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Integrated narrow-band vegetation indices for prediction of crop chlorophyll content for application to precision agriculture

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Abstract

Recent studies have demonstrated the usefulness of optical indices from hyperspectral remote sensing in the assessment of vegetation biophysical variables both in forestry and agriculture. Those indices are, however, the combined response to variations of several vegetation and environmental properties, such as Leaf Area Index (LAI), leaf chlorophyll content, canopy shadows, and background soil reflectance. Of particular significance to precision agriculture is chlorophyll content, an indicator of photosynthesis activity, which is related to the nitrogen concentration in green vegetation and serves as a measure of the crop response to nitrogen application. This paper presents a combined modeling and indices-based approach to predicting the crop chlorophyll content from remote sensing data while minimizing LAI (vegetation parameter) influence and underlying soil (background) effects. This combined method has been developed first using simulated data and followed by evaluation in terms of quantitative predictive capability using real hyperspectral airborne data. Simulations consisted of leaf and canopy reflectance modeling with PROSPECT and SAILH radiative transfer models. In this modeling study, we developed an index that integrates advantages of indices minimizing soil background effects and indices that are sensitive to chlorophyll concentration. Simulated data have shown that the proposed index Transformed Chlorophyll Absorption in Reflectance Index/Optimized Soil-Adjusted Vegetation Index (TCARI/OSAVI) is both very sensitive to chlorophyll content variations and very resistant to the variations of LAI and solar zenith angle. It was therefore possible to generate a predictive equation to estimate leaf chlorophyll content from the combined optical index derived from above-canopy reflectance. This relationship was evaluated by application to hyperspectral CASI imagery collected over corn crops in three experimental farms from Ontario and Quebec, Canada. The results presented here are from the L'Acadie, Quebec, Agriculture and Agri-Food Canada research site. Images of predicted leaf chlorophyll content were generated. Evaluation showed chlorophyll variability over crop plots with various levels of nitrogen, and revealed an excellent agreement with ground truth, with a correlation of $r^2 = .81$ between estimated and field measured chlorophyll content data.

1. Introduction

Remote sensing data and techniques have already proven to be relevant to many requirements of crop inventory and monitoring. Different studies and experiments demonstrated their usefulness and feasibility to address various agricultural issues, such as crop classification and mapping (Erol & Akdeniz, 1996; Grignetti, Salvatori, Cascchia, & Manes, 1997; Pax-Lenney & Woodcock, 1997), crop forecasting and yield predictions (Clevers, 1997; Moran, Maas, & Pinter, 1995; Rasmussen, 1992; Tucker, Holben, Elgin, & McMurtrey, 1980), crop status and condition (Blackmer, Schepers, & Varvel, 1994; Boissard, Pointel, & Huet, 1993; Clevers, Büker, van Leeuwen, & Bouman, 1994; Potdar, 1993), and crop disease and micronutrient deficiency (Adams, Norvell, Philpot, & Peverly, 2000a, 2000b; Adams, Philpot, & Norvell, 1999; Malthus & Madeira, 1993). Nowadays, there is an increased interest in precision farming and the development of smart systems for agricultural resources management; these relatively new approaches aim

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