Remote Sensing of Environment 240 (2020) 111681

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Winter wheat LAI inversion considering morphological characteristics at different growth stages coupled with microwave scattering model and canopy simulation model

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ARTICLE INFO

Edited by Jing M. Chen

Keywords:
LAI inversion
Winter wheat
Canopy simulation model
Microwave scattering model for winter wheat at different growth stages
Morphological characteristics

ABSTRACT

To better eliminate the adverse effects of the ground surface on winter wheat Leaf area index (LAI) inversions and to further improve the accuracy of regional winter wheat LAI inversion using SAR remote sensing data, considering the morphological characteristics at different wheat growth stages, a winter wheat LAI inversion model coupled with the microwave scattering model (MSM) for winter wheat at different growth stages (MSMDGS) and the canopy scattering simulation model (CSSM) was proposed. In this research, taking Hengshui City of Huanghuaihai Plain of North China as the study region, using RADARSAT-2 data as image sources and based on parameter sensitivity analysis and model calibration, the proposed model was applied and validated. The LAI inversion results of winter wheat showed that the proposed model had good performance in the regional application and that LAI inversion results with high accuracy could be obtained. Among the three key growth stages (jointing stage, booting stage and heading stage) of winter wheat, the R^2, adjusted R^2 and *RMSE* between the LAI inversion value and the ground-measured data were 0.918, 0.917 and 0.675, respectively, which indicated that the winter wheat LAI inversion model coupled with MSMDGS and CSSM had certain feasibility and applicability.

1. Introduction

Leaf area index (LAI) is one of the major parameters for describing the structure and characteristics of vegetation canopies (Liang et al., 2015), and it is widely used in research fields such as agriculture, ecology and climate change (Sun et al., 2017; Zeng et al., 2017). Additionally, many studies have shown that crop LAIs are closely related to the yields at crop-specific growth stages; thus, crop LAI is also an important quantitative indicator reflecting crop growth and yield (Huang J. et al., 2015; Li et al., 2018; Lunagaria and Patel, 2019). Therefore, the accurate acquisition of crop LAI may significantly improve the accuracy of crop growth monitoring and yield estimation in agricultural remote sensing. Presently, remote-sensing-based crop LAI inversion mainly uses optical remote sensing data (Hu et al., 2007; Ganguly et al., 2008; Liu et al., 2012; Baret et al., 2007, 2013; Xiao et al., 2013; Liang et al., 2015; Verrelst et al., 2015); however, optical remote sensing data are susceptible to meteorological conditions such as clouds, rain and fog, which not only reduces the inversion accuracy of crop LAI but also increases the uncertainty of the inversion results. With the development of active microwave remote sensing technology, synthetic aperture radar (SAR) has strong application potential to crop parameter inversions and growth monitoring due to its ability to obtain observations all day without the influence of clouds, rain, fog, etc. Furthermore, SAR is sensitive to changes in vegetation characteristics. Currently, SAR has been widely used in the fields of agricultural resource investigation, land resource utilization, crop growth monitoring and yield estimation, and agricultural disaster warnings (Abdikan et al., 2016; Erten et al., 2016; Kumar et al., 2018).

The use of SAR is advantageous because microwaves are sensitive to the structure and dielectric constant of ground objects (Ulaby et al., 1982), and shortwave multipolarization SAR is widely used in the parameter inversion fields of ground surface (soil moisture) or vegetation (LAI, biomass, etc.) (Bériaux et al., 2011; Inoue et al., 2014; Wiseman et al., 2014; Hosseini et al., 2015; Tao et al., 2016). The SAR backscattering coefficient and vegetation parameters are often used to establish parameter inversion models based on SAR data, and the

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https://doi.org/10.1016/j.rse.2020.111681
Received 29 August 2019; Received in revised form 20 January 2020; Accepted 23 January 2020