



## **Integrating drone technology into rangeland management: plants, livestock, and wildlife**

Perotto-Baldivieso, HL<sup>1</sup>; Perez, KF<sup>1</sup>; Goodwin, DJ<sup>1</sup>; Avila-Sanchez, JS<sup>2,3</sup>; Massey, L<sup>4</sup>; Gleason, SR<sup>1</sup>; Tanner, EP<sup>4</sup>; Ortega-Santos, JA

<sup>1</sup> Department of Rangeland, Wildlife, and Fisheries Management, Texas A&M University, College Station, Texas, U.S.A.; <sup>2</sup> Borderland Research Institute, Sul Ross State University, Alpine, Texas, U.S.A.; <sup>3</sup> Texas A&M AgriLife Extension Service; <sup>4</sup> Texas Parks and Wildlife Department, Cotulla, Texas, U.S.A.; <sup>5</sup> Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, Texas, U.S.A.

**Key words:** 3D models; adaptative grazing; spatial heterogeneity; multi use rangelands.

### **Abstract**

The use of drones in studies of rangeland ecology and management has increased significantly in the last 10-15 years. Drone imagery has been used to measure woody cover, forage biomass, spatiotemporal changes in vegetation cover, rangeland condition, and to monitor wildlife habitat in rangeland systems. The development of 3D models derived from drone imagery has facilitated new opportunities to quantify the spatial structure of land cover. For example, fine-scale structural changes influenced by grazing can be quantified using drones and subsequently translated to potential impacts on wildlife habitat. Technological developments like terrestrial LiDAR systems and higher resolution imagery allows for the improvement on the understanding of very-fine scale ecological processes in these dynamic systems. These terrestrial sensors can add valuable information to the current airborne data collection systems.

However, there is still a need to evaluate the relationship between different drone-based sensors and how the information collected and analysed can be integrated into traditional rangeland metrics. More importantly, we seek to better understand how to translate these analyses and metrics into practical management information that is critical for these socio-ecological systems. Here we demonstrate (1) the use of multispectral imagery to quantify the configuration of brush cover in semiarid landscapes, (2) the use of 3D drone data to assess the fine-scale impact of grazing on upland game birds (*Galliformes*), and (3) the integration of LiDAR, multispectral, and natural color cameras to generate data to inform livestock and wildlife habitat management. Finally, we provide insights on how drone technology could be potentially used in the future to assist in rangeland management to forecast forage growth and multi-species use for wildlife objectives.

## Introduction

The use of remote sensing in rangelands has been critical to understand landscape level processes (Allred et al. 2021, Rhodes et al. 2022.) In the last 50 years, a variety of satellite platforms have been used to estimate forage production (Rhodes et al. 2022, Bestelmeyer et al. 2024) and vegetation spatial configuration to integrate this information with livestock production and wildlife habitat management. In the last 15 years, the development of drone technology has emerged as a new opportunity to collect data at very-high spatial and temporal resolutions and provides a bridge between satellite imagery and field-based data collection (Rango et al. 2006, Jackson et al. 2020, Perez-Luque et al. 2022, Avila-Sanchez et al. 2024). Derived products in 2D and 3D formats from drone data acquisitions have been used to quantify woody vegetation height (Page et al. 2022), estimate forage biomass (DiMaggio et al. 2020, Perotto-Baldivieso et al. 2021), determine spatiotemporal changes in vegetation cover (Perez-Luque 2022), determine rangeland condition (Amputu et al. 2023) and monitor wildlife habitat in rangelands (Friesenhahn et al. 2023, Zabel et al. 2023). Drones offer flexibility in the variety of sensors that can be utilized to collect data. Some of the most popular sensors include natural color (with pixel resolutions from 20 to 129 megapixels), multispectral, hyperspectral, thermal-infrared and LiDAR. However, there is still a need to evaluate the relationship between the different drone-based sensors and how this information collected and analysed can be integrated into rangeland metrics. More importantly, we seek to better understand how to translate these analyses and metrics into practical management information using consumer grade drones. We demonstrate (1) the use of multispectral imagery to quantify the configuration of brush cover in semiarid landscapes, (2) the use of 3D drone sensors acquired data to assess the fine-scale impact of grazing on upland game birds (*Galliformes*), and (3) the integration of LiDAR, multispectral, and RGB cameras to generate information for livestock and wildlife habitat management. Finally, we will provide future directions on how drone technology could be potentially used to assist in rangeland management to forecast forage growth and multi-species use for wildlife objectives.

## Multispectral imagery for estimating woody cover configuration

The increasing spatial and spectral resolution of multispectral cameras to acquire rangeland imagery generates new opportunities to assess woody vegetation cover, composition, and spatial configuration, particularly in semiarid and arid landscapes. For instance, the Tamaulipan thornscrub (hereafter “thornscrub”) ecosystem is characterized by dense, diverse shrub, arid-adapted shrub communities and provides critical habitat for endemic and endangered species (Jahrsdoerfer and Leslie 1988, Creacy 2012, Mohsin et al. 2021). This ecosystem, located within northeastern Mexico and South Texas, USA, has been reduced to <2% of its historic distribution due to novel pressures related to urbanization, woody plant removal for livestock forage production, and land use change (Jurado et al. 1998, Ricketts et al. 1999, Lombardi et al. 2020). Little information exists on its current distribution, but it is estimated that there is >75% native mixed brush cover in these communities (Flores 2019). Our objective was to evaluate the feasibility of identifying brush species composition within this complex community using very-high resolution multispectral imagery. We used a MicaSense Altum Multispectral camera that collects imagery in six spectral bands: blue, (443 – 507 nm), green (533 – 587 nm), red (654 – 682 nm), red edge (705 – 729 nm), near-infrared (785 – 899 nm), and long wavelength infrared (8000-14000 nm; MicaSense 2019). Images were collected in five plots (0.4 ha per plot) in Webb County, Texas, USA. Each flight was conducted at an altitude of 21 m aboveground level with an 80% image overlap in September 2022. Once images were acquired, they were processed in Pix4D mapper (Pix4D Inc., San Francisco, CA, USA) to create orthoimagery, a digital terrain model and a digital surface model. We then used the orthoimagery to classify vegetation cover. We subtracted the digital terrain model from the digital surface model to estimate a canopy height model to remove the herbaceous layer and focused on the shrub components. We conducted an accuracy assessment (i.e. confusion matrix) with 643 points collected within the plots. Our image

classifications yielded overall accuracies of 78%. We were able to correctly classify 19 out of the 24 species present in our study area: guajillo (*Acacia berlandieri*), blackbrush (*Acacia rigidula*), shrubby blue sage (*Salvia ballotiflora*), cenizo (*Leucophyllum frutescens*), chomonque (*Nahuatlea hypoleuca*), coyotillo (*Karwinskia humboltiana*), desert yaupon (*Schaefferia cuneifolia*), lime prickly ash (*Zanthoxylum fagara*), honey mesquite (*Neltuma glandulosa*), huisache (*Acacia farnesiana*), Texas persimmon (*Diospyros texana*), prickly pear (*Opuntia engelmannii*), Spanish dagger (*Yucca treculeana*), Texas kidneywood (*Eysenhardtia texana*), whitebrush (*Aloysia gratissima*), oreja de raton (*Bernardia myricifolia*), la coma (*Sideroxylon celastrinum*), allthorn (*Koeberlinia spinosa*), and granjeno (*Celtis pallida*). These techniques have proved promising towards obtaining scalable estimates of woody plant composition and configuration within this imperilled ecosystem characterized by high woody plant species richness and complexity.

### **Fine-scale assessment of herbaceous cover during cattle (*Bos taurus*) grazing**

The development of 3D models derived from drone imagery has opened new opportunities to integrate 3D model classifications to evaluate the spatial heterogeneity of vegetation cover in rangelands (Avila-Sanchez et al. 2024). To illustrate this concept, we conducted a study in a pasture grazed by cattle with adaptive management (Derner et al. 2022, Avila-Sanchez et al. 2024) in Duval County, Texas, USA. The principle behind adaptive management is to use grazing as a tool to change herbaceous vertical structure (stubble height) to create or enhance wildlife habitat, in this case, for northern bobwhite (*Colinus virginianus*). Once average herbaceous stubble height of 30 cm was obtained, cattle were moved to a different pasture. We flew seven sites (27 ha each) at an altitude of 50 m above ground level (DiMaggio et al. 2020) with a 70° camera angle, 80% overlap, and a 20 megapixel natural color camera. We acquired natural color imagery that was processed in Pix4D (Pix4D Inc., San Francisco, CA, USA) to generate an orthoimage, a digital surface model, and a digital terrain model. We subtracted the digital surface model from the digital terrain model to obtain a canopy height model. We classified the canopy height model pixel values into five different height classes (Avila-Sanchez et al. 2024): bare ground (0 to < 5 cm), low herbaceous vegetation (5 to < 30 cm), grazing target height herbaceous vegetation (30 to < 40 cm), tall herbaceous vegetation (40 to < 120 cm), and brush/shrubs (> 120 cm; Fig. 1). The classified raster image was used to assess the amount and spatial configuration of the different vegetation classes using landscape metrics at the class level: percent class cover, patch density (PD; patches/ha), and mean patch area (MPA; m<sup>2</sup>) (Fragstats 4.2; McGarigal et al. 2023). We found that this grazing system provided 51.9% ± 5.80% low herbaceous vegetation cover and 9.55 ± 6.15% grazing target height herbaceous vegetation cover within managed pastures. The configuration of this cover resulted in a large number of small patches in the low herbaceous vegetation (PD=49,222 patches/ha [SE= 6,821 patches/ha]) and MPA= 12.14 m<sup>2</sup> [SE=2.08 m<sup>2</sup>] and the grazing target height herbaceous vegetation (PD=111,036 patches/ha [SE= 28,525 patches/ha]) and MPA= 1.14 m<sup>2</sup> [SE=0.14 m<sup>2</sup>]) covers. Moreover, the spatial configuration of stubble height in these grazed pastures were within the required vegetation cover configuration requirements suggested for northern bobwhite habitat (Hernández and Guthery 2012).

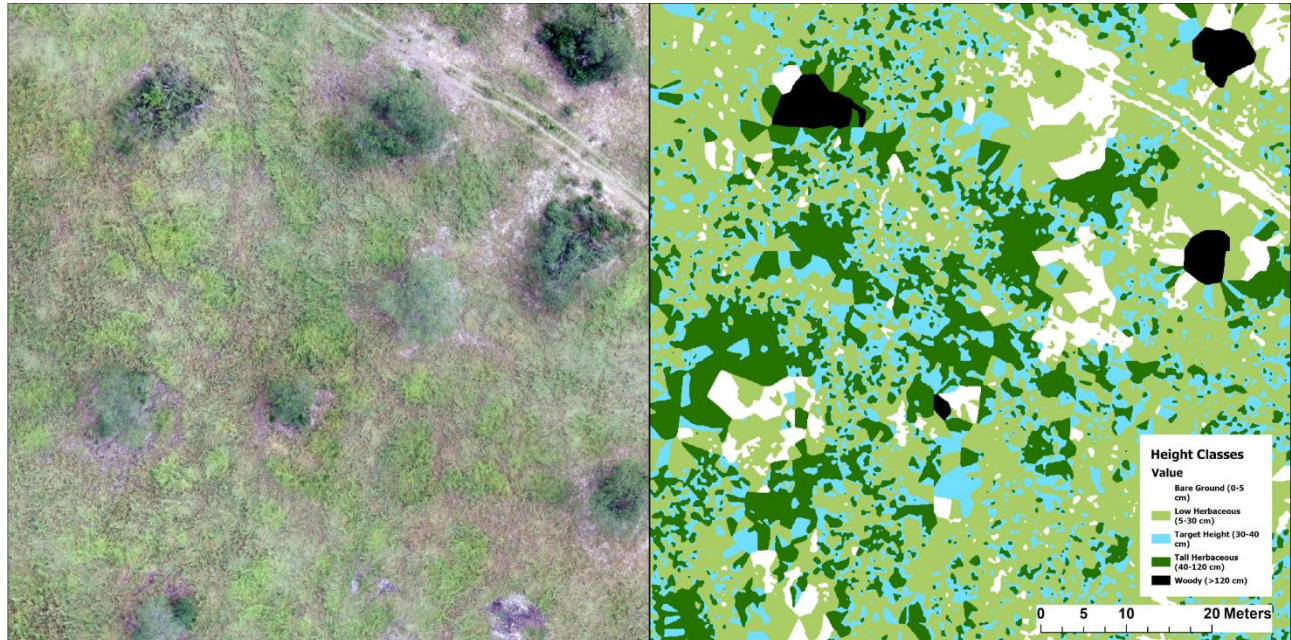


Figure 1: Example of classified vegetation height maps from drone-based imagery. white represents bare ground (<5cm), light green represents low herbaceous (5-30cm), cyan represents target grazing height (30-40cm), dark green represents tall herbaceous vegetation (10-120cm), and black represents woody vegetation (>120cm).

### **Integrating LiDAR, multispectral, and natural color data in rangelands to derive rangeland metrics**

While consumer-drone data can provide substantial information towards managing rangelands, there is still a need to evaluate the relationship between the different drone-based sensors and how the information collected and analysed can be integrated into rangeland metrics. More importantly, we seek to understand how we can translate these analyses and metrics for outreach and management purposes. Therefore, our goal is to develop methodologies and approaches that can identify proxies that can be used by ranchers and managers to assess rangeland health and condition at the pasture scale for livestock and wildlife operations. We plan to achieve this objective by collecting data in a 1200 ha research facility in South Texas, USA. Data collection is being conducted during the growing season (March-April) and at the beginning of the dormant season (September-October). We have selected a variety of land cover types (e.g. open grass, interspersed savannah, and closed canopy brush) to collect vegetation cover information. Within these land cover types, we are marking 80-100 locations using Planet imagery (daily 3-m resolution satellite imagery) based on current land management practices. We are acquiring drone-based data within two weeks of field data collection: natural color, multispectral, hyperspectral, LiDAR, and thermal data. We will select 5-10 locations and collect vegetation data using line transects similar to DiMaggio et al. (2020). Once the information is collected in the field, we will complement it with a terrestrial mobile station to collect 3D vegetation structure. Data collected with different sensors and field data will be analyzed to evaluate the relationship between data collected in the field and sensor data following similar approaches used by DiMaggio et al. (2020), Page et al. (2023), and Massey (2023). With these data, we will build a model that links multiple sensor information to natural color data to significantly improve our ability to derive information from less expensive drones with more efficient approaches. This will increase the opportunity to adopt natural color technology by ranchers to assess a variety of metrics in rangelands.

## Conclusions

The case studies highlighted in this manuscript provide a good example of the opportunities that drone technology can provide for management of multiple species in rangelands. We used technology to evaluate the use of multispectral data to assess woody cover composition in rangelands and the assessment of herbaceous vegetation cover spatial heterogeneity managed by grazing to provide a potential proxy for vegetation composition complexity. Finally, we are integrating information from multiple drone sensors to develop proxies into a meaningful and user-friendly landowner tool and resource that will be key to maintaining producer efficiency and stewardship without compromising rangeland integrity.

## Acknowledgements

Support for this manuscript was provided by Hildebrand Foundation, Ken Leonard Fund for Livestock Interactions Research, Harvey Weil Foundation, Comision Nacional de Ciencia y Tecnologia (CONACYT), Houston Safari Club, South Texas Quail Coalition Chapter, Hill Country Quail Coalition, NRCS agreement NR183A750015C017, R. Stacy from Houston, TX, Texas A&M Agrilife. Additional support was provided by the Meadows Endowed Professorship to EP Tanner and by the Joan Negley Kelleher Endowed Professorship in Ranch Management to HL Perotto-Baldivieso.

## References

- Allred BW, Bestelmeyer BT, Boyd CS, Brown C, Davies KW, Duniway MC, Ellsworth LM, Erickson TA, Fuhlendorf SD, Griffiths TV, Jansen V, Jones MO, Karl J, Knight A, Maestas JD, Maynard JJ, McCord SE, Naugle DE, Starns HD, . . . Uden DR (2021). Improving Landsat predictions of rangeland fractional cover with multitask learning and uncertainty. *Methods in Ecology and Evolution* 12: 841–849.
- Amputu V, Knox N, Braun A, Heshmati S, Retzlaff R, Roder A, Tielborger K (2023) Unmanned aerial systems accurately map rangeland condition indicators in a dryland savannah. *Ecological Informatics* 75:102007
- Avila-Sanchez JS, Perotto-Baldivieso HL, Massey LD, Ortega-S, JA, Brennan LA, Hernández F (2024). Fine spatial scale assessment of structure and configuration of vegetation cover for northern bobwhites in grazed pastures. *Ecological Processes* 13, 64.
- Bestelmeyer BT, McCord SE, Browning DM, Burkett LM, Elias E, Estell RE, Herrick JE, James D, Spiegel S, Utsumi, SA, Webb NP, Williamson J (2024). Fulfilling the promise of digital tools to build rangeland resilience. *Frontiers in Ecology and the Environment* 22:e2736.
- Creacy G (2012) Scaled quail. The Texas Breeding Bird Atlas. <https://txtbba.tamu.edu/species-accounts/scaled-quail/>. Accessed 8 March 2022.
- Derner JD, Budd B, Grissom G, Kachergis EJ, Augustine DJ, Wilmer H, Scasta JD, Ritten JP (2022) Adaptive grazing management in semiarid rangelands: an outcome-driven focus. *Rangelands* 44:111–118.
- DiMaggio AM, Perotto-Baldivieso HL, Ortega-S JA, Walther C, Labrador-Rodriguez KN, Page MT, Martinez JL, Rideout-Hanzak S, Hedquist BC, Wester DB (2020) A pilot study to estimate forage mass from unmanned aerial vehicles in a semi-arid rangeland. *Remote Sensing* 12:2431.
- Flores RI (2019) Comparison of eight remnant Tamaulipan Biotic Province plant communities in the Lower Rio Grande Valley using multivariate analysis. Theses and Dissertations. 470. <https://scholarworks.utrgv.edu/etd/47>
- Friesenhahn BA, Massey LD, DeYoung RW, Cherry MJ, Fischer JW, Snow NP, VerCauteren KC, Perotto-Baldivieso HL (2023) Using drones to detect and quantify wild pig damage and yield loss in corn fields throughout plant growth stages. *Wildlife Society Bulletin* 47:e1437
- Jackson M, Portillo-Quintero C, Cox R, Ritchie G, Johnson M, Humagain K, Subedi MR (2020) Season, Classifier, and Spatial Resolution Impact Honey Mesquite and Yellow Bluestem Detection using an Unmanned Aerial System. *Rangeland Ecology & Management* 73, 658–672.
- Jahrsdoerfer SE, Leslie Jr DM (1988) Tamaulipan brushland of the Lower Rio Grande Valley of south Texas: description, human impacts, and management options. US Fish Wildlife Services, Biological report 88.
- Jurado E, Flores J, Navar J, Jimenez J (1998) Seedling establishment under native Tamaulipan thornscrub and *Leucaena leucocephala* plantation. *Forest Ecology and Management* 105:151–157.

- Hernández F, Guthery FS (2012) ‘Beef, brush, and bobwhites: quail management in cattle country’, 2nd ed. (Texas A&M University Press: College Station).
- Lombardi JV, Tewes ME, Perotto-Baldivieso HL et al. (2020) Spatial structure of woody cover affects habitat use patterns of ocelots in Texas. *Mammal Research* 65:555–563.
- McGarigal K, Cushman SA, Ene E (2023) FRAGSTATS v4: spatial pattern analysis program for categorical maps. <https://www.fragstats.org>
- MicaSense (2019) Multispectral faqs – micasense knowledge base. <https://support.micasense.com/hc/en-us/articles/229948948-Multispectral-FAQs>. Accessed 13 January 2022.
- Mohsin F, Arias M, Albrecht C, Wahl K, Fierro-Cabo A, Christoffersen B (2021) Species-specific responses to restoration interventions in a Tamaulipan thornforest. *Forest Ecology and Management* 491:0378–1127.
- Page MT, Perotto-Baldivieso HL, Ortega-S JA, Tanner EP, Angerer JP, Combs RC, Camacho AM, Ramirez M, Cavazos V, Carroll H, Baca K, Daniels D, Kimmert T (2022) Evaluating mesquite distribution using unpiloted aerial vehicles and satellite imagery. *Rangeland Ecology and Management* 83:91–101.
- Pérez-Luque AJ, Ramos-Font M E, Tognetti Barbieri MJ, Tarragona Pérez C, Calvo Renta G, Robles Cruz AB (2022) Vegetation Cover Estimation in Semi-Arid Shrublands after Prescribed Burning: Field-Ground and Drone Image Comparison. *Drones* 6, 370.
- Perotto-Baldivieso HL, Page MT, DiMaggio AM, Martinez JL, Ortega-S A (2021) Estimating forage mass from unmanned aircraft systems in rangelands. In ‘Fundamentals of capturing and processing drone imagery and data’ (eds AE Frazier KKSingh) pp. 213–228 (Taylor and Francis: Boca Raton, FL, USA).
- Rango A, Laliberte A, Steele C, Herrick JE, Bestelmeyer B, Schmutz T, Roanhorse A, Jenkins V (2006) Using unmanned aerial vehicles for rangelands: current applications and future potentials. *Environmental Practice* 8, 159–168.
- Rhodes EC, Perotto-Baldivieso HL, Reeves MC, Gonzalez LA (2022). Perspectives on the Special Issue for Applications of Remote Sensing for Livestock and Grazingland Management. *Remote Sensing* 14:1882.
- Ricketts TH, Dinerstein E, Olson DM, Eichbaum W, Loucks CJ, Della Sala DA, Hedao P, Kavanagh K, Hurley P, Abell R, et al. (1999) ‘Terrestrial Ecoregions of North America: A Conservation Assessment’ (Island Press: Washington, DC)
- Zabel F, Findlay MA, White PJ (2023) Assessment of the accuracy of counting large ungulate species (red deer *Cervus elaphus*) with UAV-mounted thermal infrared cameras during night flights. *Wildlife Biology* 2023:e01071