Pasture Biomass Estimation Using RGB UAV Images and Deep Learning

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Main Body

Accurate estimation of pasture biomass is fundamental for precision grazing management, stocking rate optimization, and sustainable livestock production. Traditional field-based biomass measurements are labor-intensive, destructive, and difficult to perform frequently across large grazing systems. While satellite imagery provides regional coverage, its spatial resolution and susceptibility to cloud cover limit its ability to capture fine-scale variability within pasture paddocks. This study investigated the use of ultra-high-resolution RGB imagery acquired from an unmanned aerial vehicle (UAV) combined with deep learning for high-accuracy pasture biomass estimation.
Field experiments were conducted during the 2022 growing season at the Shenandoah Valley Agricultural Research and Extension Center (SVAREC), Virginia, USA. Twelve paddocks representing high-impact bale grazing, low-impact bale grazing, sacrifice, and rest paddocks were monitored during April, May, and June. Ground biomass samples were collected concurrently with UAV flights using a DJI Mavic 2 Pro. Orthomosaics and canopy height models (CHMs) were generated using photogrammetric processing. Images were divided into 1 × 1 m grids corresponding to field sampling quadrats. Structural variables derived from CHMs, RGB spectral statistics, and paddock type were extracted as predictor variables.
Artificial Neural Networks (ANN), Random Forest (RF), and Support Vector Regression (SVR) models were developed and optimized using grid-search techniques. Model performance was evaluated using the coefficient of determination (R^2), root mean square error (RMSE), and statistical agreement between predicted and observed biomass. Among the evaluated models, the ANN produced the highest prediction accuracy, achieving an R^2 of 0.94 with an RMSE of 62 g m^{-2}. Temporal analysis demonstrated clear changes in canopy height and RGB reflectance throughout the growing season. Rest paddocks exhibited greater canopy development and biomass accumulation, whereas sacrifice paddocks consistently showed lower vegetation height due to intensive grazing pressure. Integrating structural variables, spectral information, and paddock management categories substantially improved biomass prediction accuracy and enabled accurate mapping of spatial variability across diverse grazing systems.
These findings demonstrate that combining low-cost RGB UAV imagery, photogrammetric canopy height models, and deep learning provides an accurate, rapid, and non-destructive framework for pasture biomass estimation. The proposed methodology can support precision grazing management and future decision-support systems for sustainable livestock production.