Modeling the Effect of Moisture on the Reflectance of Crop Residues

Chang-kun Wang, Xian-zhang Pan,* Ya Liu, Yan-li Li, Rui Zhou, and Xian-li Xie

ABSTRACT
Models of crop residue reflectance under changing moisture conditions are required to better quantify management of crop residue in agricultural fields by remote sensing. In this study, reflectance spectra (400–2400 nm) of four different crop residues were measured in the laboratory under various moisture conditions. Crop residue reflectance decreased with increasing water content across all wavelengths, especially in the shortwave infrared (SWIR) region. For each crop residue, both linear and exponential models were capable of quantifying the relationship between reflectance and mass water content (MWC) with high accuracy [e.g., coefficient of determination ($R^2 > 0.9$) and root mean square error (RMSE) < 0.025 at each wavelength in the SWIR]. The best-fitting parameters of the two models could be directly derived from the reflectance of dry and saturated crop residues and saturated water content, which simplified the construction of the models. The results of regression analyses between the predicted MWC calculated by the inversion of the two models and measured MWC indicated that MWC could be estimated with high accuracy ($R^2 > 0.9$, RMSE < 0.15, slope close to 1.0, and intercept close to 0.0) at nearly every wavelength in the SWIR.

To construct a general model, the reflectance was normalized, and the results suggested that this method was valid. The results of this study help to quantify the effect of water on the spectral reflectance of crop residue and should contribute to better correct the effects of water on remote sensing estimation of crop residue cover in the future.

Crop residues left in agricultural fields decrease soil erosion and improve soil physical and chemical properties (Karlen et al., 1994). The bulk of crop residues consists of cell wall materials and cellular constituents that are difficult to break down. These materials mainly include cellulose, hemicellulose, and lignin, which form a vast reservoir of fixed C and exert a great influence on atmospheric CO2 concentrations (Elvidge, 1990). Thus, efficient estimates of crop residue cover are needed. The method most widely used to estimate the crop residue percentage is the line transect; however, this method has been found to be tedious and subjective (Morrison et al., 1993). Remote sensing techniques with rapid and objective characteristics are promising for the estimation of residue cover.

Many studies have used remote sensing techniques to estimate crop residue cover or to classify tillage intensity. Corresponding optical remote sensing methods for estimating crop residue fall into two basic categories: (i) spectral indices and (ii) spectral unmixing analysis methods. Spectral indices mainly include the normalized difference index (McNairn and Protz, 1993), crop residue index multiband (Biard and Baret, 1997), cellulose absorption index (CAI) (Nagler et al., 2000), and lignin–cellulose absorption index (Daughtry et al., 2005). Spectral unmixing analysis methods are used to estimate crop residue cover by determining the relative contribution of endmembers (i.e., crop residue and soil) using multispectral and hyperspectral data (Arsenault and Bonn, 2005; Gelder et al., 2009; Pacheco and McNairn, 2010). These studies facilitate the estimation of crop residue cover. The results have been mixed, however, because values of the spectral indices and reflectance of the endmembers are affected by many factors, such as the water content of the soil and crop residue (Daughtry and Hunt, 2008; Nagler et al., 2000), soil composition and mineralogy (Serbin et al., 2009), the age of the residue (Nagler et al., 2000), and the degree of crop residue decomposition (Daughtry et al., 2010).

Although many factors affect the accuracy of remote sensing estimation of crop residue cover, water is the most prominent factor. Water reduces the reflectance of soil and crop residues across all wavelengths (400–2400 nm) and nearly obscures the cellulose–lignin absorption feature at 2100 nm, which decreases the contrast of the reflectance spectra of soil and crop residue and thus makes discrimination between soil and crop residue difficult (Daughtry et al., 2004; Nagler et al., 2000). Daughtry and Hunt (2008) have further noted that water in crop residue significantly weakens the CAI, which is defined as the relative intensity of an absorption feature near 2100 nm, and alters the slope of the linear relationship between residue cover and CAI. Although the effects of water on crop residue reflectance were observed in these studies, little attention has been given to modeling of the quantitative relationship between reflectance and water content in crop residue.

C.K. Wang, X.Z. Pan, Y.L. Li, R. Zhou, and X.L. Xie, Key Lab. of Soil Environment and Pollution Remediation, Institute of Soil Science, Chinese Academy of Sciences, No. 71 East Beijing Rd., Nanjing, Jiangsu 210008, PR China; C.K. Wang, Y. Liu, and Y.L. Li, Graduate School of the Chinese Academy of Sciences, Beijing 100049, PR China. Received 23 Apr. 2012. *Corresponding author (panxz@issas.ac.cn).

Published online 12 Sept. 2012
doi:10.2134/agronj2012.0133
Copyright © 2012 by the American Society of Agronomy, 5585 Guilford Road, Madison, WI 53711. All rights reserved. No part of this periodical may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Abbreviations: CAI, cellulose absorption index; MWC, mass water content; SWIR, shortwave infrared; VNIR, visible and near infrared.