Examining the relationship between SPAD, LAI and NDVI values in a maize long-term experiment

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Abstract. In Hungary, the preconditions for the use of precision crop production have undergone enormous development over the last five years. RTK coverage is complete in crop production areas. Consultants are increasingly using the vegetation index maps from Landsat and Sentinel satellite data, but measurements with on-site proximal plant sensors are also needed to exclude the influence of the atmosphere.

The aim of our studies was to compare the values measured by proximal plant sensors in the polyfactorial split-split-plot long-term maize field experiment at the trial site of the University of Debrecen (Hajdúság loess plato, N 47.554164, E 21.448111, 112 m elevation) in 2017. The soil type of the experimental site is a lowland calcareous chernozem. During these studies, we used Minolta SPAD-502 chlorophyll meter, LI-COR LAI-2000 leaf area index meter and Trimble GreenSeeker NDVI measuring instrument. The measurements were performed in V4; V8 and R1 phenological stages. The statistical analyses were carried out in Rstudio.

In V4 phenological phase the correlation between the SPAD values and the NDVI values has been found weak ($r = 0.18$). The correlation between the SPAD and NDVI values was not significant during the V8 phenological phase. During the phenological phase R1, the correlation between the SPAD and NDVI values was moderate ($r = 0.32$). The SPAD and LAI values measured in phenophase R1 significantly ($P < 0.001$) influenced the measured NDVI values, the relationship between these values was moderate ($r = 0.47$), SPAD and LAI values had 22.34% influence on the NDVI values. When in the phenophase of maize R1 the variation coefficients of the NDVI measurements were taken into account, they significantly ($P < 0.001$) affected the measured NDVI values by 43.1%.

Keywords. *Maize, SPAD, NDVI, Leaf Area Index, multilinear regression.*

Introduction

In Hungary, the preconditions for the use of precision crop production have undergone enormous development over the last five years. RTK coverage is complete in crop production areas. Consultants are increasingly using the vegetation index maps from Landsat and Sentinel satellite data. However measurements with on-site proximal plant sensors were also needed to exclude the influence and noise of the atmosphere (Houborg et al., 2015). The recorded signal from the remote sensing sensors was a composite of atmospheric and surface contributions (Houborg and McCabe, 2017).

Materials and Methods

The aim of our studies was to compare the values measured by proximal plant sensors in the polyfactorial split-split-plot long-term maize field experiment at the trial site of the University of Debrecen (Hajdúság loess plato, N 47.554164, E 21.448111, 112 m elevation) in 2017. The soil type of the experimental site was a lowland calcareous chernozem.

During these studies, we used Minolta SPAD-502 chlorophyll meter, which has an active light source and measures the ratio of the NIR (940 nm) and RED (650 nm) light passing through the leaf (Süß et al., 2015) and it also calculates the SPAD values with the following the equation (1).

$$SPAD = \frac{NIR_{940}}{RED_{650}} \quad (1)$$

where SPAD = SPAD value, NIR_{940} = transmittance in the 940 nm wavelength, RED_{656} = transmittance in the 650 nm wavelength

For NDVI measurement we used a Trimble GreenSeeker (NTech Industries Inc., Ukiah, CA, USA) with a handheld OTG capable android tablet PC. GreenSeeker Data Logger application (Oklahoma State University.) has been used to record the NDVI and the Coefficient of Variance (CV) values for each measurement. The GreenSeeker sensor has an active light source and measures in the NIR (774 nm) and in the RED (656 nm) spectrum (Ali et al., 2014), and it calculates the NDVI values with the following the equation (2).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR}_{774} - \mathrm{RED}_{656})}{(\mathrm{NIR}_{774} + \mathrm{RED}_{656})} \quad (2)$$

where NDVI = Normalized difference vegetation index, NIR_{774} = reflectance in the 774 nm wavelength, RED_{656} = reflectance in the 656 nm wavelength

We measured the Leaf area index (LAI) with Licor LAI-2000 (LI-COR Inc., Lincoln, NE, USA.), which measures the incoming light through the canopy in the 320-490 nm range.

The plant measurements were performed in V4; V8 and R1 phenological stage. The statistical analyses were carried out in Rstudio. Linear regression analysis was performed to examine the correlation between SPAD and NDVI values. Multilinear regression analysis was performed to investigate the relationship between SPAD and CV NDVI measured in Phenological phase R1 and SPAD LAI, CV NDVI values with NDVI.

Results

In V4 phenotype the connection between the SPAD and the NDVI values were weak (r = 0.18), the SPAD values influenced significantly (P < 0.05) the NDVI readings by 3.1%. In the V8 phenophase the connection between the SPAD and NDVI values was not significant. During the phenological phase R1, the relationship between the SPAD and NDVI values was moderate (r = 0.32). The SPAD values influenced the NDVI readings significantly (P < 0.001) by 10.4%. The SPAD and LAI values measured in phenotype R1 had a significantly (P <0.001) effect on the measured NDVI, the relationship between these values was moderate (r = 0.47), SPAD and LAI values influenced the NDVI readings in 22.34%.

In case the Coefficient of Variance data for each NDVI measurement were taken into account, in V4 phenophase the effect of SPAD and CV NDVI on the NDVI measurements was moderately strong (r = 0.68). The SPAD and CV NDVI values influenced the NDVI readings by 46.6%. In the V8 stage the SPAD and CV NDVI values had no significant effect on the NDVI measurements. In the R1 phenological phase the SPAD and CV NDVI values influenced significantly (P < 0.001) the NDVI readings moderately strong (r = 0.66). The SPAD and CV NDVI readings had a 43.1% effect on the NDVI measurements. In this phenological phase the SPAD, CV NDVI and LAI values had a moderately strong (r = 0.66) effect on the NDVI readings. The SPAD, LAI and CV NDVI values influenced the NDVI measurements by 43.2%.

In average of the three measurement times the SPAD readings had a significantly (P < 0.001), moderately weak (r = 0.29) effect on the NDVI readings. With the CV NDVI for the NDVI readings were taken into account in average of the three measurement times in both values had a significant (P < 0.001) effect on the NDVI readings. The CV NDVI and SPAD values influenced the NDVI readings in 21.7%.

Conclusion

The correlation between the SPAD and handheld NDVI data depends on the measuring time, such as the growth stage of the maize plant. The handheld GreenSeeker detects much soil in the early development stages of maize and as a result the plant heterogeneity greatly influenced our measurements.

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