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A Novel Machine Learning Method for Estimating Biomass of Grass Swards Using a Photogrammetric Canopy Height Model, Images and Vegetation Indices Captured by a Drone

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Abstract

Silage is the main feed in milk and ruminant meat production in Northern Europe. Novel drone-based remote sensing technology could be utilized in many phases of silage production, but

advanced methods of utilizing these data are still developing. Grass swards are harvested three times in season, and fertilizer is applied similarly three times—once for each harvest when aiming at maximum yields. Timely information of the yield is thus necessary several times in a season for making decisions on harvesting time and rate of fertilizer application. Our objective was to develop and assess a novel machine learning technique for the estimation of canopy height and biomass of grass swards utilizing multispectral photogrammetric camera data. Variation in the studied crop stand was generated using six different nitrogen fertilizer levels and four harvesting dates. The sward was a timothy-meadow fescue mixture dominated by timothy. We extracted various features from the remote sensing data by combining an ultra-high resolution photogrammetric canopy height model (CHM) with a pixel size of 1.0 cm and red, green, blue (RGB) and near-infrared range intensity values and different vegetation indices (VI) extracted from orthophoto mosaics. We compared the performance of multiple linear regression (MLR) and a Random Forest estimator (RF) with different combinations of the CHM, RGB and VI features. The best estimation results with both methods were obtained by combining CHM and VI features and all three feature classes (CHM, RGB and VI features). Both estimators provided equally accurate results. The Pearson correlation coefficients (PCC) and Root Mean Square Errors (RMSEs) of the estimations were at best 0.98 and 0.34 t/ha (12.70%), respectively, for the dry matter yield (DMY) and 0.98 and 1.22 t/ha (11.05%), respectively, for the fresh yield (FY) estimations. Our assessment of the sensitivity of the method with respect to different development stages and different amounts of biomass showed that the use of the machine learning technique that integrated multiple features improved the results in comparison to the simple linear regressions. These results were extremely promising, showing that the proposed multispectral photogrammetric approach can provide accurate biomass estimates of grass swards, and could be developed as a low-cost tool for practical farming applications. View Full-Text

Keywords: photogrammetry; drone; unmanned aerial vehicle; digital surface model; canopy height model; grass sward; biomass; machine learning; Random Forest; multiple linear regression

Figures

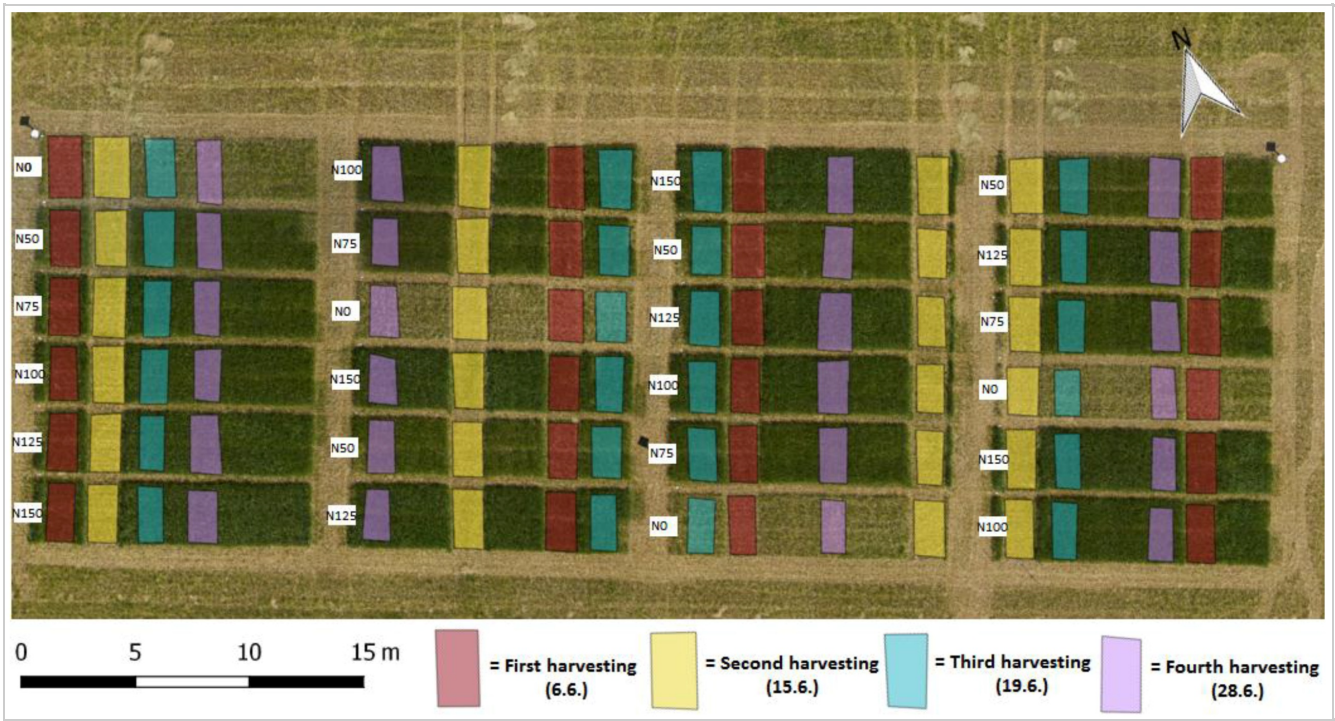

Figure 1

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