rice is one of the most important cereals in the world. With the change of agricultural land, it is urgently necessary to update information about rice planting areas. This study aims to map rice planting areas with a field-based approach through the integration of multi-temporal Sentinel-1A and Landsat-8 OLI data in Wuhua County of South China where has many basins and mountains. This paper, using multi-temporal SAR and optical images, proposes a methodology for the identification of rice-planting areas. This methodology mainly consists of SSM applied to time series SAR images for the calculation of a similarity measure, image segmentation process applied to the pan-sharpened optical image for the searching of homogenous objects, and the integration of SAR and optical data for the elimination of some speckles. The study compares the per-pixel approach with the per-field approach and the results show that the highest accuracy (91.38%) based on the field-based approach is 1.18% slightly higher than that based on the pixel-based approach for VH polarization, which is brought by eliminating speckle noise through comparing the rice maps of these two approaches. Therefore, the integration of Sentinel-1A and Landsat-8 OLI images with a field-based approach has great potential for mapping rice or other crops' areas.

1. Introduction

Rice, which is one of the most important cereals, constitutes more than 12 percent of global cropland area and provides food for nearly half of the world's population (Corcione et al., 2016; Dong and Xiao, 2016; Xie et al., 2015). Nevertheless, rapid urban expansion and population growth in China pose a threat to food security in recent decade. Nearly 60 percent of the newly built-up areas are converted from cropland(He et al., 2017) and from 2000 to 2016, the yearly average population growth rate is about 0.55 percent based on the latest United Nations estimation. Moreover, China, with 7.8 percent of the world's total cropland, has to feed 19 percent of the total world population (He et al., 2017). Therefore, it is urgently necessary to update information about rice planting areas in order to estimate its production accurately and to maintain a close balance between rice production and food needs (Le Toan et al., 1997; Wang et al., 2015).

Recently, remote sensing technology has developed rapidly and widely applied to monitor and map rice. Compared with the conventional ground-based monitoring, remote sensing technique is an effective mean to monitor and map rice at regional scale, especially in the mountainous districts and hilly lands. This is because remote sensing ensures a synchronous and cost-effective monitoring (Corcione et al., 2016). Meanwhile, there are more and more remote sensing images mainly divided into optical data (e.g., SPOT-VGT, MODIS, and Landsat) and microwave data (e.g., RADARSAT, PALSAR and ENVISAT). Electromagnetic spectrum of optical data depends on reflection and emission properties of the earth's surface, and spectral features, texture and tone of optical data are the important information for image classification(Lu and Weng, 2007). But the spatial resolution of optical images (i.e., Landsat, MODIS, AVHRR, and SPOT-VGT) are relatively lower than that of SAR image and it is very difficult to obtain cloud-free images over the rice growing regions in Southern China (Mosleh et al., 2015). Whereas an important advantage of SAR is its all-weather and all-day capabilities, backscatter coefficient (σ°) of SAR depends on the structural and dielectric properties of the target surface (Chu and Ge, 2010; Haack et al., 2000; Sukawattanavijit et al., 2017). Therefore, the combination of SAR and optical images can potentially improve the accuracy of land-cover classification (Bagan et al., 2012; Brisco and Brown, 1995; Chu and Ge, 2010; Lu and Weng, 2007; Sukawattanavijit et al., 2017). Moreover, there are multi-temporal Sentinel-1A and Landsat 8 OLI data. So the study uses the temporal variation of backscattering coefficient of Sentinel-1A data and the spatial information of Landsat 8 OLI for rice mapping.

Currently, many efforts, such as different data sources and various

* Corresponding author at: School of Remote Sensing and Information Engineering, Wuhan University, Wuhan, Hubei, China.
E-mail addresses: panbin@whu.edu.cn, huijiny@whu.edu.cn (B. Pan).

https://doi.org/10.1016/j.jag.2018.02.019
Received 12 December 2017; Received in revised form 25 February 2018; Accepted 26 February 2018
Available online 07 April 2018

algorithms, have been made in rice mapping and monitoring. Besides, the temporal variation of radar backscatter over the growing season is the key factor in delineating rice area and multidate classifications can improve classification accuracy (Brisco and Brown, 1995; Mosleh et al., 2015). Many researchers use multi-temporal optical images ((e.g., Landsat, MODIS, AVHRR, and SPOT-VGT) to produce rice maps under the help of following measures as: Spectral Matching Techniques (SMT), Decision Tree algorithm (DT), Maximum Likelihood algorithm (ML) and Support Vector Machine (SVM) with commonly used remote sensing-based vegetation indices [i.e., Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI)] (Gumma et al., 2011; Gumma et al., 2014; Nuarsa et al., 2012; Peng et al., 2011; Qin et al., 2015; Xiao et al., 2005). Due to the development of SAR, some researchers use $\sigma^{o}$of different polarizations of multi-temporal SAR to map rice under the knowledge-based approaches or phenology-based classifiers (Bouvet and Le Toan, 2011; Le Toan and Laur, 1988; Miyaoka et al., 2013; Nguyen et al., 2016; Oyoshi et al., 2016; Qiu et al., 2015; Yang et al., 2014), and polarimetric parameters from polarimetric decompositions of quad-pol SAR data are also used for crops mapping by unsupervised classification [i.e., K-means and iterative self-organizing data analysis (ISODATA)] or supervised classification [i.e., SVM, ML and DT] (Fan et al., 2015; Hoang et al., 2016; Kumar et al., 2016; Li et al., 2012; Tan et al., 2007; Yonezawa and Watanabe, 2015; Zeyada et al., 2016). In addition, previous studies hold that the combination of hyper-temporal optical data and multi-temporal high-resolution SAR data can improve the accuracy of identification and the mapping of rice(Asilo et al., 2014; Fontanelli et al., 2015; Mansaray et al., 2017; Torbick et al., 2011a; Torbick et al., 2011b; Wang et al., 2015). Rosenthal and Blanchard (1984) did a study showing that the inclusion of microwave data in visible and infrared classification models improved classification accuracy from 73 percent to 92 percent; Brisco and Brown (1995) held that classification accuracy was improved to 92 percent by including the SAR data with the near-infrared (VNIR) data. But these studies are based on per-pixel algorithms instead of per-field approaches. Although there are some per-field rice classifications, they are only single-sensor data. What's more, the object of classification is mainly applied to other land covers instead of rice. For example, Shiu et al. (2012) mapped the rice fields with single-sensor data (FORMOSAT-2) in an object-based post classification; Based on the per-field approach, Chu and Ge (2010), using the synergy of TM images and SAR data, did a study about the classification of crop types, which did not include rice. Whereas some researchers held that the per-field classification provides consistently more accurate results than traditional per-pixel classification (Blaes et al., 2005; Brisco and Brown, 1995; Jiao et al., 2014; Rosenthal and Blanchard, 1984; Shiu et al., 2012). But altogether, it is still rare for studies using the per-field rice classification methods with multi-sensor data integration. Therefore, a field-based approach will be applied for rice mapping on the integration of multi-temporal Sentinel-l A and Landsat-8 OLI data.

For hyper-temporal images, SSM can offer powerful, qualitative and quantitative techniques and methods to identify and label information classes(Thenkabail et al., 2007). It is a better method for hyper-temporal images than traditional ones [e.g., fast Fourier transformation (FFT), wavelet techniques (WT), and principal component analysis (PCA)], and the detailed reasons can refer to Thenkabail et al. (2007). Through vegetation indices of optical images, previous studies have applied SSM for obtaining information on different rice cropping systems and achieved nice effects(Gumma et al., 2011; Gumma et al., 2014). For example, Gumma et al. (2014) used Spectral Similarity Measures (SSM)and NDVI derived from temporal MODIS data to map rice areas. Therefore, SSM will be applied to analyze the multi-temporal images.

The aim of this paper is to map rice planting areas through the integration of multi-temporal Sentinel-1A and Landsat-8 OLI data with SSM and a field-based approach. The objectives of the study presented in this paper are specifically as follows:

(1) To calculate the backscatter coefficient and NDVI of rice from field survey area
(2) To evaluate and compare the rice classification accuracies through different sensors data (Sentinel-1A and Lansat-8 OLI data) and different approaches (per-pixel and per-field approaches).
(3) To analyze and discuss the improvement in rice classification accuracy through the integration of SAR and optical data with a per-field approach.

2. Study area and data

2.1. Study area

The field used in the present study (115°30′ E−115°54′10″E, 23°40′55″ N−24°04′25″) is crossed by Qinjiang River and Wuhua River, located in Wuhua County of Guangdong province in the South of China. The topography of the study area is characterized by lots of basins and mountains. Climatically, the study area, with an annual average temperature of 21 °C and precipitation of 1498 mm, enjoys a sub-tropical humid monsoon climate, which is regarded as a land of fish and rice. Rice, accounting for 80 percent of all crops, is the predominant crop in Wuhua County. In addition, rice is cultivated at twice a year and called as early season rice and late season rice, and there are five stages in the growing season, see Table 1 (Shao et al., 2001).

2.2. Datasets

Sentinel-1A, with a 12-day repeat cycle, is a European C-band radar satellite launched in 3 April 2014. The data are freely provided by the European Space Agency (ESA) (https://scihub.copernicus.eu/dhus/). Sentinel-1A has four modes: Interferometric Wide Swath (IW), Extra Wide Swath (EW), Wave Mode (WV) and Stripmap (SM). Sentinel-1A IW Level 1 (L1) GRDH products are used in this study. Fourteen scenes of Sentinel-1A IW mode (VV, VH) data are observed and available from May 24, 2016 to November 19, 2016, see Table 2. In addition, Landsat-8 Operational Land Imager (OLI) satellite images (http://glovis.usgs.gov/) are also used in this study. The acquisition dates of Landsat-8 images are March 3, September 27 and December 18 in 2016 with nearly cloud-free conditions in the area of interest. Specifications of the Sentinel-1A and Landsat-8 OLI are listed in Table 3.

The sample dataset (Fig. 1) has 94990 pixels. Paddy fields (21987 pixels) are identified on October 9, 2016 by field survey with GPS Watch and Vitial Map like Google Earth which is installed in my smartphone. Other land covers (73003 pixels including forest, urban, water and other crops) are identified from the Google Earth by the visual interpretation of the images. These ground truth data is divided randomly into two parts which are used to model and validate the method for rice field identification. Training dataset consists of 5228

Table 1
The growing phases of rice in Wuhua County.

	Transplanting period	Seedling development period	Ear differentiation period	Heading period	Maturation period
Early season rice	March 25–April 5	April 15–25	May 10–30	June 10–25	July 5–31
Late season rice	July 20–August 5	August 10–20	September 1–30	October 1–20	November 1–25