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An alternative method using digital cameras for continuous monitoring of crop status

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ABSTRACT

Crop physiological and phenological status is an important factor that characterizes crop yield as well as carbon exchange between the atmosphere and the terrestrial biosphere in agroecosystems. It is difficult to establish high frequency observations of crop status in multiple locations using conventional approaches such as agronomical sampling and also remote sensing techniques that use spectral radiometers because of the labor intensive work required for field surveys and the high cost of radiometers designed for scientific use. This study explored the potential utility of an inexpensive camera observation system called crop phenology recording system (CPRS) as an alternative approach for the observation of seasonal change in crop growth. The CPRS consisting of two compact digital cameras was used to capture visible and near infrared (NIR) images of maize in 2009 and soybean in 2010 for every hour both day and night continuously. In addition, a four channel sensor SKYE measured crop reflectance and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images were acquired over crop fields. The six different camera- radiometer- and MODIS-derived vegetation indices (VIs) were calculated and compared with the ground-measured crop biophysical parameters. In addition to VIs that use digital numbers, we proposed to use daytime exposure value-adjusted VIs. The camera-derived VIs were compared with the VIs calculated from spectral reflectance observations taken by SKYE and MODIS. It was found that new camera-derived VIs using daytime exposure values are closely related to VIs calculated using SKYE and MODIS reflectance and good proxies of crop biophysical parameters. Camera-derived green chlorophyll index, simple ratio and NDVI were found to be able to estimate the total leaf area index (LAI) of maize and soybean with high accuracy and were better than the widely used 2g-r-b. However, camera-derived 2g-r-b showed the best accuracy in estimating daily *f*APAR in vegetative and reproductive stages of both crops. Visible atmospherically resistant vegetation index showed the highest accuracy in the estimation of the green LAI of maize. A unique VI, calculated from nighttime flash NIR images called the nighttime relative brightness index of NIR, showed a strong relationship with total aboveground biomass for both crops. The study concludes that the CPRS is a practical and cost-effective approach for monitoring temporal changes in crop growth, and it also provides an alternative source of ground truth data to validate time-series VIs derived from MODIS and other satellite systems.

1. Introduction

In recent years, there have been many attempts to use remote sensing techniques to quantitatively assess seasonal changes in vegetation growth in order to estimate phenological and physiological status of vegetation, predict yield, and understand the temporal features of carbon exchange between the atmosphere and the terrestrial biosphere. There is increasing momentum toward the expansion of the phenology network in Japan, Phenological Eye Network (Nishida, 2007) and the United States, National Phenology Network (NPN) (Betancourt et al., 2005). There are several tower flux observation sites, where both downwelling and upwelling light is measured using automatically rotating custom-ordered spectral radiometers coupled with color digital cameras (Motohka et al., 2010; Nagai et al., 2010; Nishida, 2007). However, unlike the weather monitoring network, it is difficult to accumulate fixed point spectral reflectance observations of crop growth in multiple locations because of the high cost of spectral radiometers designed

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