Imaging Alfalfa to Predict Yield & Quality & Impacts of Water Deficits Using Innovative Over-head Irrigation Systems

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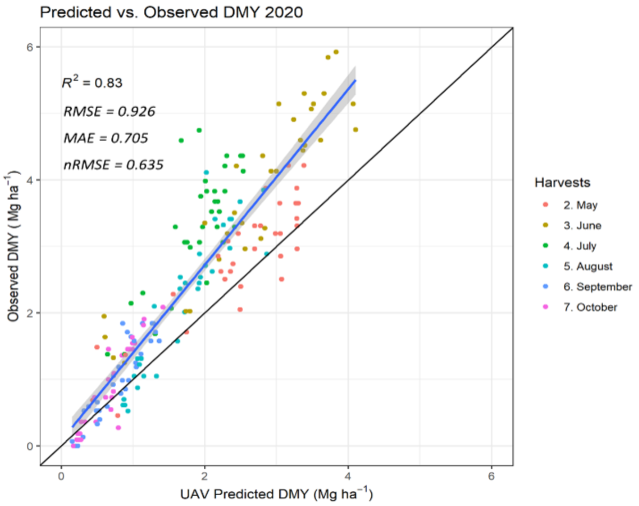
Sustainable forage production requires informed decisions for forage availability at any time of the year or across seasons. Remote estimation of within-field variability could also help to improve forage yield gaps by analyzing yield-limiting factors such as soil type, stand loss, traffic, salinity, or drought. A research experiment was designed to test the applicability of using both multispectral and Light Detection and Ranging (LiDAR) technologies in a second-year drought-affected (irrigation treatments ranging from 100% ET to 60% summer cutoff to 60% and 40% sustained deficits) alfalfa field for estimating spatial-temporal variability of yield and quality of alfalfa. We used unmanned aerial vehicles (UAVs), equipped with multispectral (6 selected harvests) and LiDAR sensors (4 selected harvests) during 2020. The UAV flights were conducted around solar noon just before harvest. Hundreds of alfalfa samples were collected over a range of soil moisture conditions to measure the forage biomass and quality assessment along with plant height and used to predict yields. Models were created for both multispectral and LiDAR datasets, respectively. The stepwise regression model predicted the dry matter yield (R^2= 0.82, RMSE= 0.692 Mg ha^{-1}) better than the support vector machine (SVM, R^2= 0.81, RMSE= 0.709 Mg ha^{-1}) and random forest (RF, R^2= 0.79, RMSE= 0.738 Mg ha^{-1}) algorithms, based on data from multispectral images. The trained multispectral model (using vegetation indices, UAV estimated plant height) was also used to estimate the yield in an independent harvest area (11.15 m^2), and successfully predicted dry matter yields (R^2= 0.83, RMSE= 0.926 Mg ha^{-1}). Similarly, LiDAR also performed well for an independent harvest area (11.15 m^2) with an R^2= 0.91, RMSE= 0.425 Mg ha^{-1}. Both the sensors were successful in the development of yield maps and yield predictions while performance in forage quality predictions (crude protein (CP), neutral detergent fiber (NDF)) was lower (CP (R^2= 0.4, RMSE= 13.481 g kg^{-1}), NDF (R^2= 0.58, RMSE= 29.145 g kg^{-1}). Multi-spectral sensor and LiDAR differ in mechanism, availability and cost. Timing of image capture using multispectral and LiDAR did have an effect on the prediction equations. These prediction equations should be tested more widely. Once built, these UAV based model had the capability of producing yield and quality variability maps. These spatial-temporal maps can be utilized for diagnosing crop problems and estimating yield and quality variability in alfalfa, especially due to drought, with due attention to stage of growth.

Relationship between dry matter yield (DMY) predicted by the UAV and observed DMY from 11.15 m^2 (*n*= 190).



Relationship between predicted dry matter yield (DMY) using LiDAR (adjusted) and observed DMY (*n*= 126).