# Applying novel remote sensing techniques in a rainfall manipulation experiment – progress and updates from RainManSR

Charles Devine[1], Dong Yan[1], Jeffrey Gillan[1], Fangyue Zhang[1,2], Nathan Pierce[1,2], William K. Smith[1], Joel Biederman[2]

1. School of Natural Resources and the Environment, University of Arizona, Tucson, AZ
2. USDA – ARS Southwest Watershed Research Center, Tucson, AZ

Support for this work was provided by the United States Department of Agriculture (USDA; cooperative agreement number 58-2022-8-010).

## 1. Introduction

- **Satellite observations of dryland ecosystem dynamics are limited (Smith et al., *RSE* 2019).**
  - Coarse spatiotemporal resolution.
  - Retrievals are poorly constrained.
  - Upscaling high-resolution observations to the satellite level is needed to improve monitoring of dryland vegetation/climate interactions over large spatial and temporal domains.
- We tested two novel close-range remote sensing techniques for observing dynamic responses of semiarid grassland vegetation phenology, biomass, productivity, and structural characteristics to temporally repackaged precipitation.

## 2. Research objectives

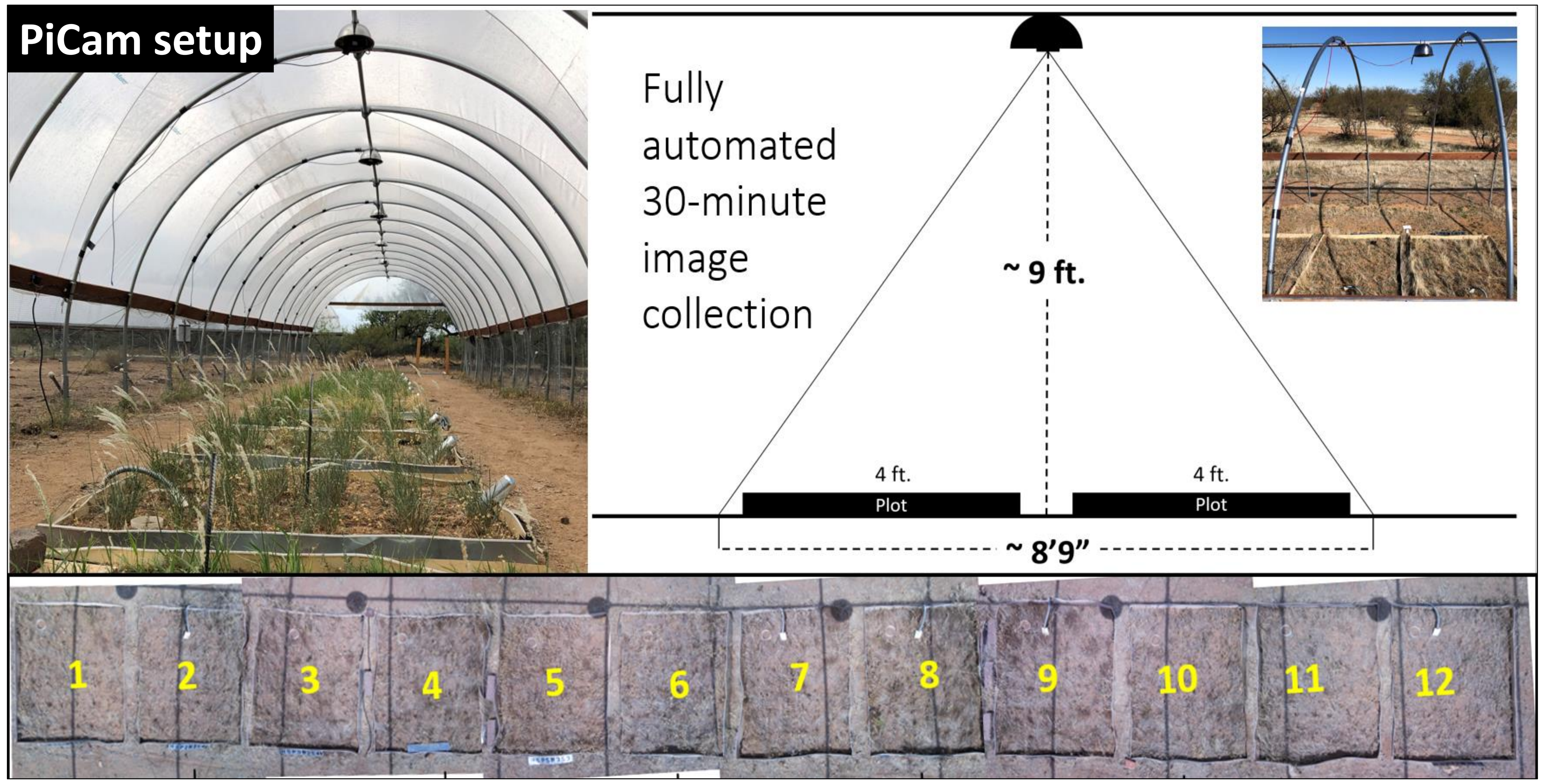
1. **Demonstrate utility of these techniques for observing vegetation greenness, productivity, and biomass across different irrigation treatments.**
2. **Explore how high spatiotemporal resolution observations improve understanding of vegetation/climate dynamics in semiarid grassland ecosystems.**

## 3. Techniques

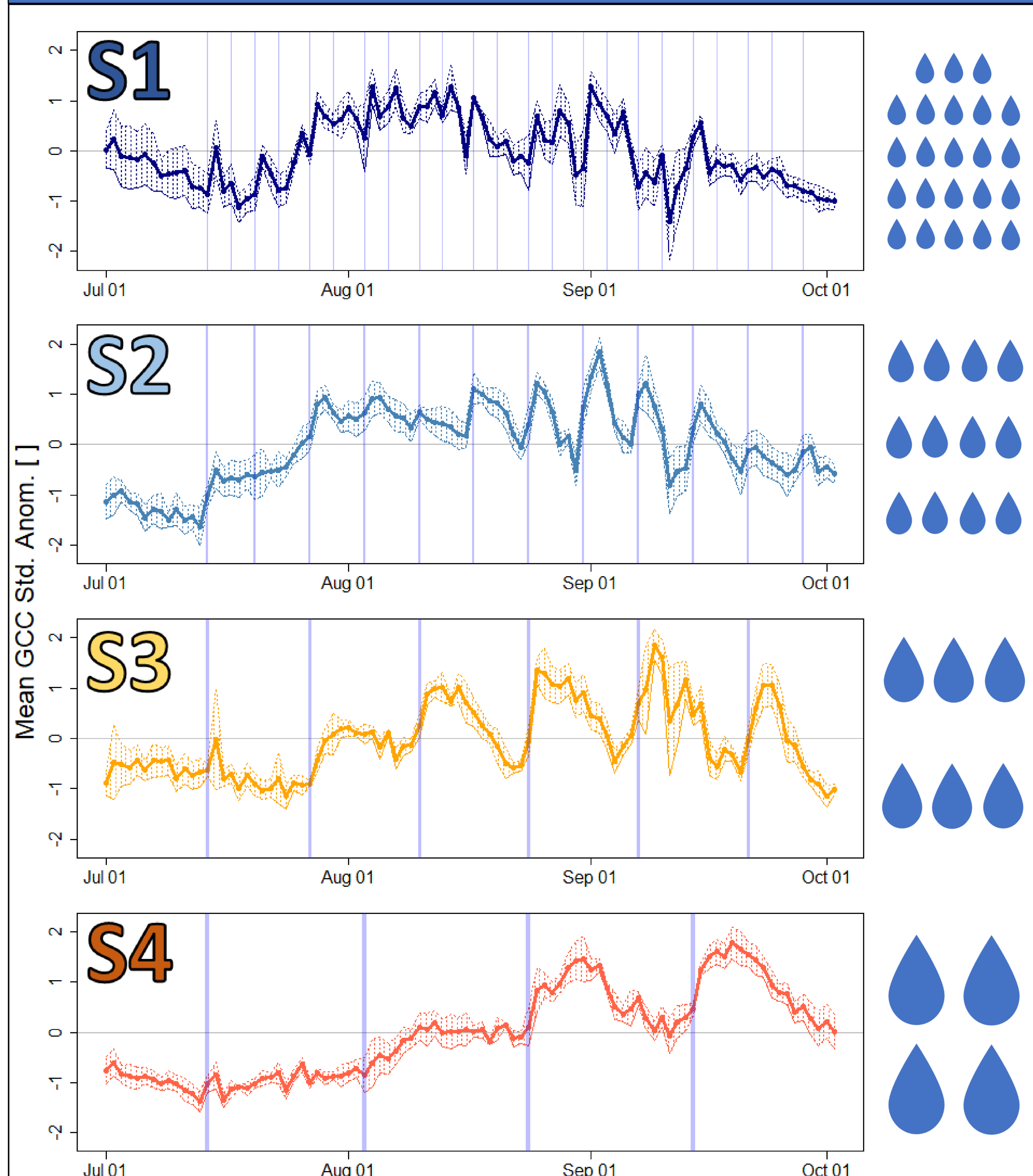
1. **Raspberry Pi phenology cameras (PiCams) were used to collect high temporal frequency RGB images (30 PiCams covering 60 plots).**
   - 30-minute capture from 8:00 AM through 5:00 PM.
   - Vegetation greenness was tracked by deriving daily green chromatic coordinate (GCC):

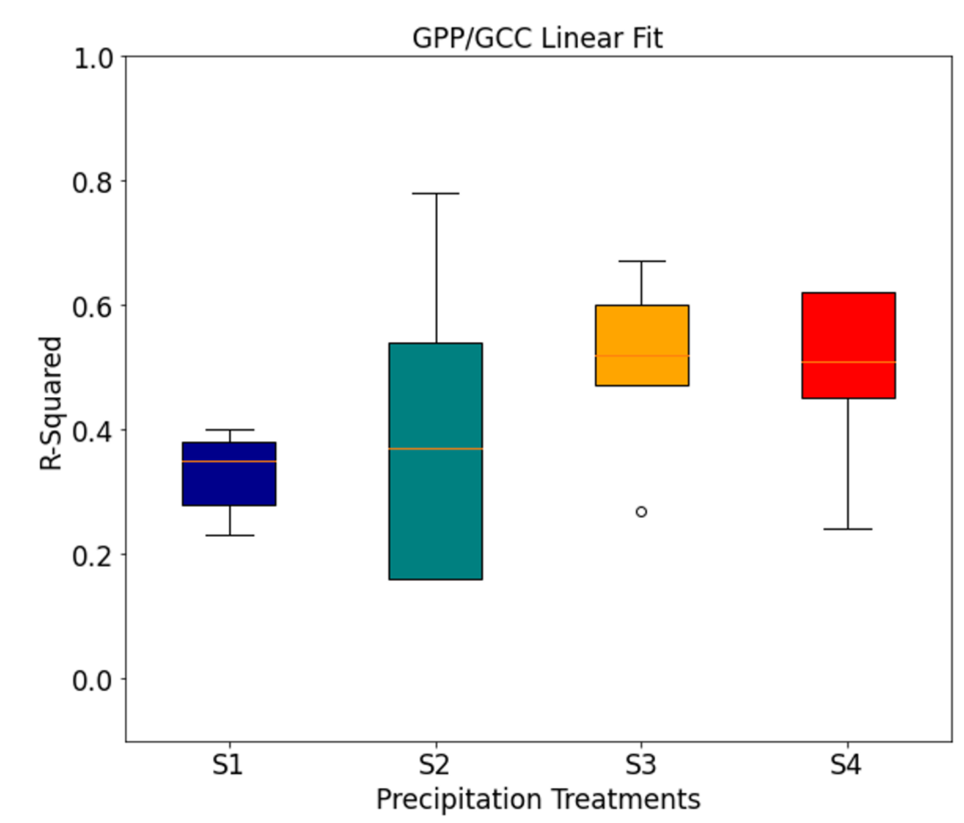
$$GCC = \frac{Green_{DN}}{Red_{DN} + GreenDN + BlueDN}$$

2. **Structure-from-motion (SfM) photogrammetry.**
   - Millimeter-scale 3D vegetation models derived from overlapping images collected with a high resolution DSLR camera mounted on a 2-meter stand.
   - Models were generated using Agisoft Metashape photogrammetric image processing software version 1.7.3.
   - Vegetation volume and height derived from 3D models using R programming language.



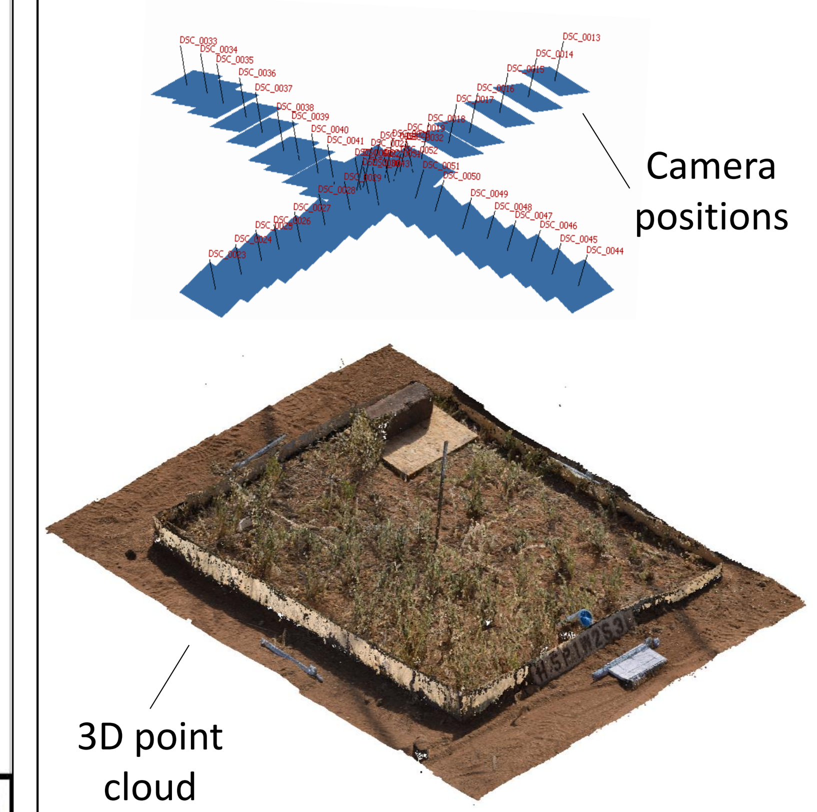

## 4. Results -- PiCams



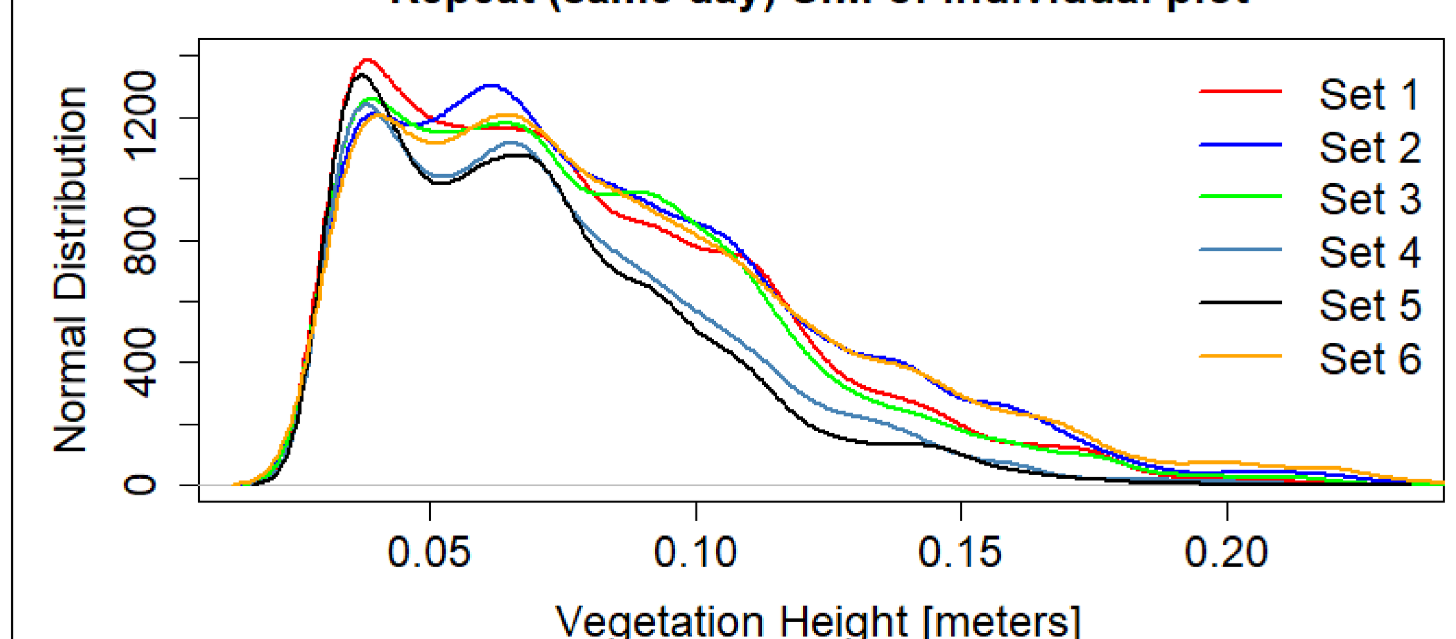

- PiCam GCC captures distinct phenological response to the four irrigation treatments (left figure).
- Linear relationship between weekly GCC and GPP (averaged per treatment type) is strongest for larger magnitude/longer drought interval treatments (S3 and S4) (above figure).

## 5. Results -- SfM




| SET NAME | MAX | MEAN |
|---|---|---|
| Set 1 | 0.2170 | 0.0781 |
| Set 2 | 0.2530 | 0.0835 |
| Set 3 | 0.2360 | 0.0787 |
| Set 4 | 0.2080 | 0.0725 |
| Set 5 | 0.2210 | 0.0694 |
| Set 6 | 0.2380 | 0.0853 |
| MEAN ALL SETS | 0.2288 | 0.0779 |

**Repeat (same day) SfM of individual plot**




- Vegetation height values for multiple repeat collections show similar distributions and demonstrates repeatability of technique.
- Variables that impact model output: wind, lighting, manual processing errors.

## 6. Next steps

- Derive allometric equations to compute biomass from SfM vegetation volume; apply equation to all vegetation models collected during Summer 2021 campaign season.
- Quantify error/uncertainty of volume-to-biomass technique.
- Continue exploring GCC/GPP/biomass relationships.

## 7. References

Smith, W. K., Dannenberg, M. P., Yan, D., Herrmann, S., Barnes, M. L., Barron-Gafford, G. A., Biederman, J. A., Ferrenberg, S., Fox, A. M., Hudson, A., Knowles, J. F., MacBean, N., Moore, D. J. P., Nagler, P. L., Reed, S. C., Rutherford, W. A., Scott, R. L., Wang, X., & Yang, J. (2019). Remote sensing of dryland ecosystem structure and function: Progress, challenges, and opportunities. *Remote Sensing of Environment*, *233*(August), 111401. https://doi.org/10.1016/j.rse.2019.111401