Vegetation indices (VIs), traditionally used for estimation of green leaf area index (gLAI), have different sensitivities along the range of gLAI variability. The goals of this study were to: (i) test 12 VIs for estimating gLAI in maize (Zea mays L.) and soybean [Glycine max (L.) Merr.]; (ii) estimate gLAI in both crops without the need to reparameterize the algorithms for different crops; and (iii) devise a combined VI that is maximally sensitive to gLAI along its entire range of variability. The study was performed for eight growing seasons (2001–2008) in one irrigated and one rainfed field under a maize–soybean rotation and one irrigated field under continuous maize in eastern Nebraska for a total of 24 field-years. The gLAI ranged from 0 to 6.5 m²/m² in maize and 0 to 5.5 m²/m² in soybean. Normalized difference indices, e.g., the normalized difference vegetation index (NDVI) were most sensitive to gLAI below 2 m²/m², while ratio indices, e.g., simple ratio (SR) and chlorophyll indices (CIs), were most sensitive to gLAI above 2 m²/m². For the crops evaluated, relationships between gLAI and the VIs were species specific with the exception of the red-edge NDVI and the CI

Combining VIs. For sensors with spectral bands in the red and near-infrared regions, the best combination was NDVI and SR (maize: coefficient of variation [CV] = 20%; soybean: CV = 23%); however, this combined index is species specific. For sensors with bands in the red-edge and near-infrared regions, the best combination was red-edge NDVI and CI

The leaf area index (LAI), the ratio of leaf area to ground area, is commonly reported as square meters per square meter, is a commonly used biophysical characteristic of vegetation (Watson, 1947). The LAI can be subdivided into photosynthetically active and photosynthetically inactive components. The former, the gLAI, is a metric commonly used in climate (e.g., Buermann et al., 2001), ecological (e.g., Bulcock and Jewitt, 2010), and crop yield (e.g., Fang et al., 2011) models. Because of its wide use and applicability to modeling, there is a need for a nondestructive remote estimation of gLAI across large geographic areas.

Various techniques based on remotely sensed data have been utilized for assessing gLAI (see reviews by Pinter et al., 2003; Hatfield et al., 2004, 2008; Doraismwamy et al., 2003; le Maire et al., 2008, and references therein). Vegetation indices, particularly the NDVI (Rouse et al., 1974) and SR (Jordan, 1969), are the most widely used. The NDVI, however, is prone to saturation at moderate to high gLAI values (Kanemasu, 1974; Curran and Steven, 1983; Asrar et al., 1984; Huete et al., 2002; Gitelson, 2004; Wu et al., 2007; González-Sanpedro et al., 2008) and requires reparameterization for different crops and species. The saturation of NDVI has been attributed to insensitivity of reflectance in the red region at moderate to high gLAI values due to the high absorption coefficient of chlorophyll. For gLAI below 3 m²/m², total absorption by a canopy in the red range reaches 90 to 95%, and further increases in gLAI do not bring additional changes in absorption and reflectance (Hatfield et al., 2008; Gitelson, 2011). Another reason for the decrease in the sensitivity of NDVI to moderate to high gLAI values is the mathematical formulation of that index. At moderate to high gLAI, the NDVI is dominated by near-infrared (NIR) reflectance. Because scattering by the cellular or leaf structure causes the NIR reflectance to be high and the absorption by chlorophyll causes the red reflectance to be low, NIR reflectance is considerably greater than red reflectance: e.g., for gLAI >3 m²/m², NIR reflectance is >40% while red reflectance is <5%. Thus, NDVI becomes insensitive to changes in both red and NIR reflectance.

Other commonly used VIs include the Enhanced Vegetation Index, EVI (Liu and Huete, 1995; Huete et al., 1997, 2002), its

**ABSTRACT**

Vegetation indices (VIs), traditionally used for estimation of green leaf area index (gLAI), have different sensitivities along the range of gLAI variability. The goals of this study were to: (i) test 12 VIs for estimating gLAI in maize (Zea mays L.) and soybean [Glycine max (L.) Merr.]; (ii) estimate gLAI in both crops without the need to reparameterize the algorithms for different crops; and (iii) devise a combined VI that is maximally sensitive to gLAI along its entire range of variability. The study was performed for eight growing seasons (2001–2008) in one irrigated and one rainfed field under a maize–soybean rotation and one irrigated field under continuous maize in eastern Nebraska for a total of 24 field-years. The gLAI ranged from 0 to 6.5 m²/m² in maize and 0 to 5.5 m²/m² in soybean. Normalized difference indices, e.g., the normalized difference vegetation index (NDVI) were most sensitive to gLAI below 2 m²/m², while ratio indices, e.g., simple ratio (SR) and chlorophyll indices (CIs), were most sensitive to gLAI above 2 m²/m². For the crops evaluated, relationships between gLAI and the VIs were species specific with the exception of the red-edge NDVI and the CI

**THE LEAF AREA INDEX**

The leaf area index (LAI), the ratio of leaf area to ground area, is commonly reported as square meters per square meter, is a commonly used biophysical characteristic of vegetation (Watson, 1947). The LAI can be subdivided into photosynthetically active and photosynthetically inactive components. The former, the gLAI, is a metric commonly used in climate (e.g., Buermann et al., 2001), ecological (e.g., Bulcock and Jewitt, 2010), and crop yield (e.g., Fang et al., 2011) models. Because of its wide use and applicability to modeling, there is a need for a nondestructive remote estimation of gLAI across large geographic areas.

Various techniques based on remotely sensed data have been utilized for assessing gLAI (see reviews by Pinter et al., 2003; Hatfield et al., 2004, 2008; Doraismwamy et al., 2003; le Maire et al., 2008, and references therein). Vegetation indices, particularly the NDVI (Rouse et al., 1974) and SR (Jordan, 1969), are the most widely used. The NDVI, however, is prone to saturation at moderate to high gLAI values (Kanemasu, 1974; Curran and Steven, 1983; Asrar et al., 1984; Huete et al., 2002; Gitelson, 2004; Wu et al., 2007; González-Sanpedro et al., 2008) and requires reparameterization for different crops and species. The saturation of NDVI has been attributed to insensitivity of reflectance in the red region at moderate to high gLAI values due to the high absorption coefficient of chlorophyll. For gLAI below 3 m²/m², total absorption by a canopy in the red range reaches 90 to 95%, and further increases in gLAI do not bring additional changes in absorption and reflectance (Hatfield et al., 2008; Gitelson, 2011). Another reason for the decrease in the sensitivity of NDVI to moderate to high gLAI values is the mathematical formulation of that index. At moderate to high gLAI, the NDVI is dominated by near-infrared (NIR) reflectance. Because scattering by the cellular or leaf structure causes the NIR reflectance to be high and the absorption by chlorophyll causes the red reflectance to be low, NIR reflectance is considerably greater than red reflectance: e.g., for gLAI >3 m²/m², NIR reflectance is >40% while red reflectance is <5%. Thus, NDVI becomes insensitive to changes in both red and NIR reflectance.

Other commonly used VIs include the Enhanced Vegetation Index, EVI (Liu and Huete, 1995; Huete et al., 1997, 2002), its