Use of unmanned aerial vehicles for in field evaluation of phenotypic traits of wheat

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Abstract:
The utility of unmanned aerial vehicles (UAV) imagery in retrieving phenotypic data to support plant breeding research has been a topic of increasing interest in recent years. The advantages of image-based phenotyping are related to the high spatial and temporal resolution of the retrieved data and the non-destructive and rapid method of data acquisition. This study trains parametric and nonparametric regression models to retrieve leaf area index (LAI), fraction of absorbed photosynthetically active radiation (fAPAR), fractional vegetation cover (fCover), leaf chlorophyll content (LCC), canopy chlorophyll content (CCC), and grain yield (GY) of winter durum wheat breeding experiment from four-bands UAV images. A ground dataset, collected during two field campaigns and complemented with data from a previous study, is used for model development. The dataset is split at random into two parts, one for training and one for testing the models. The tested parametric models use the vegetation index formula and parametric functions. The tested nonparametric models are partial least square regression (PLSR), random forest regression (RFR), support vector regression (SVR), kernel ridge regression (KRR), and Gaussian processes regression (GPR). The retrieved biophysical variables along with traditional phenotypic traits (plant height, yield, and tillering) are analysed for detection of genetic diversity, proximity, and similarity in the studied genotypes. Analysis of variance (ANOVA), Duncan's multiple range test, correlation analysis, and principal component analysis (PCA) are performed with the phenotypic traits. The parametric and nonparametric models show close results for GY retrieval, with parametric models indicating slightly higher accuracy (R^2 = 0.49; MRSE = 0.58 kg/plot; rRMSE = 6.1%). However, the nonparametric model, GPR, computes per pixel uncertainty estimation, making it more appealing for operational use. Furthermore, our results demonstrate that grain filling was better than flowering phenological stage to predict GY. The nonparametric models show better results for biophysical variables retrieval, with GPR presenting the highest prediction performance. Nonetheless, robust models are found only for LAI (R^2 = 0.48; MRSE = 0.64; rRMSE = 13.5%) and LCC (R^2 = 0.49; MRSE = 31.57 mg m^{-2}; rRMSE = 6.4%) and therefore these are the only remotely sensed phenotypic traits included in the statistical analysis for preliminary assessment of wheat productivity. The results from ANOVA and PCA illustrate that the retrieved remotely sensed phenotypic traits are a valuable addition to the traditional phenotypic traits for plant breeding studies. We believe that these preliminary results could speed up crop improvement programs; however, stronger interdisciplinary research is still needed, as well as uncertainty estimation of the remotely sensed phenotypic traits.

Keywords: biophysical variables retrieval; machine learning; multispectral imagery; phenotyping; remotely sensed phenotypic traits