Remote estimation of green LAI in maize using UAV-based low-cost imagery

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Background and Methodology

Introduction

- Green leaf area index (gLAI) one of the key parameters in crop growth analysis (Wilhelm et al., 2000).
- Measuring field trial gLAI using in-situ measurements is labor-intensive, costly work with often inaccurate results.
- Unmanned Aerial Vehicle (UAV)-based remote sensing (RS) facilitates estimation due to quick and easy deployment of sensors that are able to cover a number of treatment plots in little time.
- Modified low-cost cameras with sensitivity in the visible and near-infrared (NIR) domain have recently gained the attention of the scientific community.
- Their potential to sense differences in gLAI in maize induced by management factors is largely unexplored.
- We ask: To what extent do broadband vegetation indices based on low-cost imagery cover gLAI temporal dynamics induced by plant density and/or nitrogen supply?

Study Site and Field Experiment

- Study site located at the University of Bonn‘s agricultural research facility Campus Klein-Altendorf, 15 km southwest of Bonn.
- Field experiment consisted of a combination of two plant densities (50,000 plants (S1) and 100,000 plants (S2) ha^{-1})and two treatments of nitrogen (100 kg (N1) and 200 kg (N2) ha^{-1}) (Figure 1)
- Hybrid Panash (AGA Saat AG, Neunkirchen, Germany) used in 2015, hybrid Ricardinio (KWS Saaten AG, Einbeck, Germany) in 2016.
- Destructive green LAI measurements using the LI-COR LI-3100C area meter (LI-COR Inc., Lincoln, NE, USA).
- 32 samples per sampling date, with eight dates in 2015 and ten in 2016.

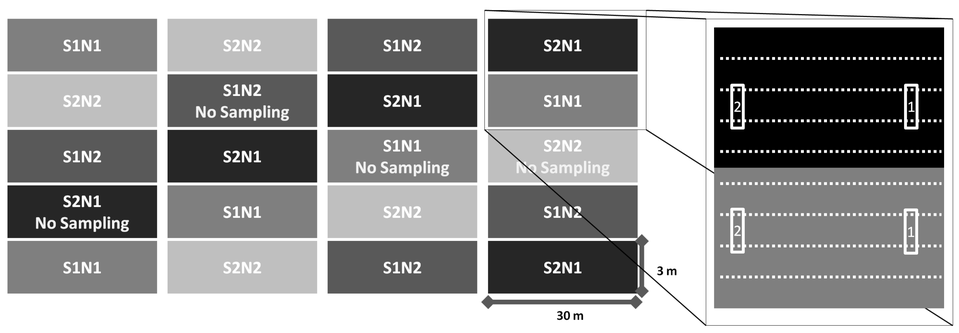

Figure 1. Experimental setup. Enlargement on the right shows gLAI sampling spots.

Camera System and UAV

- We employed two Canon ELPH 110 HS digital compact Red-Green-Blue (RGB) cameras, modified by LDP LLC Inc. (Carlstad NJ, United States).(Figure 2).
- CMOS sensor with 4608 x 3456 recording pixels (i.e. 16.1 Megapixels).
- First camera: Red – Green - NIR (680-780 nm)
  Second camera: Blue – Green – NIR (800-900 nm)
- UAV: Mikrokopter OktoXL6S12 (HiSystems GmbH, Moormerland, Germany)
- Flight altitude 50 m, with ground sampling distance of ~1.5 cm
- Multispectral data was collected on mostly cloud-free days immediately before the sampling of the plants.

Figure 2. UAV and camera setup. Left picture shows the octocopter employed in this study, the right picture the two cameras mounted inside the frame.

Methodology cont.

Spectral Vegetation Indices Used

- Three spectral vegetation indices chosen (Table 1)
- NDVI and GNDVI widely used in RS
- 3BSI was introduced by Verrelst et al. (2015) and outperformed most two-band vegetation indices in parametric LAI regression performance

Table 1. Index formulations.

$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}}$	(1)
$\mathrm{GNDVI} = \frac{\mathrm{NIR} - \mathrm{Green}}{\mathrm{NIR} + \mathrm{Green}}$	(2)
$\mathrm{3BSI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{Green} + \mathrm{Red}}$	(3)

Results

LAI – SVI Parametric Regression

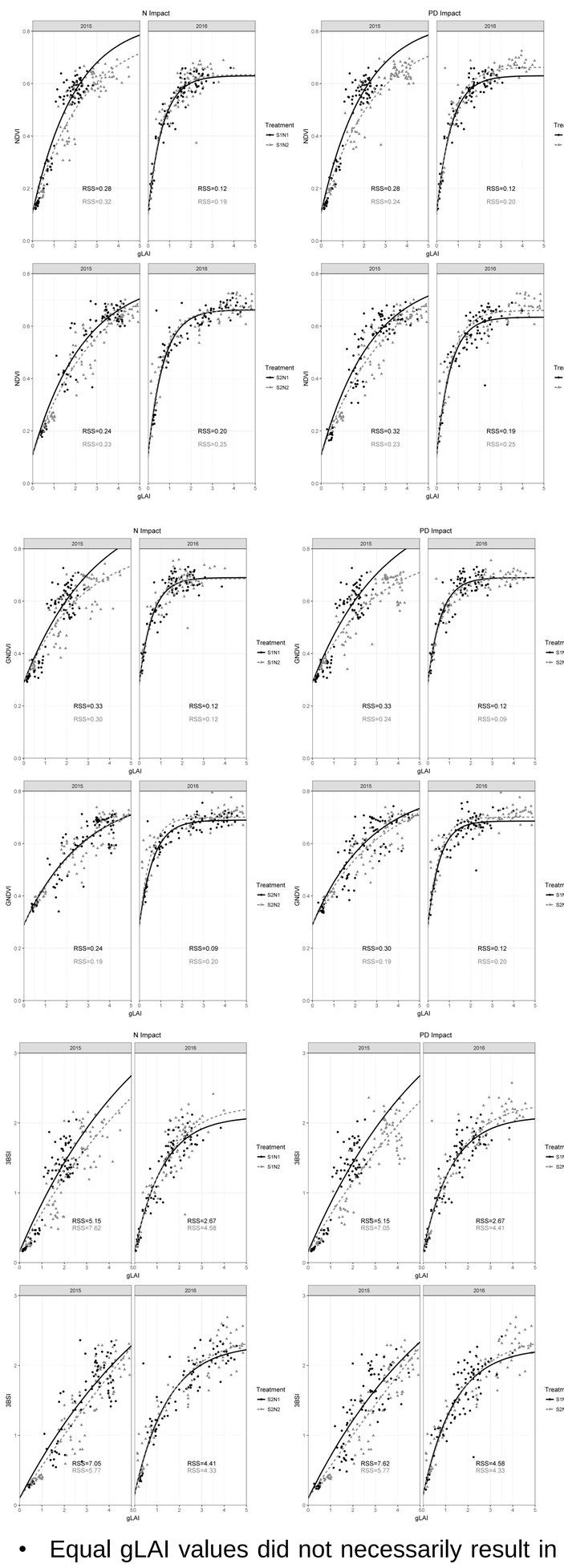

Figure 3. gLAI - NDVI relationships per management factor. The left column shows N treatment effects, the right column plant density effects.

- NDVI models differed for 2015, and resembled for 2016.
- For 2015, no saturation effect could be noticed within the range of measured gLAI values.

Figure 4. gLAI – GNDVI relationships per management factor.

- Similar to the results above, GNDVI – gLAI models resembled for 2016, and differed for 2015.
- A clear effect of saturation was noticed in the 2016 data, with gLAI values > 3 not showing an increase in GNDVI values.

Figure 5. gLAI – 3BSI relationships per management factor.

- No clear saturation effect could be determined for the 3BSI – gLAI models within the measured range of values
- Contrary to the NDVI and GNDVI models, this applied to both years.

- Equal gLAI values did not necessarily result in equal spectral vegetation index values.
- Differences in chlorophyll content might have caused differences in reflectance.

Conclusion

- Spectral data derived from UAV-based modified low-cost cameras delivered a meaningful relationship with measured gLAI values.
- We found differing but definite relationships per treatment factor.
- GNDVI performed slightly better than NDVI; a 3-band combination did not offer any advantages.
- Selected band combinations reached their limits at gLAI values > 3.

References

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