Enhanced Grazing Management Assessment Using Drone-Based Lidar Measurements

Temu, V.W.[*]; Hession, W.C. [†1], Sforza, P. [†2] and Wang, H. [†2].
* Agricultural Research Station, Virginia State University; †1 Biological Systems Engineering, Virginia Polytechnic Institute & State University †2 Center for Geospatial Information Technology, Virginia Polytechnic Institute & State University

Key words: Biomass, Drone, Forage

Abstract

Globally, there is an urgent need of research-based technologies for small ruminant producers to benefit from rapidly growing market demands for ruminant meat and related food products from forage-based operations. However, effective forage-based animal production requires a rapid assessment, and monitoring of grazing management needs to adjust stocking rates and/or spatial animal distribution in a timely manner. Applicability of unmanned aerial vehicles (drones) for grazing management offers opportunities to rapidly estimate biomass build-ups, ground coverage, and monitor animal behaviour. The reliability of drone-based laser scanning (DLS) for monitoring warm-season grass responses to simulated grazing intensities was assessed at Virginia State University. Aerial DLS point-cloud data were collected from pure and mixed native warm-season grass stands at early- and mid-season post-harvest regrowth in early May and June, respectively, along with ground-based estimates of yield and ground cover. Animal behavioural responses to drone activity at different heights were also recorded. The aerial estimates from DLS point cloud characteristics were compared with matching ground-based measurements of forage biomass, sward heights, and ground cover. Discernible correlations between the point cloud-based estimates and actual measurements for forage biomass, ground cover and sward heights were observed. Goats showed no changes in activity due to drone flights at ≥15 m above ground but demonstrated curiosity to drone presence between 10 & 15 m. These preliminary results suggest reliable applicability of DLS for expedited assessment of plant and animal responses to grazing management.

Introduction

Precision agriculture technologies enable managers to quickly establish current plant growth problems, such as lodging for maize (Zhou et al. 2010), and take appropriate measures to improve or sustain productivity on specific areas. Likewise, effective management of forage-based animal production requires informed decisions on specific plant and animal responses to changes in environmental conditions that affect yield and quality. In grazing management, this includes the rapid assessment of plant growth responses to biomass removal, specific fertility management needs, and necessary changes to stocking rates or supplemental feeding. Other necessary components of ecological pasture management include concurrent monitoring of soil moisture and health, and greenhouse gas emissions. The advents of unmanned aerial vehicles (UAV), or drones, with various sensors, offer technological alternatives to conventional monitoring of vegetation dynamics (biomass build-up, phenology, ground coverage, weed challenges), as well as grazing preferences and behaviour (Lu et al. 2019). However, the suitability of recent laser scanning or Light Detection and Ranging (lidar) sensors as payloads on drones is uncertain due to the scarcity of research studies related to the efficacy of their use in agriculture.

Lidar uses pulsed laser reflected off remote surfaces to measure distances (or ranges) from the instrument, and generate precise, three-dimensional information about these surfaces. The lidar provides detailed mappings of land surfaces and the vegetation height, canopy structure, standing biomass, etc. (Howell et al. 2020). In managed forests, our research team has utilized a drone-based laser scanning (DLS) system for such vegetation measurements, successfully, to include creating high-resolution flood inundation maps and roughness at different flood stages due to vegetation (Resop et al. 2019). However, information on detailed measurements with lidar for the purposes of improving forage management is scarce. This study was, therefore, designed to (i) assess the reliability of DLS for estimating tall-grass responses to simulated grazing and (ii) monitor the response of small ruminants to drone activities on pasture. The study compared drone-based forage data to conventional on-the-ground sward-height and forage biomass measurements with respect to forage production and growth response to intensity of defoliation, as well as likely flight-height effects on animal behaviour.

Methods and Study Site

The study was conducted on 160 (7× 6 m) plots of native warm-season grasses separated by ≥3 m alleys at Virginia State University research farm in Chesterfield County, Virginia (37º 13" 43' N; 77 º 26" 22' W, 45 m above sea level). Each research plot was subdivided into four parallel harvest strips (1.2 m wide) that had received three-, two-, one-, or zero-cuts in a growing season over three consecutive years. In mid-April, the research area had the outermost plot-margins marked out on a google-map and flight-patterns for eight overlapping fly-overs were set. On May 1, and June 4, Aerial imagery and point-cloud data were collected using a DLS system that consists of two primary components: (1) the drone system (Pulse Aerospace Vapor 35) and (2) the lidar system (YellowScan Core System Mapper). The Vapor 35 drone is a helicopter-style UAV that can be mounted with remote sensing devices like lidar and has a maximum hover time of 45 min. The YellowScan Core System Mapper is an ultra-light lidar system that is integrated with the Vapor 35. The YellowScan lidar system contains embedded GNSS, IMU, and computer. Up to two discrete returns are recorded for each lidar pulse produced by YellowScan. At a flight elevation of 20 m, a DLS is point density of 455 points m^{-2} is reported (Resop et al. 2019). Matching actual sward-height measurements, ground cover estimates, and late-summer plot forage biomass records were also collected. Whole-field aerial-view photos were also taken over the research plots and adjacent grazing paddocks stocked with goats. To assess effects of the drone-activities on goat behavior, a series of still aerial-view photos of the goats on pasture were taken as the flight-height decreased from 20 m down to slightly below 10 m above ground. Animal responses to the drone activities were remotely monitored using a 3D Visual Reality head set that allowed for close views while physically away and to instantaneously signal for the pilot to take descriptive photos.

The flight row data were processed into LAS format (one designed for the interchange and archiving of lidar point cloud data) and analyzed for the plant parameter estimates and 3D visualization. Late-summer forage harvest was done using a plot harvester equipped with a weighing system for on-site fresh weight records. Fresh samples of the harvested material were also collected from each strip and weighed before and after oven-drying to constant weight at 65°C to determine moisture content at harvest and convert the plot weights into forage dry matter (DM). The resulting drone-based biomass estimates (kg DM ha^{-1}) and their matching actual measured forage yield from respective harvest strips were then organized into a dataset on a spreadsheet and statistically analyzed using the Random Forest (Breiman et al. 2018) and Multiple Regression to establish their predictive powers. From the point cloud data, classified color images were also developed showing ground elevation and grass details in field cross-section views of plots in a row and cut-strips within a plot.

Results

Lidar and Vegetation structure

The results of drone-based aerial view of the research plots (Figure 1) shows the ground elevation as gently sloping North-West (left-top) to South-East (bottom-right). The layered points cloud output separated below shows differences in sward heights across the field and distinctive plot alleys. From the same data, single-plot vegetation details (not included) showed discernible patterns of sward-heights for different harvest-strips and separating alleys. The classified colour images could also be presented separately with desired details of each attribute. Based on the drone-captured still photos at different heights over the adjacent grazing paddocks, goats were not disturbed by the drone activities when 15 m or higher above ground. Below 15 m the goats showed curiosity to the drone but still did not appear disturbed. With the drone flying just below 10 m above ground, however, few goats that were resting on pasture got up and became more attentive and ready to move.

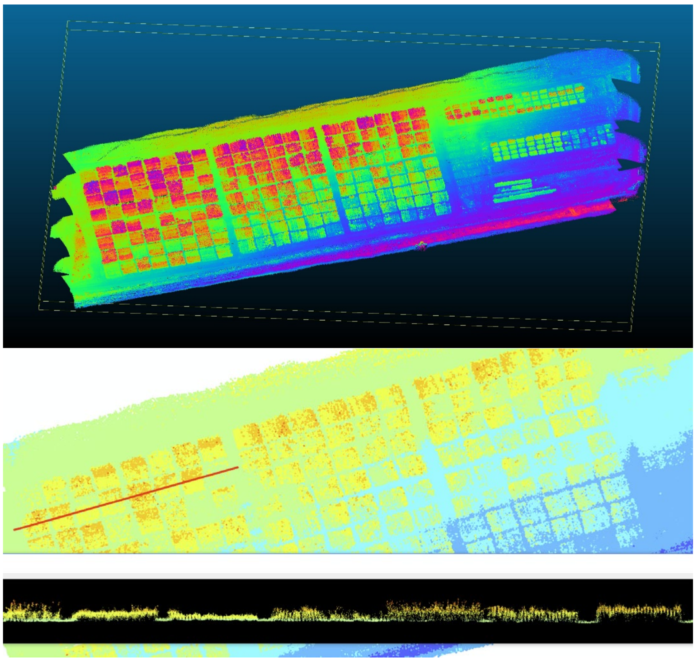

Figure 1: Classified colour images of 160 native warm-season grass plots in three rectangular clusters (L-R), from June-4 drone-based point-cloud data showing plot lay-out, vertical elevation (top plate; red for high- & blue for low-ground) and field cross-section vegetation details (bottom).

Forage Biomass Estimates

Statistical analyses comparing the measured forage biomass to their matching drone-based estimates (Figure 2) indicated stronger correlations when run through the Random Forest model than the multiple regression. For both models, the predicted forage biomass was closer to the actual measured value for the single-cut strips than their three-cut counterparts and in-between for the two-cut ones. For the three-cut strips, the Random Forest model tended to overestimate the actual forage biomass at higher harvest weights.

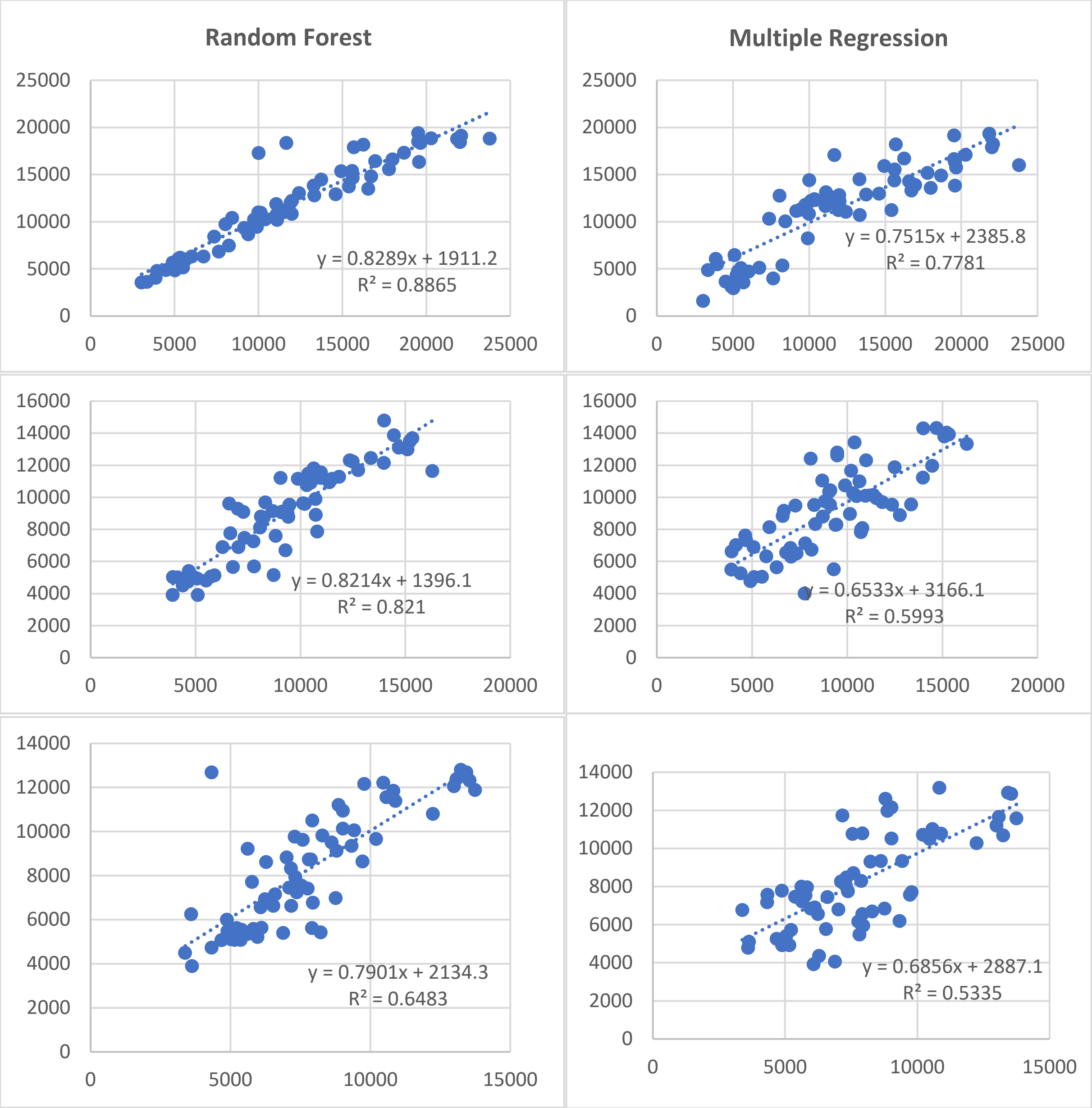

Figure 2: Late-summer forage biomass (kg DM ha^{-1}) of native warm-season grass strips that previously received one- (top), two- (middle) or three-cuts (bottom) a season, as harvested (x-axis) or drone point-cloud data predicted (y-axis) by Random Forest model (left) and Multiple Regression (right). Proportions of weed plants were greater in the three-, but none in the one-cut strips.

Discussion and Conclusions

Although not analysed, similar result patterns were assumed for the zero- as well as the one-cut strips. However, consistent with their taller swards, higher forage biomass values were also expected. The observed weaker correlation between the measured and predicted forage biomass for the three-cut strips may have resulted from inconsistencies in the proportions of weeds, shorter than the cutting height, that were not reflected in the point-cloud data. The time lapse from the drone-flights and actual harvest dates also allowed for inconsistent changes in harvestable weed biomass as some matured and lodged below the cutting height while others expanded to cover voids between the perennial grasses. Overall, these results still indicate a dependable suitability of DLS technologies for real-time monitoring of plant and animal responses to grazing management. The demonstrated ability to closely predict the forage biomass will also be helpful for timely adjustments to specific stocking densities and grazing duration or feed supplements.

Acknowledgements

This study was financially supported by the United States Department of Agriculture – Evans Allen program and the Institute for Critical Technology and Applied Sciences at Virginia Tech while the management of the Agricultural Research Station at Virginia State University provided land and material support for the research. Our UAV pilots were Laura Lehmann and Brittany Grutter with students Lauren Wind and Charles Aquilina (Virginia Tech) and Areal Coleman (Virginia State University) helping with data collection and processing.

References

Breiman, L., Cutler, A., Liaw, A., Wiene, M. (2018). Breiman and Cutler's Random Forests for Classification and Regression, R package version 4.6-14, http://cran.r-project.org/web/packages/randomForest.

Howell R.G., Jensen R.R., Petersen S.L., Larsen R.T. (2020). Measuring height characteristics of sagebrush (Artemisiasp.) using imagery derived from small unmanned aerial systems (sUAS). *Drones* 4, 6: 1-15.

Lu, N., Zhou, J., Han, Z.X., Li, D., Cao, Q., Yao, X., Tian, Y.C., Zhu, Y., Cao, W.X., Cheng, T. (2019). Improved estimation of aboveground biomass in wheat from RGB imagery and point cloud data acquired with allow-cost unmanned aerial vehicle system. *Plant Methods* 15: 1-16. DOI: 10.1186/s13007-019-0402-3

Resop, J.P., Lehmann, L., Hession, W.C. (2019). Drone laser scanning for modeling riverscape topography and vegetation: Comparison with traditional aerial lidar. *Drones* 3, 35: 1-15. doi:10.3390/drones3020035

Zhou, L., Gu, X., Cheng, S., Yang, G., Shu, M., Sun, Q. (2020) Analysis of plant height changes of lodged maize using UAV-LiDAR Data. *Agric.*10, 146: 1-14.