"What Are Those?" Pixels: Evaluating Drone Altitude Effects on Vegetation and Bare Ground Mapping Variables in Xeric Landscapes

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Motivation

This project aims to determine the optimal drone height for detecting patch-level variables accurately, balancing resolution with identification efficiency.

Introduction

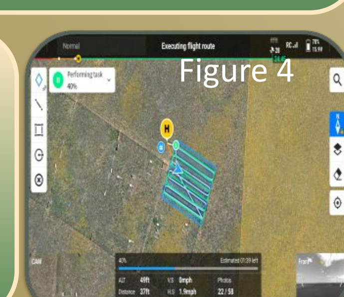
Xeric (low-water) grasslands are among the most vulnerable ecosystems under intensifying drought conditions. Over 80% of U.S. grasslands have been lost, including 99% of tallgrass prairies[1]. In response, a drought-manipulated site was established at the Tracy Collins Open Space in South Boulder, Colorado. This unique mixed-grass site— 50/50 balance of grasses and forbs, with both tall and short vegetation—offers an ideal setting to study resilience in dryland ecosystems.

- To detect ecological shifts, researchers are shifting from biomass estimates to spatial indicators such as patch size and distribution of vegetation and bare soil[2][3]. Accurately identifying these indicators from drone imagery requires segmentation models and spatial analysis.
- Due to trade-offs between flight time, image resolution, and processing efficiency, **this project asks which UAV flight altitude is best to identify pixel-level classes** to support early detection of rangeland change[4].

Methods

Field Data

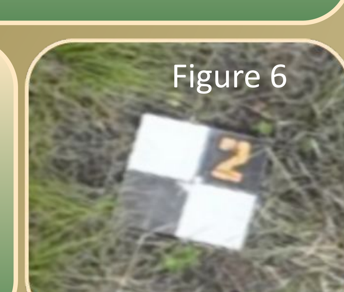
- 44 transects (imaginary lines, 0-10cm wide) extended N, E, S, W from 21 ground control points (GCPs).
- Cover types recorded: **Live Vegetation(LV), Dead Litter(DL), Bare Soil(BS), Rock(RK).**



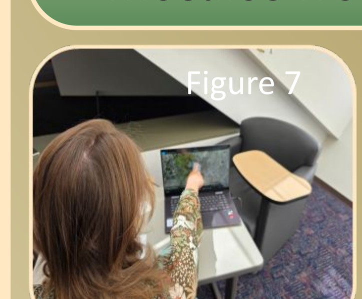
- DJI Mavic 3 Multispectral flown at 12m, 15m, 20m, 30m, 40m, 50m in a snake pattern on July 8th, 2025.
- Flight plans created in DJI Pilot App, not open source.

Data Analysis

- Orthomosaics stitched using Open Drone Map and supercomputer (HPC).
- RGB Bands exported as JPEGs for classification.



- Field cover estimated by dominant patch type in each transect (canopy or ground patch cover).
- Investigator manually located matching transects in mosaics from low to high altitude to conduct test.



- Five participants classified each transect (264 total) using manually located transects at 800X zoom.
- Pixel accuracy by height (0.3–1.2 cm/pixel) calculated in Excel and analyzed in R Studio.

Results

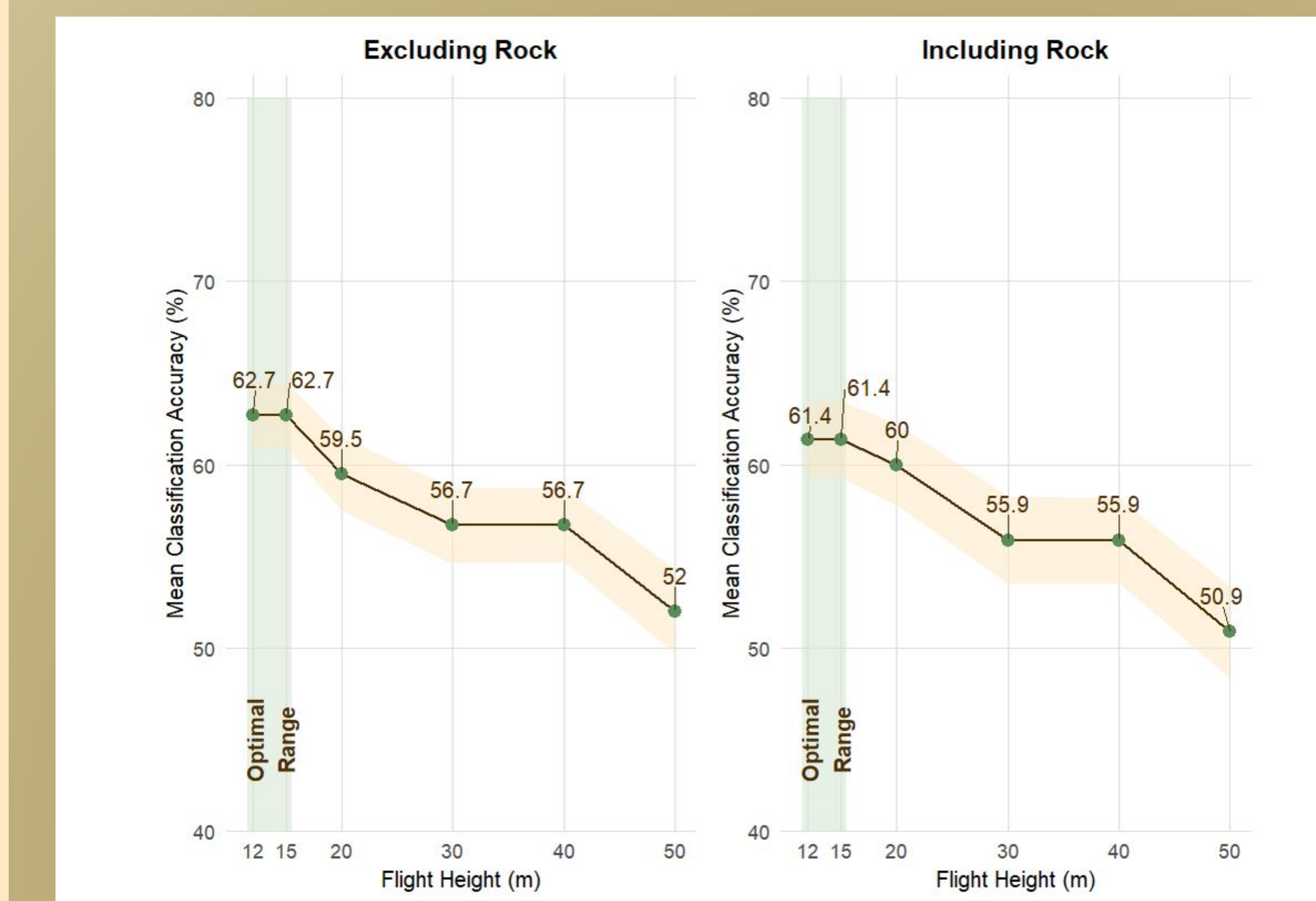
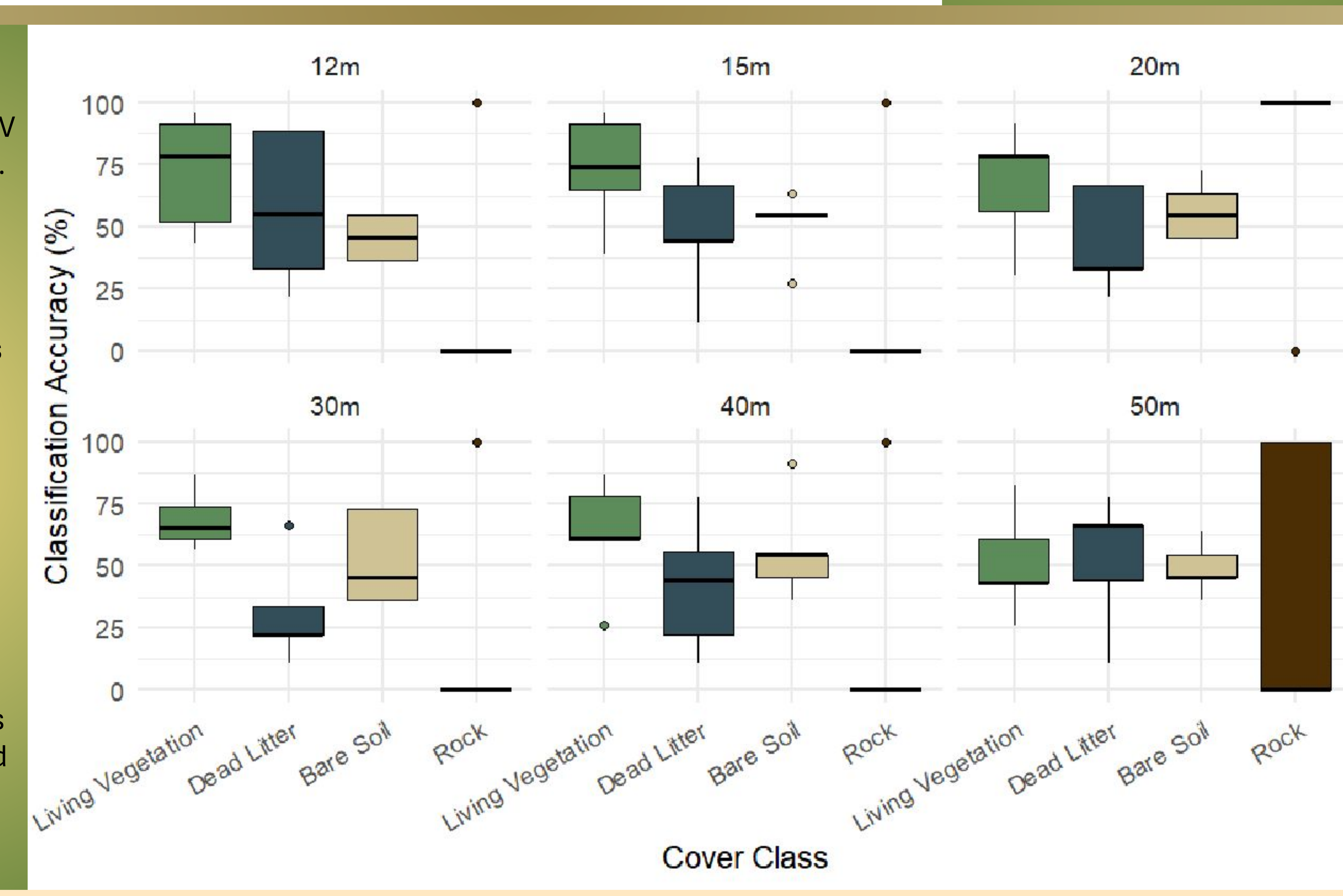


Figure 1 (left): Mean classification accuracy across UAV flight heights (12–50 m), comparing results with and without rock as a cover class. Each point represents the average accuracy across five observers per height. LOESS smoothed curves show consistent decline in accuracy with increasing altitude, with **highest performance observed at lower flight heights (12–15 m)**. Excluding rock slightly increases mean accuracy and narrows confidence intervals (shaded bands), suggesting rock's sparse presence (1 of 44 transects) inflated variability.

Figure 2 (right): Classification accuracy by cover class across UAV flight heights (12–50 m). Boxplots illustrate how classification performance varies by cover type and altitude. **Living vegetation shows the highest accuracy overall, particularly at lower altitudes (12–15 m). Dead litter exhibits the greatest variability across heights.** Bare soil maintains relatively consistent accuracy. Rock, recorded in only one transect, introduces variability but is included for completeness.



Conclusion

- This study contributes to methodology of UAV monitoring by identifying **optimal flight heights (12–15 m)** and highlights **variability across observers**. While not the original focus, participant differences emerged as an important factor to consider for future image training (see Figures S1–S5 in the QR code supplement).
- Future methods should incorporate Near-Infrared (NIR) which may better detect subtle differences in vegetation condition and structure, especially under shadow, litter, or dense canopy[5]. This could improve classification accuracy for dead litter, which showed high variability in this study.
- Future work should explore the minimum resolution needed to detect fine-scale ecological changes.

Discussion

Key Findings

- Living vegetation most accurately identified at 12-15m.
- Most variable class was dead litter.
- Bare soil was identified most consistently.

Unexpected Results

- Dead litter showed high variability even at lower altitudes (12–20m), indicating potential challenges in identifying surface-level features overlapped by vegetation or confused with similarly colored materials like bare soil.
- Classification accuracy dropped sharply from 15m to 20m for living vegetation and dead litter.

Limitations

- Rock was present in only 1 out of 44 transects, potentially causing high variability in accuracy; additional analysis excluding rock to better interpret results.
- Manual pixel selection and cropping were varied, leading to different image interpretation and inconsistencies.
- Ground truth labeling is challenging in ambiguous areas where dead litter and bare soil overlapped, despite using dominant cover estimation.

Context

- Understanding how pixel resolution relates to vegetation patch size and distribution is essential for detecting early ecological shifts.

References/Acknowledgemen

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