Non-destructive monitoring of grassland canopy height using a UAV

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Introduction

Grasslands cover one third of the agricultural area in Europe and provide a substantial part of the ruminant feed requirements in the dairy and meat industry. Furthermore, these ecosystems are very effective in preventing soil erosion, building soil fertility, require minimal pesticide use, and contribute multiple positive effects on the environment. Permanent grasslands, and the species they contain, have evolved spontaneously to adapt to the pedo-climatic conditions in which they occur. Hence, these different ecotypes are crucial in breeding under climate change scenarios. One of the main component species in North-West European grasslands is *Lolium perenne* (perennial ryegrass). Due to its rapid growth and establishment, high yield potential and feed quality, perennial ryegrass is also the most frequently sown grassland species in Europe.

We are currently developing a methodology, based on the use of unmanned aerial vehicles (UAVs) combined with different (spectral range) sensors, to monitor perennial ryegrass growth in a non-destructive way. The field trial used is part of GrassLandscape, a FACCE-JPI ERA-NET+ project. In this trial, 500 accessions sampling the natural diversity of the species across Europe and North Africa are grown in replicated micro-swards. This set of accessions displays a very broad range of genetic and phenotypic diversity including growth characteristics. Frequent flights at low altitudes are performed to collect imagery at high spatial and temporal resolution throughout the growing season to estimate canopy height and its temporal evolution. These data are combined with manual on-field measurements of canopy height, performed with an herbometer, for validation. Correlations between the UAV data and on-field measurements will be calculated. Finally, canopy height data derived from UAV flights in combination with vegetation indices will be used to estimate the biomass volume.
http://www.faccejpi.com/Research-Themes-and-Achievements/Climate-Change-Adaptation/ERA-NET-Plus-on-Climate-Smart-Agriculture/Grasslandscape

Materials and Methods

The field trial was sown at the beginning of October 2015 on a sandy loam soil in Merelbeke (Belgium). It consists of 4 blocks according to the earliness of the accessions. Block 1 till 4 contain 124 late accessions, 132 intermediate accessions, 123 early accessions and 41 very early accessions respectively. Each block is organized in a randomized block design, with 3 repetitions. Individual plots measure 1.04 m² and were sown at a density of 2 g seeds/m². In 2016 the field was harvested four times (13/05, 1/07, 5/08 and 2/09). In-between harvests, canopy height was measured weekly using a herbometer (Fig. 1E).

In 2017, a dodecacopter Hydra-12 Onyxstar (Mikrokopter, Germany) (Fig. 1A) equipped with a RGB camera Sony a6000 (Sony, Japan) with a Carl Zeiss Touit 12 mm f2,8 lens was used to collect imagery of the experimental field at a height of 30 m (above soil level) weekly. The overlap in both directions was 80% and 35 Ground Control Points (GCPs) were located in the field. Orthophoto and DEM derived from each flight were built in Agisoft Photoscan v1.2.6 (Agisoft LLC, St. Petersburg, Russia). Spatial resolution was 1 cm and 1,5 cm respectively.

A Digital Terrain Model (DTM) was built based on the imagery collected from a flight carried out as close as possible to the date of the mowing of the field (25/04/17).
Digital Surface Models (DSMs) were built from the flights carried out in the consecutive weeks after the cut. The canopy height of the plots was estimated by the difference between the DSM and the DTM. A correction of 5 cm was applied for height of the stubble that remained after mowing.

Materials and Methods - images

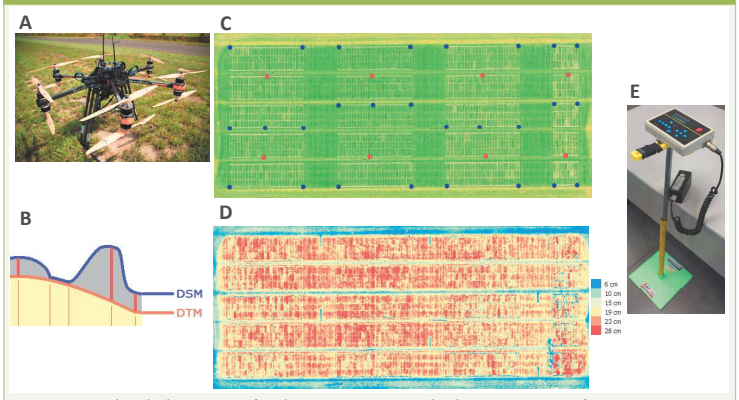

Figure 1 A: The dodecacopter (Hydra-12 Onyxstar, Mikrokopter, Germany); B: Grass canopy height estimation by subtracting the digital terrain model (DTM) from the digital surface model (DSM) and correcting for the height of the stubble that remains after mowing; C: Orthophoto with GCPs located (blue to build the orthophoto, red as checkpoints); D: Canopy height variation on 16/05/10 (15 days after mowing); E: Herbometer used for measuring canopy height.

Results and discussion

1. In 2016, preliminary tests of canopy height estimation displayed variability within the experimental plots (Fig. 2).
2. Accuracy test of the orthophoto and DSM derived from one flight using eight ground control points (Table 1)
3. In 2017, the variability within plots is tested by measuring in three different location with the herbometer (Fig. 3)
4. In 90 plots, correlation between herbometer measurements and the canopy height derived from the DSMs are estimated (Fig. 4). Higher correlations are obtained in subsequent weeks after the cut (Table 2)

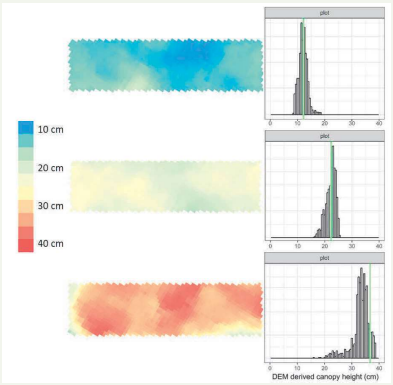

Figure 2: Canopy height variability on 26/07/2016 for three different plots (18 days after mowing), derived from the DSM. Herbometer measurements represented by the green line.

Table 1: Root-mean-square-error (RMSE) as indicator of the horizontal and vertical accuracies.

Pt_ID	RMSE_X (cm)	RMSE_Y (cm)	RMSE_Z (cm)
1	1.19	1.61	2.44
2	1.23	0.76	1.44
3	2.39	0.66	1.02
4	1.54	0.22	0.69
5	1.07	0.48	2.06
6	1.08	0.97	1.30
7	0.61	2.73	1.40
8	0.01	0.26	1.24
average:	1.14	0.96	1.45

Table 2: Correlations between the herbometer measurements and different canopy height values extracted from the DSM.

Correlations	10/05/2017	16/05/2017
Mean canopy height	0.537	0.625
P90 canopy height	0.517	0.593
Max canopy height	0.537	0.625

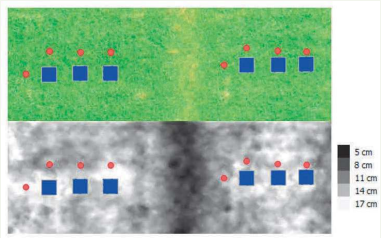

Figure 3: Location of the measurements with the herbometer per plot in the orthophoto and DSM.

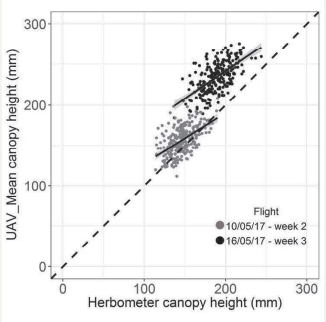

Figure 4: Correlations between the canopy height measured with the herbometer and derived from the DSM at the same location for two dates 10/05/2017 (grey, n=270) and 16/05/2017 (black, n=252). 10 and 15 days after the mowing.

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