USING COMPACT POLARIMETRIC PARAMETERS FOR RAPE (BRASSICA NAPUS L.) LAI INVERSION

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ABSTRACT

In this study, 5 compact polarimetric (CP) data were simulated from 5 consecutive fully polarimetric images, which covered the whole rape growth period. Four groups including 25 CP parameters were extracted from each CP image at different rape growth stages, respectively. With the analysis of the relationships between CP parameters and LAI, g_3 in stokes parameter group, U_c in stokes child parameters group, σ_{RR} in backscattering parameters group and $P_{V\alpha}$ in decomposition parameters group were chose to inverse rape LAI. The results showed that, among these four CP parameters, $P_{V\alpha}$ performed best for rape LAI inversion, the determination coefficient R2 between inversion results and the ground truth data is 0.917, root mean square error (RMSE) is 0.36.

Index Terms— CP, Rape LAI, Inversion

1. INTRODUCTION

Leaf area index (LAI) is one of most useful indicators of crops for their canopy structural development, growth changes and yield estimation. Reasonable and reliable estimation of LAI can improve crop fertilizer application, water irrigation, disease and weed control [1]. Measuring LAI directly is a destructive and time-consuming procedure, it is also cost. Remote sensing has been proved an effective and accurate way to inverse LAI timely and easily conducting in large regions [2-4]. Recently, full-polarimetric SAR, thanks its sensitivity to crops scattering mechanisms, demonstrated to be a powerful tool for crops growth parameter inversion, crops mapping and monitoring [5,6]. Although full-polarization SAR has good performance in crops monitoring and related application, its known limitation is the reduced swath produced by the doubled pulse repetition frequency employed to scan all combinations of transmitted/received polarisations. To avoid such a constraint, compact polarimetric (CP), transmitting only a single polarization and receiving two orthogonal polarizations had been proposed [7]. As a new technology, its potential in crop LAI retrieve has not been explored fully now. Moreover, its application in rape (Brassica napus L.) LAI inversion has rarely been found in current published literatures. Rape is the most important oil crop in China, moreover, China's rape cultivated area and yield ranks first in the world. The present study aims to fully exploring the potential of CP SAR in rape LAI inversion. As a first step, four groups, including 27 CP parameters were extracted and analyzed, and single parameter empirical regression models were used for rape LAI inversion by CP parameters that have the highest determination coefficients (R^2) with LAI in each groups, respectively.

2. TEST SITE, SAR DATA AND, GROUND MEASUREMENT CAMPAIGN

The test site is a farmland named Shangkuli of 2800 hm^2 in City Hailar, Inner Mongolia, Northeast of China, where spring rape (Brassica napus L.) is cultivated annually from May to September, approximately.Fig.1 shows the location of test site (120.76º ~ 120.89º E; 50.28o ~ 50.39º N). The Pauli basis RGB composite image in Fig.1 is obtained from RADARSTA-2 image acquired on May 23, 2013. The specific variety rape cultivated in the test site is called hybrid-5 rape, quite common in North of China. Leached chernozem soil dominates this area, which has higher water retention. The terrain is gentle here with slope less than 1%. Climate in the test site is the cold temperate continental monsoon climate. It has a cold and dry long winter and warm and wet short summer, which supports one harvest per year. A set of five fully polarimetric RADARSAT-2 images were acquired over this area during the whole rape growth cycle, all of them with the same mode, beam and orbit pass, in order

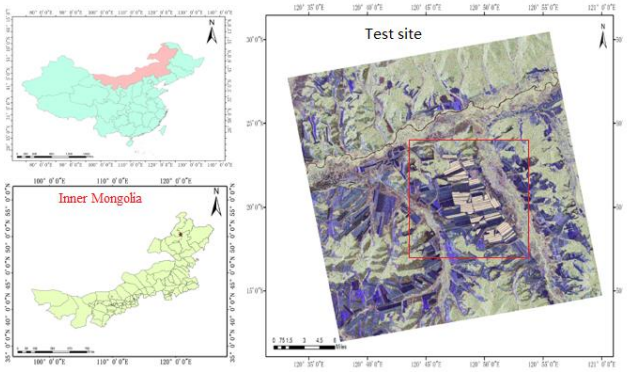

Fig.1. Location map of the test site in Inner Mongolia, China: Pauli-basis RGB image of Radarsat-2, acquired on May 23, 2013. All the rape field in this study are located in the red box.

To build time series in the most consistent way. All of these images were provide in single look complex (SLC) format with pixel size of 4.73 m and 4.96 m in azimuth and ground

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range direction, respectively. Table1 shows the image acquisition parameter details.

Table1 The details of 5 Radarsat-2 images

Parameters	Values
Polarisation	Quad
Frequency	5.405 GHz
Incidence angle	37.4 ~ 38.8
Range pixel spacing	4.96 m
Azimuth pixel spacing	4.73 m
Orbit direction	Ascending
Beam mode	FQ18

The crop temporal evolution can be better described by identifying a number of main stages which are usually described by a simple linear interpolator known as general BBCH scale (from *Biologische Bundesanstalt Bundessortenamt und CHemische Industrie*). In this paper, the whole rape growth cycle was divided into 5 stages according to the particular features and aspects of rape development as a function of time and also the acquisition dates of SAR images. The principal stages, the corresponding BBCH scales and the related SAR images are introduced in Table2.

Table 2 Principal stages of rape and relative BBCH scales

Acquisition date	Phenology stages of rape	
2013/05/23	Germination(0)	BBCH1
2013/06/16	Leaf development(1) and formation of side shoots (2)	BBCH2
2013/07/10	Stem elongation(3),inflorescence emergence(5) and flowering(6)	BBCH3
2013/08/03	Development of fruit (7)	BBCH4
2013/08/27	Ripening(8) and senescence(9)	BBCH5

In this research project, five synchronous ground measurement campaigns were carried out at each satellite overpass with no more than one day lag. we recorded the sowing dates of all the 101 rape fields in the test site, where the sowing period lasted from 8 May to 31 May and included 17 different sowing dates and the duration was 24 days. All the sizes of sample parcels vary from 3.3 hectares to 47 hectares and the average size is 18.6 hectares. In each campaign, we recoded 11~14 parcels with leaf area index (LAI), plant height, surface soil moisture and above ground biomass including fresh and dry height per square meter as representatives. For LAI and 7.5 cm volumetric water content measurement, we randomly measured three sample sites within each field by LI-COR LAI-2200 instrument and FieldScout TDR 300 (Time Domain Refectometry) Soil Moisture Meter in High Clay mode after its calibration, respectively. Each biomass sample was collected in a square of 0.5 m×2 rows and the related global position system (GPS) position was also recorded for better matching the SAR data later. We also took digital photographs for visually recording rape development stages (Figure 2).

Fig.2. Rape morphology at different stages in the test site

3. EXTRACTION OF COMPACT POLARIMETRIC PARAMETERS

Fully polarimetric systems (quad-pol systems), which alternately transmit two orthogonal polarizations and recode both received polarisations, suffer from the increases of pulse repetition frequency and data rata that cause the limitation of associated energy budget, data storage, and downlink requirement. To avoid these constraints of fully polarimetric systems, compact polarimetry (CP), transmitting only a single polarization and receiving two orthogonal polarisations, has been proposed [8]. There are three CP modes named $\pi/4$ mode, dual circular polarimetric (DCP) mode and circular transmits while linear receive (CTLR) mode, respectively[9]. Some investigations have demonstrated that the two circular transmit (DCP and CTLR) modes significantly outperform the $\pi/4$ mode. The physical reason for the result is that the single linearly polarized transmit of the $\pi/4$ mode will not be able to excite a target response for linear structures that are oriented orthogonal to the incident electric field while DCP and CTLR work well in these area. Even DCP and CTLR will not be able to excite a target response in helical structures with their helicity oriented opposite that of the incident radiation, it does not affect their better performance on fully interrogation of polarization states of typical terrain and manmade features because typical terrain tends to be composed more of linear structures (tree trunks and branches, buildings, fence posts, etc.) than helical structures (plowed fields viewed at near 45°). Some researchers believed that DCP mode was the linear combination of the CTLR mode and both of them had the same decomposition characteristics [8]. For above mentioned reason, in this paper, most of CP parameters were extracted from CTLR mode, and only backscatter of RR and RL were extracted from DCP mode, the $\pi/4$ mode has not been analyzed further in the paper.

Due to the objective of reasonable and effective interpretation CP data, different interpretation methods were proposed by extracting different CP observations with their different nature, like stokes methods proposed by Raney [5,6], entropy and scattering angle alpha decomposition methods by Cloude [10] and so on. According to the extraction ways or the related physical scattering mechanisms of these extracted CP parameters, in these paper, all the CP observations were divided into three groups, named Stokes parameters, Stokes child parameters, backscattering parameters and decomposition parameters.

3.1. Stokes parameters

Stokes parameters, which is proposed by Stokes in 1851 [10] and could be represented by four real numbers (g_0, g_1, g_2, g_3), were proved a very convenient means to describe the received