Remote sensing of crop primary productivity: from close range to satellite observations

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Since 2001, continuous eddy covariance measurements of CO_2 fluxes, water vapor and energy fluxes have been made at three agricultural study sites located at Mead, NE (*Verma et al., 2005*). We have found that gross primary production (GPP) was closely related to the total crop chlorophyll content. Thus, chlorophyll content can be used as an accurate measure of gross primary production in crops. We applied a recently developed technique for remote estimation of chlorophyll content to assess GPP. The technique based on reflectance in two spectral bands: the near-infrared and either the green or the red-edge, provided accurate estimations of GPP in maize and soybeans by means of close range, aircraft-based and satellite techniques.

MATERIALS & METHODS

Study Area

Three Ameriflux sites located at Mead, NE (*Verma et al., 2005*).

Site 1: irrigated continuous maize
Site 2: irrigated maize-soybean rotation
Site 3: rainfed maize-soybean rotation

Remotely Sensed Data

Close range – hyperspectral reflectance – "Goliath" data

Reflectance measurements were obtained 6 m above the top of canopy using a dual-fiber system consisting of two inter-calibrated Ocean Optics radiometers in the range 400-1000 nm mounted on an all-terrain platform (*Rundquist et al., 2004*).
The inter-calibration of the radiometers is accomplished by measuring the upwelling radiance of a white Spectralon reflectance standard, simultaneously with incident irradiance.
All radiometric measurements were taken during the growing seasons of 2001 (18 campaigns), 2002 (31 campaigns), 2003 (36 campaigns), 2004 (32 campaigns), 2005 (21 campaigns), 2006 (15 campaigns), 2007 (14 campaigns), and 2008 (9 campaigns).

Close range – SKYE data

In 2009, upwelling radiance of crop and downwelling irradiance were measured using SKYE radiometers each day installed 5 m above the soil concurrently with eddy covariance measurements of CO_2 fluxes. Four bands used:

537-562, 665-680, 700-710, 860-875 nm

Aircraft altitudes – AISA-Eagle data

AISA-Eagle Hyperspectral Imaging Spectrometer data, taken from an altitude of 1,000 m (3 m^2 per pixel) in the spectral range of 450-850 nm, with a spectral resolution of 2.5 nm, have been used to estimate GPP and total chlorophyll content in maize and soybean and to map spatial distributions of these biophysical characteristics.

Satellite Altitudes – Landsat & MODIS images

Images have been atmospheric corrected to produce top-of-canopy reflectance. Site reflectance values were calculated by averaging all the per-pixel reflectance values within the fields.

CO_2 Fluxes

Each site is equipped with an eddy covariance tower flux and meteorological sensors to measure net ecosystem carbon dioxide exchange. Daytime estimates of ecosystem respiration R_e were obtained from nighttime CO_2 fluxes vs. temperature relationships (*Verma et al., 2005*). The GPP was then obtained by subtracting R_e from net ecosystem production.

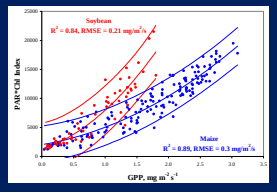
Total Canopy Chlorophyll Content

Weekly spectral reflectance measurements of leaves in the range 400 to 900 nm were carried out *in situ* using an Ocean Optics USB2000 radiometer, equipped with a leaf clip. Chl content in each leaf was retrieved from reflectance spectra (*Gitelson et al., 2003; 2006a*). Green LAI was measured at six intensive measurements zones in each site and total crop Chl content was calculated (details are in *Gitelson et al., 2005; Ciganda et al., 2008, Ciganda et al., 2009*).

RESULTS

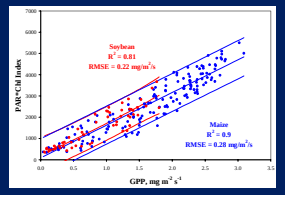
GPP ∝ Chl×PAR

Green Chlorophyll Index MODIS and Landsat bands

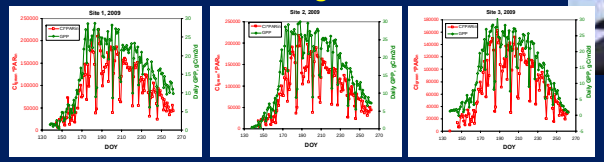


Gitelson et al., 2006b

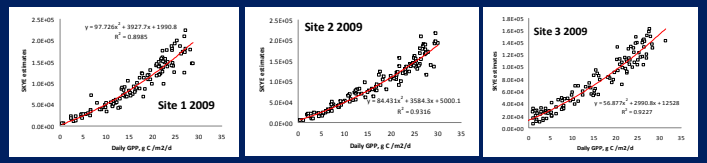
Red Edge Chlorophyll Index MERIS bands



GPP estimation using *SKYE* radiometers

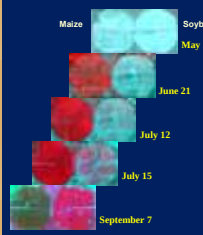


CO_2 fluxes and Chlorophyll Index

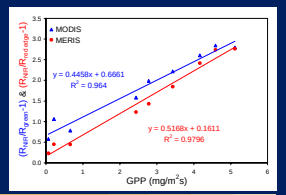


GPP estimation using *AISA-Eagle*

Five AISA-Eagle images were obtained over NE Mead sites in 2002



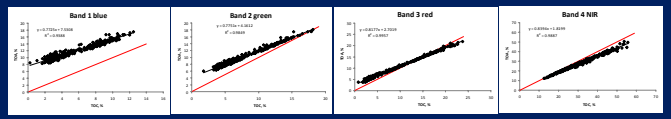
Chlorophyll indices (Gitelson et al., 2005) are simulated in MODIS, LANDSAT and MERIS bands:
CI_{green} = ρNIR/ρgreen -1 $CI_{red\ edge}$ = ρNIR/ρred edge -1



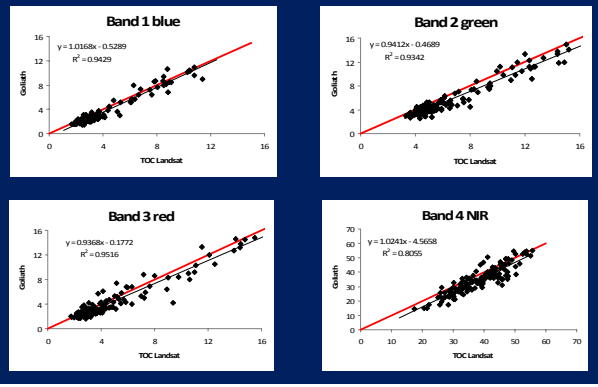
LANDSAT 2001-2008

111 Landsat images (TM: 59, ETM: 52) were obtained over NE Mead sites throughout 2001-2008 and atmospherically corrected (Masek et al., 2006).

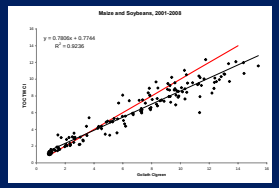
Top of Atmosphere vs. Top of Canopy Landsat Reflectance



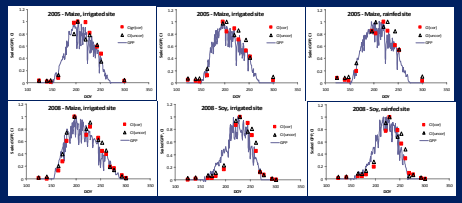
Top of Canopy Landsat vs. "Goliath" Reflectance



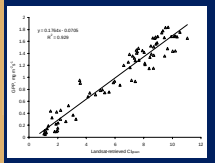
Chlorophyll Index: Top of Canopy Landsat vs. "Goliath"

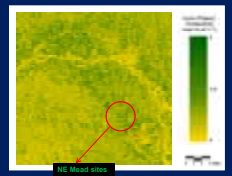


GPP Estimates using *LANDSAT*



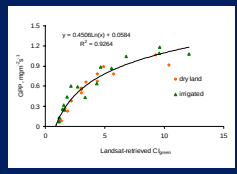
Irrigated and rainfed maize 2001-2008



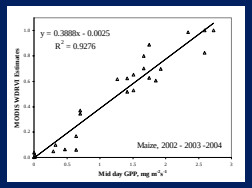


GPP distribution in South-Eastern Nebraska

Irrigated and rainfed soy 2002, 2004, 2006, 2008



GPP Estimates using *MODIS 250 m*



The Moderate Resolution Imaging Spectroradiometer (MODIS), with high temporal and spatial (250m) resolution, can be efficiently used to estimate GPP at large scale in crops. Wide Dynamic Range Vegetation Index (*Gitelson, 2004*):

WDRVI = (a * ρNIR–ρred) / (a *ρNIR+ρred)

derived from the red (662 – 672nm) and NIR (743 – 753nm) bands of MODIS 250m product with weigh coefficient *a = 0.1*, explained more than 92% of GPP variation in both irrigated and rainfed maize.

CONCLUSIONS

The remote sensing technique was capable of accurately predicting widely variable GPP in maize and soybean under both rainfed and irrigated conditions

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