Upscaling winter wheat above-ground biomass measurements using multispectral imagery and 3D data from unmanned aerial vehicles

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I. UPSCALING ICOS MONITORING PROGRAM WITH UAV IMAGERY

Field measurements in the ICOS (Integrated Carbon Observation System) program are spatially limited
→ Monitored gas fluxes may have a large footprint

Case of Above-Ground Biomass (AGB)
→ Field sampling time consuming
→ Spatially limited

Can UAV imagery time series be (part of) a solution?
→ Cost effective and final user-controlled systems
→ Higher spatial (0.1 m imagery) and temporal resolution than other remote sensing technique (e.g. satellite or other airborne imagery)

ICOS candidate station of Lonzée (Belgium, Wallonia)
- Four years rotation crop (winter wheat in 2017)
- One of the first European site devoted to production crops
- 3 m high mast
- Intensive biomass monitoring, soil respiration, NDVI (Normalized Difference Vegetation Index) and PRI (Photochemical Reflectance Index), nitrogen, volatile organic compounds fluxes, N₂O fluxes

II. ACQUISITION AND PREPROCESSING OF UAV IMAGERY

Octocopter drone
- X frame type, PixHawk controller
- High spatial resolution consumer grade RGB camera (Sony RX100)
- Multispectral camera (Parrot Sequoia)

Acquisition of time series
- 8 flights from 14th of February to the 7th of July 2017
- Production of reflectance maps (green, red, NIR and Red-Edge, derived from Sequoia camera)
- Two straight-forward vegetation indices (Normalized Difference Vegetation Index - NDVI and Green NDVI - GNDVI)
- Production of Crop Height Model maps (RX100)

III. MODELING AND MAPPING ABOVE-GROUND BIOMASS (AGB) WITH UAV IMAGERY

AGB field reference data
- Sampling approach: use of data monitored by the ICOS program and by field research conducted in experimental fields within the area of interest
- Field measurement: Crop samples were collected (destructive), dried and weighted in order to compute a reference AGB normalized per unit area (t / Ha)

AGB modelling with UAV data
- Each AGB field estimation was associated with the imagery associated to the closest flight date
- Multiple linear regressions modelling:

\[ AGB = a + b \times GNDVI + c \times NDVI + d \times CHM \]

- Good result for multdate \((r^2 = 0.85, \text{RMSE} = 2.3 \text{t/Ha}, 96 \text{obsrv.})\) and single date approach \((4^{th} \text{July}, r^2 = 0.71, \text{RMSE} = 1.9 \text{t/Ha}, 16 \text{obsrv.})\)

Mapping AGB with UAV data
- Predicted AGB map displays a high spatial heterogeneity with some spatial patterns
- Low AGB values are found along two old pedestrian trails
- Higher AGB values for crop sprayed twice (in-between two tractor tracks)

IV. PERSPECTIVES

Upscaling AGB monitoring within entire footprint of the station with UAV imagery? → Clear potential of UAV imagery to monitor the AGB variation

Operational recommendation for UAV integration in ICOS AGB monitoring:
- The ICOS monitoring provides for this site only 20 AGB observations just before the harvest
→ need for specific (and more frequent) sampling strategy to enable UAV multitemporal AGB monitoring within the footprint of the flux tower

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