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Evaluation of leaf area index of winter wheat canopy by means of ground-based stereoscopic vision

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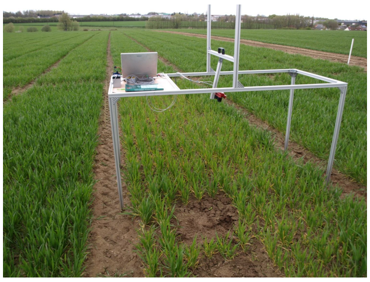
OBJECTIVES

Precision agriculture, variety testing and studies in ecotron requires the development of reliable and robust measurement systems in order to assess in a non-destructive way the crop growth dynamics. In this context, the measurement of agronomical traits such as the Leaf Area Index (LAI) is of utmost importance. The aim of this study is to evaluate the LAI of winter wheat canopy by means of a low-cost ground-based stereoscopic vision system. The tests were carried out during the growing seasons of 2013 and 2017 on micro plots of *AgricultureIsLife* platform of TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liège, Belgium.



MATERIAL & METHODS

Field experimentation and reference measurements

The precision of the 3D method was evaluated in field experimentation on wheat crop (*Triticum aestivum L.*) with variable nitrogen fertilization resulting in contrasted growing conditions.

In 2013, measurements were made on 8 plots:
- 2 nitrogen application modalities (0, 180 kg/ha)
- 4 plot repetitions
- 3 dates (8th April, 6th May, 4th June)

In 2017, measurements were made on 36 plots:
- 9 nitrogen application modalities (0, 60, 120, 180, 270 kg/ha)
- 4 plots repetitions
- 6 dates (21st March, 4th April, 17th April, 2nd May, 7th June, 5th July)

Destructive reference measurements were performed by harvesting manually the plants in 0.5 m of a line in each plot. The leaves were stripped and stuck on paper sheet and scanned. The area of photosynthetically active leaves were computed by image analysis.

Image acquisition

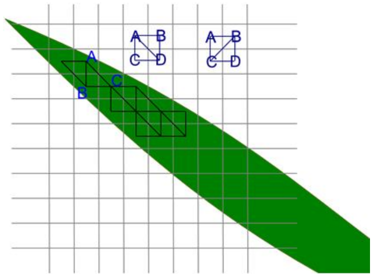
The devices used in the experiments were twin RGB CMOS cameras model STH-MDCS2-VAR-C from Videre Design. The two points of view were distant of 115 mm. The focal lengths were 16 mm and a vergence of 4.5° was applied to the system to maximise the area inspected simultaneously by the two cameras. The cameras were observing the plants from around 1 m with their medium optical axis presenting a zenith angle equal to half the vertical angle of view (15°). In order to obtain a representative value of the LAI, five pairs of images were acquired per plot. For the two last dates in 2017 (7th June and 5th July), twin RGB CMOS cameras model JAI-GO-5000M-USB were used and the images were acquired with a nadir view.

Moreover, to assess the repeatability of the measurement method, five images were acquired at the same spot on one plot and different natural lightning conditions were considered.

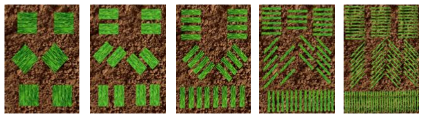
Image analysis

A stereo vision system calibration was carried out indoor using a check board in order to extract the intrinsic parameters of the systems. An image rectification was performed to improve the matching between the left and right images. The disparities in pixels were then computed by looking for corresponding points in the same raw between the both images. By using the calibration, the pixel disparities were converted in camera-linked three-dimensional metric referential XYZ with the origin centred on the sensor, the coordinate pointing from the objects to the camera.

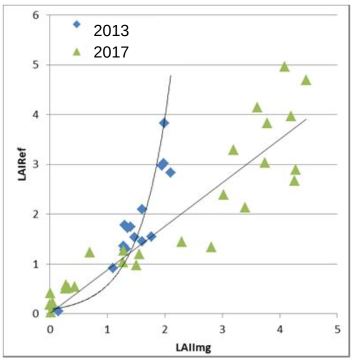
The plants were segmented from the soil by linear discriminant analysis on the colour parameters of the pixels. The leaf area was evaluated for each triplet of adjacent pixels belonging to leaves by computing a cross product of two vectors joining the three pixels in XYZ coordinate system. The total area of plant leaves was computed by summing the local areas.



The precision of the area estimation method was evaluating by means of patterns having known green area positioned at different distances and different angles.



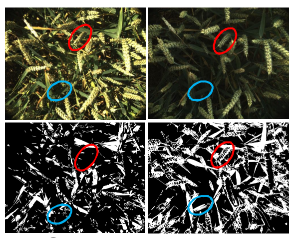
RESULTS



Regression	2013	2017
Linear	R^2 = 0.76	R^2 = 0.84
Exponential	R^2 = 0.89	R^2 = 0.73

For the 2017 season, the coefficient of variation (CV) of the estimation of the LAI was 0.29.

Sources of variabilities:
- Inter-plot variability: CV = 0.207
- Intra-plot variability: CV = 0.14
- Wind variability: CV < 0.04
- Lightning variability: CV was from 0.05 to 0.25



CONCLUSIONS & PRESPECTIVES

A method to evaluate the leaf area index by using a ground-based stereoscopic vision system was presented. The results showed that the 3D-LAI could be used to estimate the real LAI in an efficient way with respect to the reference method.

The proposed 3D vision method is promising to measure morphological traits of plants in a non-destructive way and monitor the growth dynamics of cereal crops in natural and controlled environments.