GROUND AND AIRBORNE LEVEL OPTICAL SENSORS: IS IT POSSIBLE TO ESTIMATE MAIZE CROP N STATUS?

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Adjusting N fertilizer application to crop requirements is a key issue to improve fertilizer efficiency, reducing unnecessary input costs to farmers and N environmental impact. Among the multiple soil and crop tests developed, optical sensors that detect crop N nutritional status may have a large potential to adjust N fertilizer recommendation (Samborski et al. 2009). Optical readings are rapid to take and non-destructive, they can be efficiently processed and combined to obtain indexes or indicators of crop status. However, other physiological stress conditions may interfere with the readings and detection of the best crop nutritional status indicators is not always and easy task. Comparison of different equipments and technologies might help to identify strengths and weakness of the application of optical sensors for N fertilizer recommendation. The aim of this study was to evaluate the potential of various ground-level optical sensors and narrow-band indices obtained from airborne hyperspectral images as tools for maize N fertilizer recommendations. Specific objectives were i) to determine which indices could detect differences in maize plants treated with different N fertilizer rates, and ii) to evaluate its ability to identify N-responsive from non-responsive sites.

Materials and Methods

The study was conducted in the central Tajo river basin near Aranjuez (Spain) in 2012. The soil is a silty clay loam (Typic Calcixerept) and the climate Mediterranean semiarid. The experiment was design as a randomized complete block with six treatments per block and four replications. Plot size was 6 by 12 m. Treatments consisted in N fertilizer rates, and ranged from 0 to 200 kg N ha^{-1}, with 40 kg N ha^{-1} increases. The experiment was sown with maize (*Zea mays* L.) in early spring (20/04/12) with a plant population density of 80000 plants ha^{-1}. N fertilizer was hand broadcast to plots as ammonium nitrate in two applications: ½ when maize had 4 leaves (23/05/12), and ½ when had 8 leaves (26/06/12). Irrigation was uniformly applied by a sprinkle according to the crop evapotranspiration. Sensors Readings were conducted in two different dates: at stem elongation just before the second fertilizer application (21/06/12), and at flowering when treatment differences were expected to be more evident (23/07/12). Ground level measurements were taken with three optical sensors (SPAD® (Konica Minolta Inc., Japan), Dualex® and Multiplex® (Force-A, Orsay, France)). Airborne data acquisition was conducted by flying a hyperspectral (Micro Hyperspec VNIR model, Headwall Photonics, MA, USA) and an incoming irradiance (Ocean Optics HR2000 fiber-optic spectrometer, FL, USA) sensors 300 m over the experimental plots. In both sampling dates, fifteen measurements were taken with the hand held optical sensors in the uppermost fully developed leaf of 15 representative plants in the central plot rows.

Results and Discussion

Maize yield was highly correlated with N uptake and fertilizer application (Figure 1). During both dates, and at ground level, chlorophyll (Chl; SPAD, Chl Dualex, SFR) and N balance (NBI, NBI-G) indices tended to increase with N rate application and showed differences between lower and higher N application treatments, whereas flavonoids (Flav) and anthocyanins (Anth) tended to decrease. These results are in agreement with Cerovic et al. (2005) and Tremblay et al. (2007) who observed that N deficiency reduced Chl content and increased polyphenols. Good correlation between sensors indices was observed (~0.9) except for the Multiplex at steam elongation, due to the low signal intensity when leaves were too narrow. The structural index presenting a better relationship with LAI and ground level Chl measurements was NDVI (Table 1). However, other airborne indices calculated from narrow-band reflectance measurements (i.e. R750/710 or TCARI/OSAVI) and Chl solar-induced fluorescence (FSIF) were higher correlated with Chl than NDVI and presented a larger potential for future application to estimate crop N status (Fig 1). Table 1. Pearson correlation coefficients for the linear model between indexes (shadowed for those based on ground level sensors) and crop parameters at steam elongation (SE) and maize flowering (Fl). Indexes are frequently used in the remote sensing literature. A detailed description can be found in Quemada et al. (2014). Maize yield versus crop N uptake (A), N applied as fertilizer (B) and R750/R710 index (C).

Conclusion

The results suggest that despite numerous sources of variation, indices based on airborne measurements were as reliable as ground level equipment at assessing crop N status and predicting yield at stem elongation and flowering. Ground level indices more reliable to differentiate between maize plants treated with different N fertilizer rates were SPAD readings, Chl Dualex and SFR Multiplex. The airborne chlorophyll indices (i.e. R570/R710) and SIF were more accurate in detecting N stress in maize that structural indices (i.e. NDVI). More research is needed to account for other sources of variability that may interfere in the identification of the N nutritional status.

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		SPAD	Chl	Flav	NBI	SFR	NBI-G	Anth	FERARI	NDVI	RDVI	R750/ R710	R700/ R760	TCARI	TCARI/ OSAVI	PRI	BGII	FSIF
Yield	SE	0.48	0.44	-0.10	0.22	-0.07	-0.10	0.04	0.12	0.46	0.47	0.55	0.33	0.14	-0.17	-0.48	0.23	0.59
	Fl	0.67	0.62	-0.06	0.54	0.55	0.38	-0.45	0.26	0.61	0.57	0.67	-0.04	-0.29	-0.42	-0.55	0.33	0.52
Biomass	SE	0.43	0.38	-0.18	0.26	-0.09	-0.04	-0.08	0.07	0.43	0.44	0.51	0.28	0.10	-0.20	-0.43	0.27	0.49
	Fl	0.65	0.56	-0.05	0.49	0.52	0.34	-0.42	0.26	0.60	0.56	0.63	-0.04	-0.27	-0.40	-0.53	0.30	0.49
Grain N	SE	0.49	0.42	-0.02	0.15	-0.04	-0.12	0.04	0.19	0.50	0.52	0.57	0.42	0.24	-0.05	-0.54	-0.30	0.57
	Fl	0.64	0.59	0.00	0.49	0.55	0.30	-0.43	0.31	0.64	0.61	0.66	0.03	-0.23	-0.37	-0.59	-0.18	0.57
N uptake	SE	0.50	0.47	-0.18	0.30	-0.09	-0.03	-0.01	-0.01	0.37	0.38	0.48	0.20	0.00	-0.29	-0.38	0.30	0.15
	Fl	0.65	0.57	-0.17	0.55	0.47	0.42	-0.42	0.15	0.53	0.47	0.61	-0.14	-0.35	-0.46	-0.47	0.34	-0.07