Estimating harvest index of winter wheat from canopy spectral reflectance information

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Abstract

Harvest index (HI), ratio of grain yield to above-ground biomass, is a key parameter for crop yield prediction via remote sensing based on radiation use efficiency approach or crop simulation models. Thus, for an accurate estimation of grain yield, an accurate estimate of HI is very important. Experiments including five nitrogen treatments were conducted at field level to investigate the feasibility of estimating HI of winter wheat from canopy spectral reflectance information in present study. Total nine common vegetation indices (VIs), such as normalized difference vegetation index (NDVI), ratio vegetation index (RVI), transformed vegetation index (TVI), soil adjusted vegetation index (SAVI), modified soil adjusted vegetation index (MSAVI), renormalized difference vegetation index (RDVI), difference vegetation index (DVI), enhanced vegetation index (EVI) and green chlorophyll index (CIgreen), were investigated in this work. Results demonstrated that estimating HI from canopy reflectance information based on the partitioning of crop activity before and after flowering can give good results but required long-term dataset of total growing season. Further analysis showed that HI had strong correlations with the accumulated values of VIs from anthesis to maturity period. Moreover, it was found that the correlation between HI and accumulated VI after anthesis was greatly improved by introducing another variable of VI at anthesis using binary regression analysis. The coefficients of determination (R²) of binary regression equations were higher than 0.80, and the root mean square deviations (RMSD) between the estimated HI and measured HI were as low as 0.04. It was suggested canopy spectral reflectance from anthesis to maturity had good performances on HI estimation. With short-term data requirement and good accuracy, the method based on VI dataset of anthesis-maturity period would be more favourable for large area application since the dataset can be easily collected by means of remote sensing.

Key words: Harvest index, spectral reflectance, vegetation indices, winter wheat.

Introduction

As a primary food source for millions of people around the world, wheat is the most important crop grown worldwide with winter wheat constituting approximately 80% of global wheat production. Harvest index (HI), ratio of grain yield to total above-ground biomass, has been considered one of the most important contributing factors associated with the dramatic increases in wheat yields that have occurred in the twentieth century. HI also plays a key role in wheat yield prediction using radiation use efficiency-based approach or process-based crop simulation models. It has been proved that various environmental and agronomic conditions can have great influences on HI. Even if crop biomass is well simulated, it is insufficient for accurate estimation of grain yield at regional scale due to the low correlation of the uncertainty of HI on final yield, so an estimate of HI is necessary. However, simulating the fraction of the final above-ground biomass that is allocated to grain remains a greater challenge. This may be the reason that HI is usually treated as a constant in many studies related to yield estimation.

Several methods for HI estimation had been proposed in previous studies. Richards and Townley-Smith found a nonlinear relationship existing between HI and proportion of water transpired after anthesis under drought conditions. Sadras and Connor further examined this relationship and presented a model to estimate HI as a function of the fractional transpiration after anthesis based on water-stressed treatments. Kemanian et al. proposed two variants of a method to estimate HI based on proportion of biomass accumulated in post-anthesis phase. Moriondo et al. used normalized difference vegetation index (NDVI) to estimate HI in regional yield simulating. It was assumed that environmental effects on optimal HI were related to the reduction of NDVI from pre-anthesis to post-anthesis. The actual HI was obtained by modifying the optimal HI using NDVI data throughout the growing season.

For the above-mentioned techniques of HI estimation, the fractional transpiration and the fractional biomass methods need datasets of crop transpiration or biomass production. At large areas, direct measurements of crop biomass and transpiration require labor-intensive surveys or even impossible. They are commonly computed via remote sensing information. By contrast, the third method which directly uses remote sensed NDVI data to estimate HI seems favourable for regional application. Nevertheless, NDVI data of winter wheat are quite noisy in long period from emergence to inter-row closing owing to bare soil, and the long-term dataset acquisition is also limited by variable atmospheric conditions.

Spectral reflectance information of crop canopy has been increasingly used in crop monitoring, and it can be captured by remotely sensed satellites from space with unprecedented...