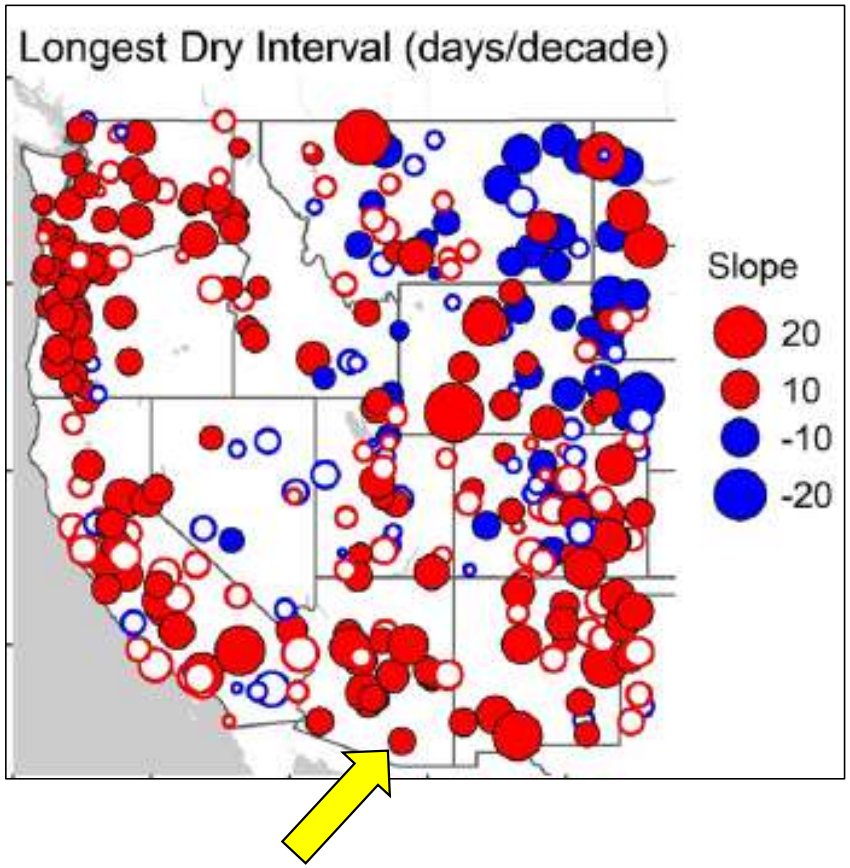
Proximal remote sensing enhances a global change experiment & tests assumptions of large-scale approaches

Joel Biederman, Bill Smith, Nathan Pierce, Fangyue Zhang et al.

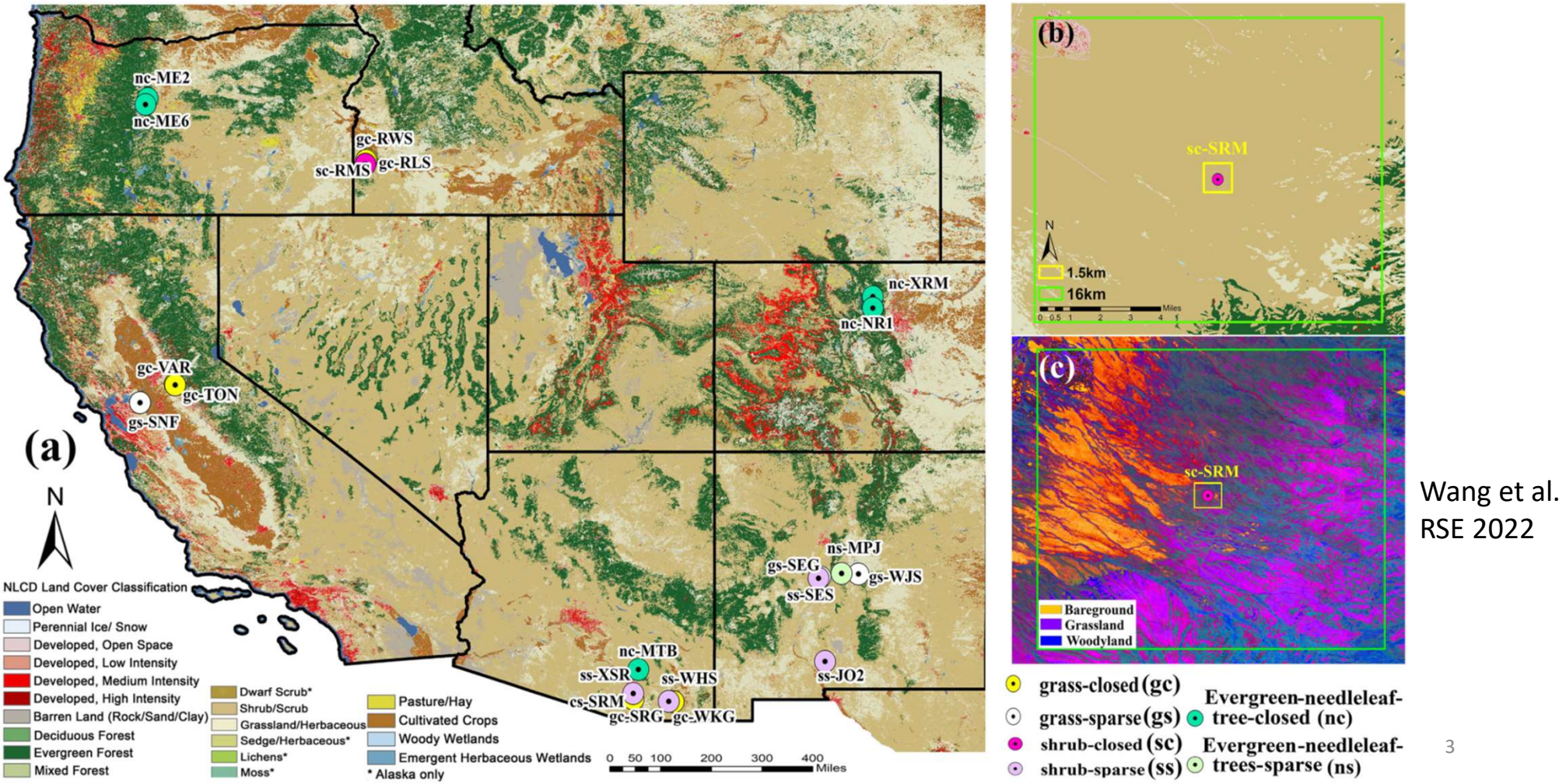
Motivation: temporal repackaging of rainfall



Zhang et al., GRL 2021

Since 1974, rainfall has been “repackaged” into fewer, sometimes larger storms with longer dry intervals between

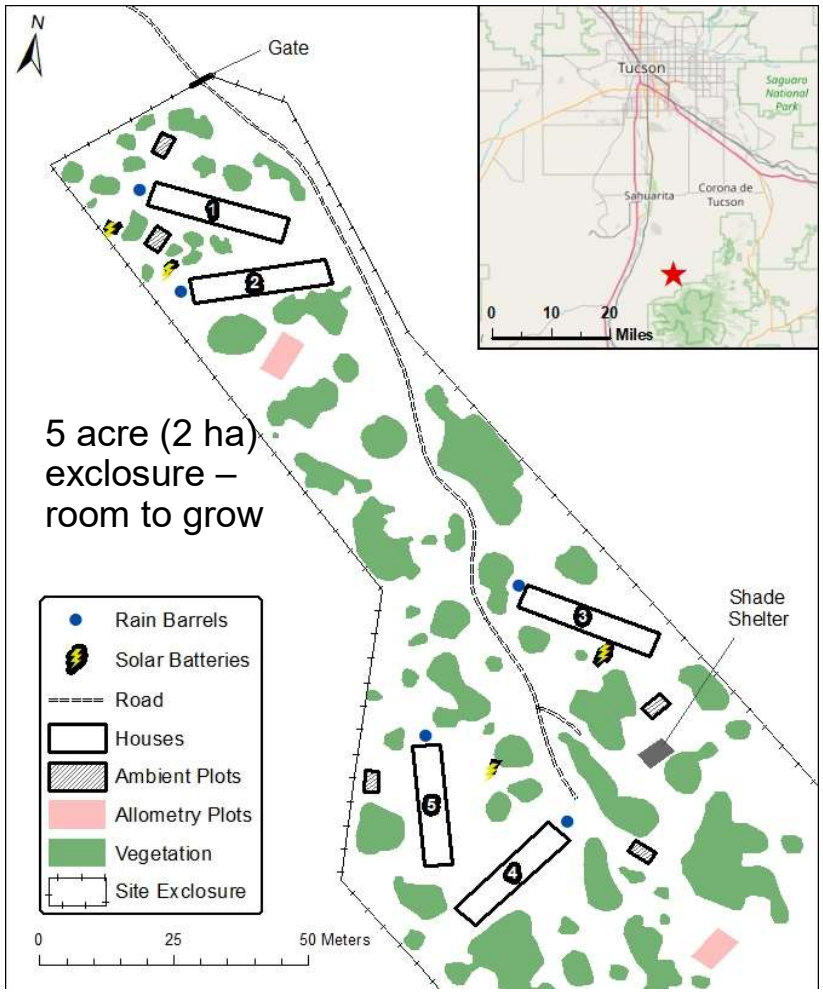
Motivation: spatial challenges of dryland remote sensing



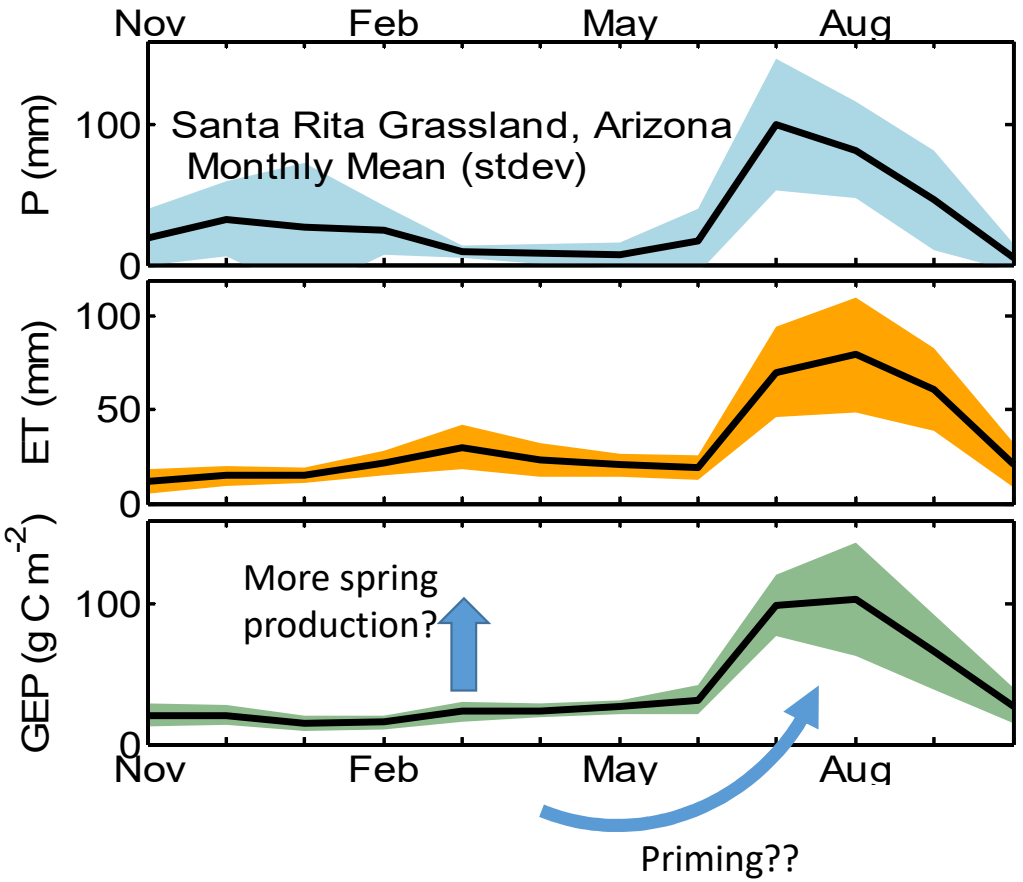
Wang et al. RSE 2022

RainMan-SR

Rainfall **Man**ipulation in the **S**anta **R**ita Experimental Range

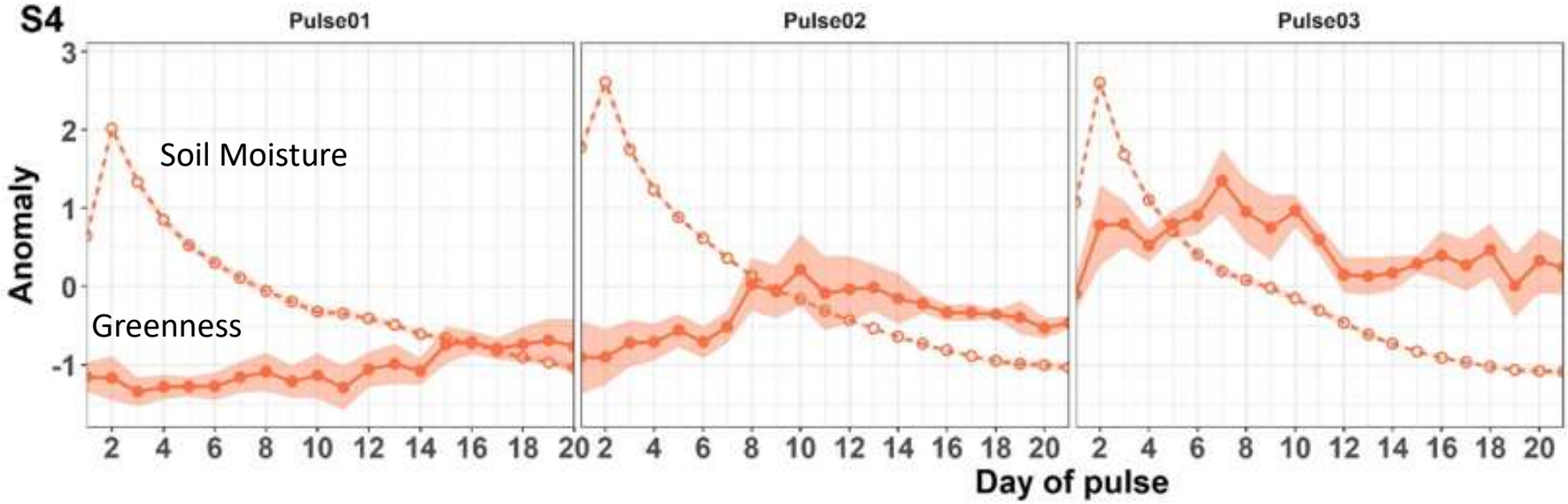


Unique aspects of RainMan



- Bimodal Sonoran Desert growing season
  - Spring fluxes increasing?
  - priming for summer?
- Fully manipulated rainfall allows altered *timing*
- **P**roximal **R**emote **S**ensing test bed

Proximal **R**emote **S**ensing in global change experiments



PRS can improve measurements *within* local experiments (Shiklomanov, 2019)

- Easier/cheaper/quicker than traditional measures
- Measure different things
- Non-destructive sampling
- Increased coverage spatially & temporally

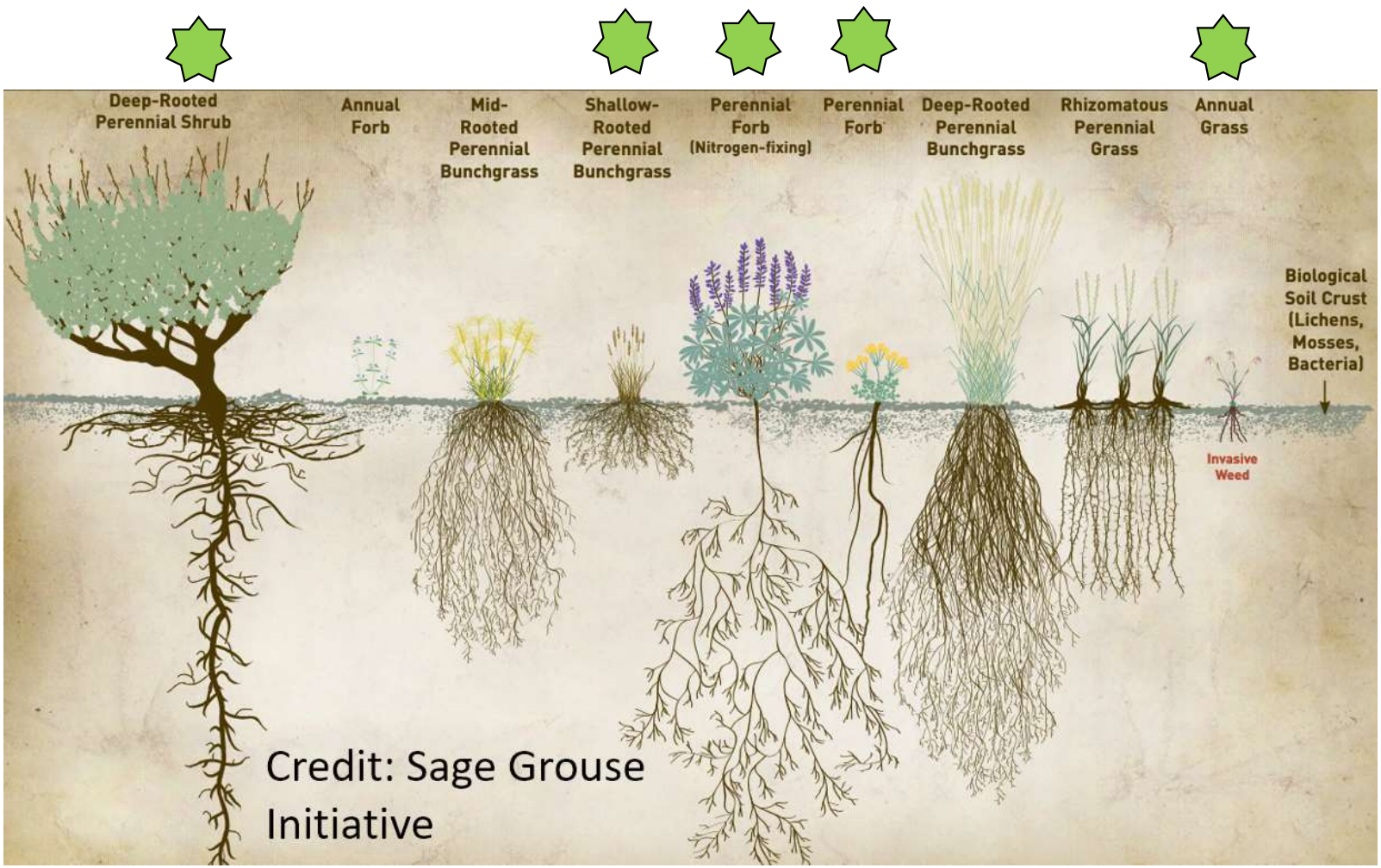
RainMan Infrastructure

- 60 plots 4 x 5 ft, hydraulically isolated
- Full rainfall exclusion with manual irrigation using captured rainwater
- Soil water content & water potential
- Automated phenocams

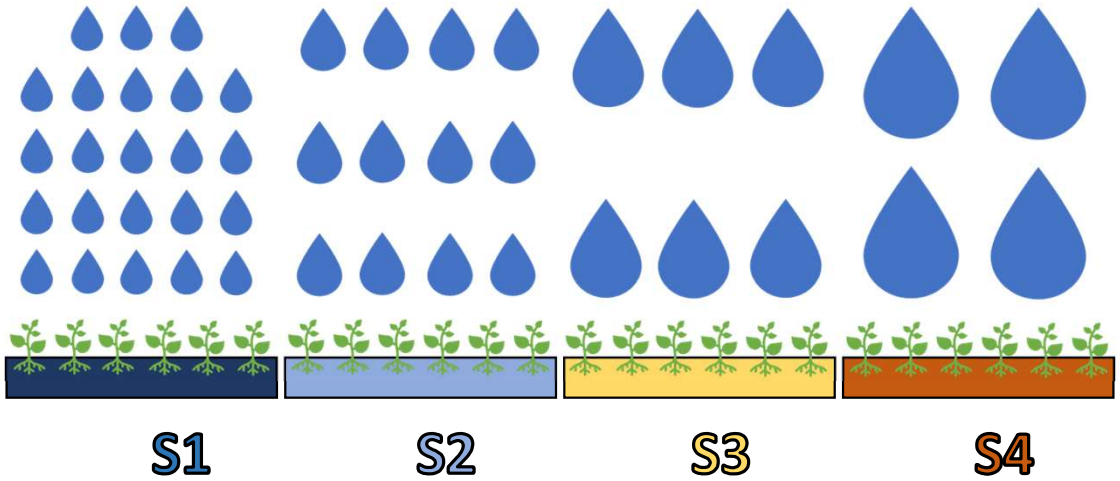
Single grassland ecosystem type

- Typical Sonoran Desert grassland
- Annual forbs & grasses
- Perennial forbs & small shrubs
- Transplanted Arizona Cottontop perennial bunchgrass 36/plot
- Mix of rooting depths

Mix of rooting depths from ~10 to 60+ cm



Experiment 1: temporal repackaging of summer precip: fewer, larger storms, longer dry intervals:



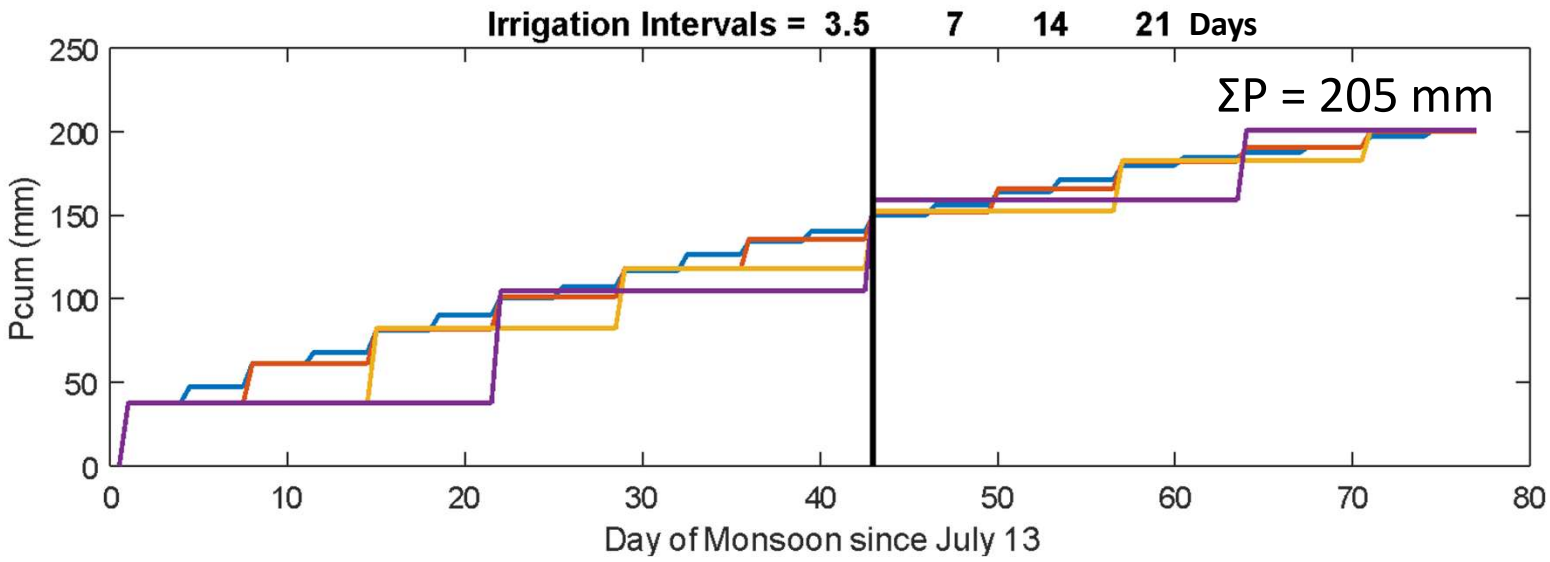
Design: 5 blocks (houses) of 12 plots. 4 treatments (n = 15) repeated each summer. Control is manipulated to historical norm (S2 = weekly rainfall)

Q1: What plants will be successful? Deep vs. shallow rooting.

Q2: What are the consequences for CO2 uptake, water evaporation, surface temperature?

Q3: What proximal remote sensing captures ecosystem structure, function, productivity?

Temporal repackaging of summer rainfall



Treatments span annual longest dry interval between rainfall events (since 1974)

S2 = historical normal frequency

RainMan Direct and PRS Measurements - Where

GPP & ET - plot

Aboveground biomass (allometry) - individual

hyperspectral – plot

LAI - plot

Plant Community -plot

water potential – leaf

Aboveground volume (SfM) - *map

Plant cover - *map

Leaf traits (e.g. %N)

RGB Imagery – *maps hourly (lowres) weekly (high res)

Gas exchange– leaf

Thermal *map

fluorescense - leaf

Structural traits– individual/leaf

Spectral - leaf

Soil water and temp profiles - plot

Soil microbial C/N/P & diversity - plot

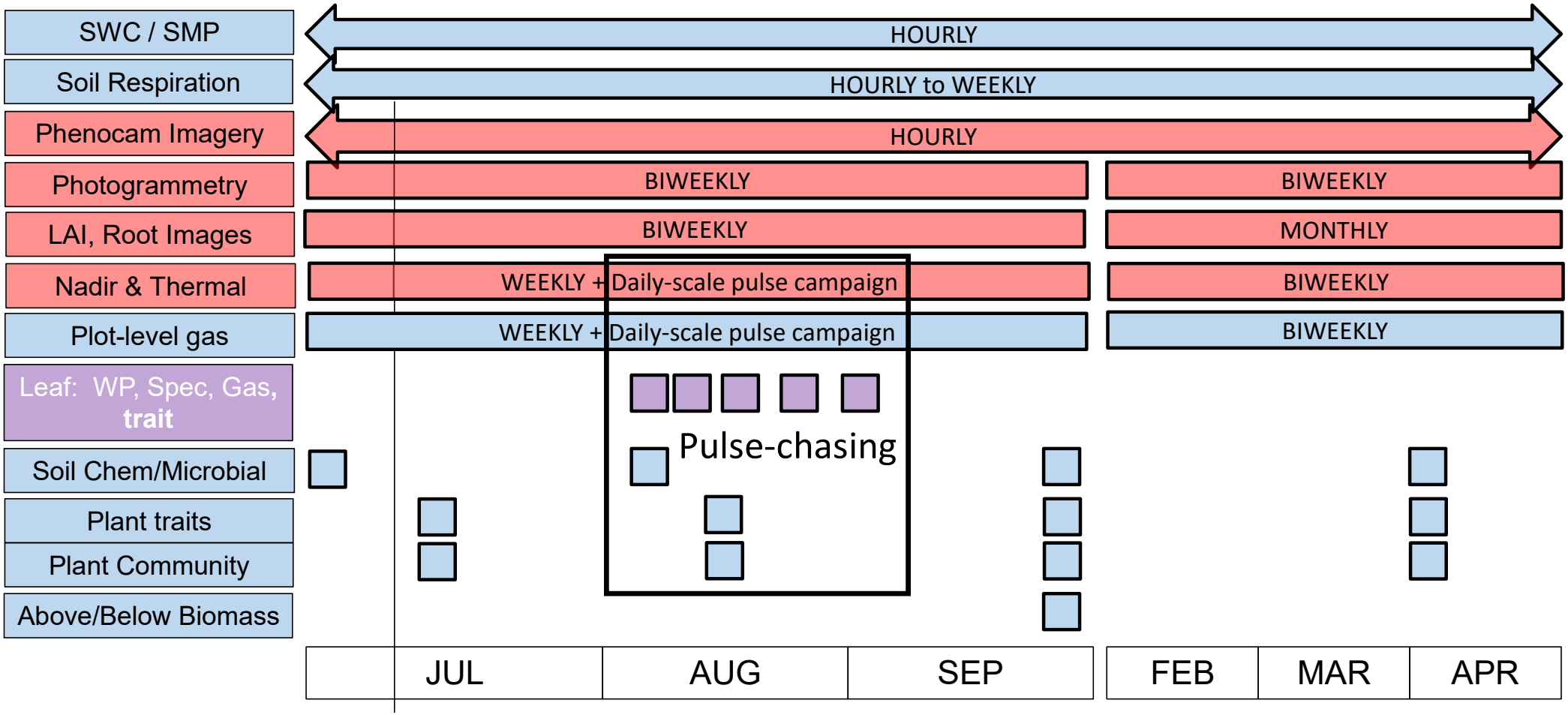
Root images - plot

belowground biomass (allometry) - plot

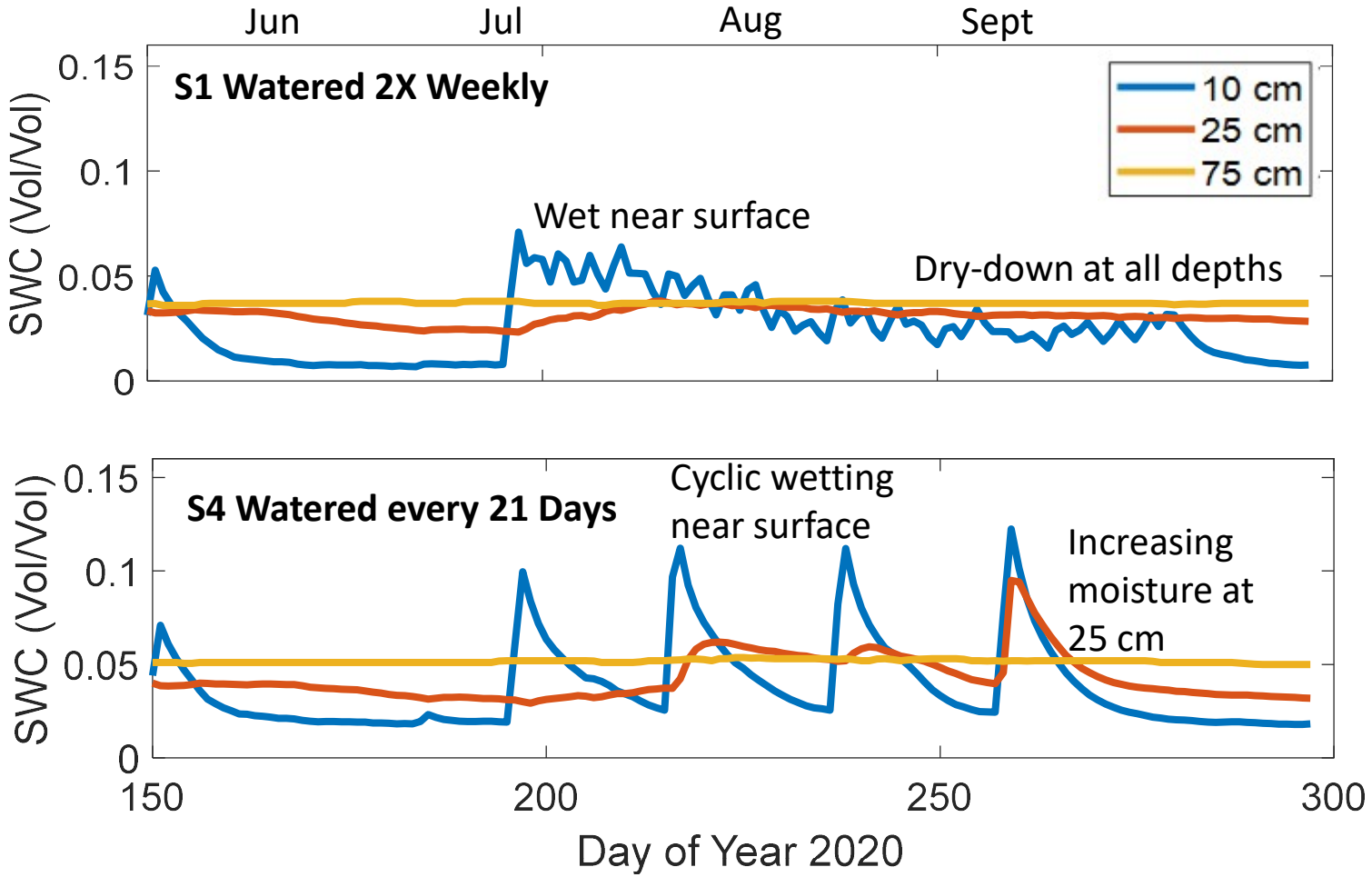
(?)Soil N species – plot

*Map = collected for whole plot but resolvable at sub-plot scale

RainMan Direct and PRS Measurements - When

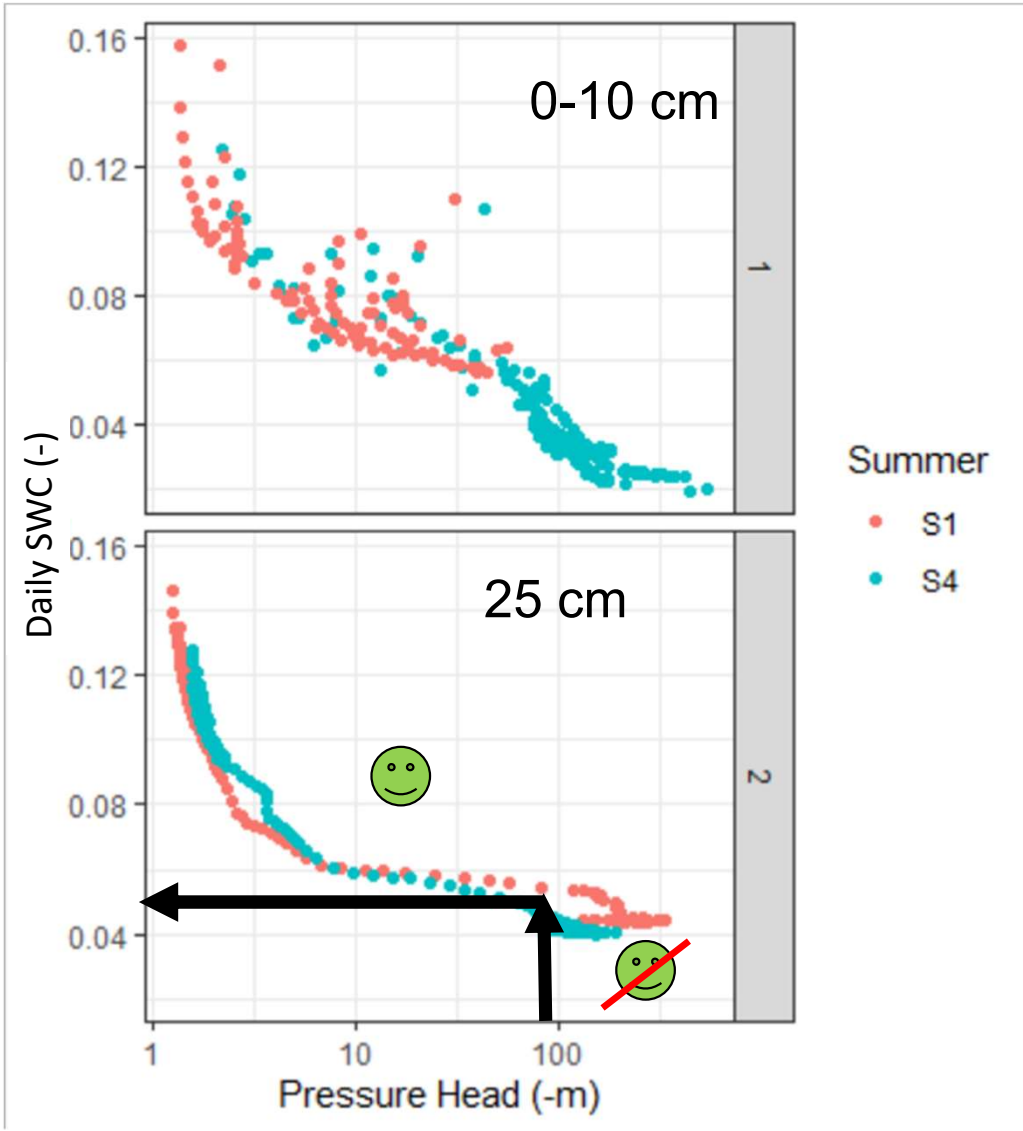


Soil water: many/small vs. few/large rainfalls

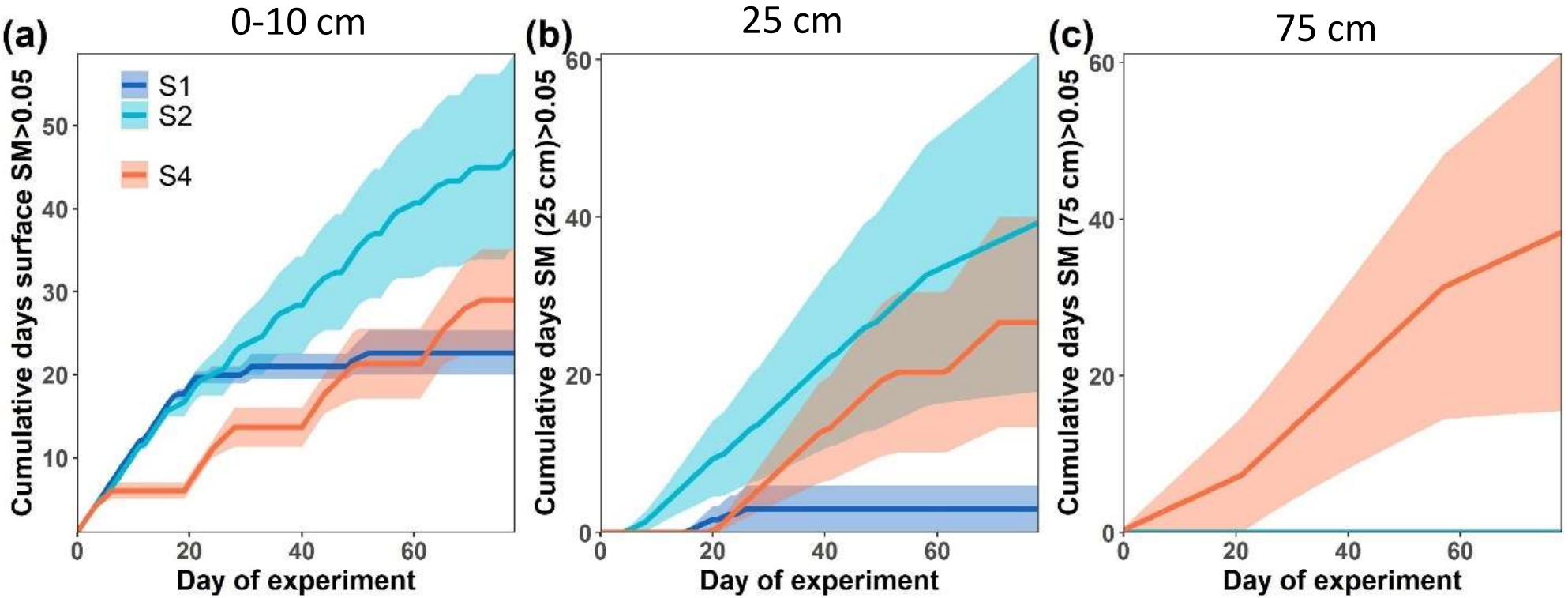


What do we mean by plant stress?

- Depth, duration, and intensity of soil water potential stress (SWP)
- Paired SWC & SWP Sensors
- Extensive screening for ~steady state
- -100 m water ~ -1MPa = 0.05% SWC

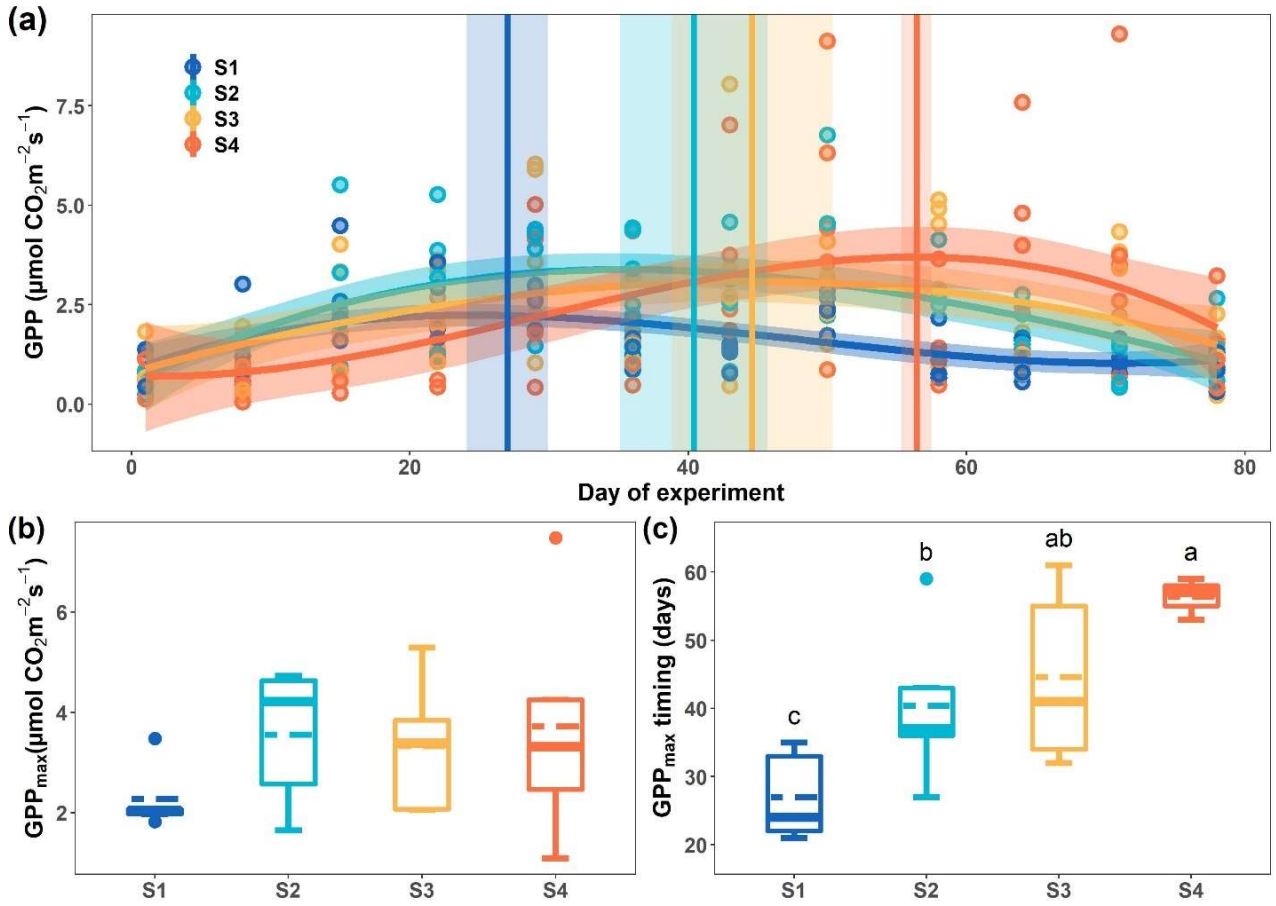


Cumulative days *without* major water stress



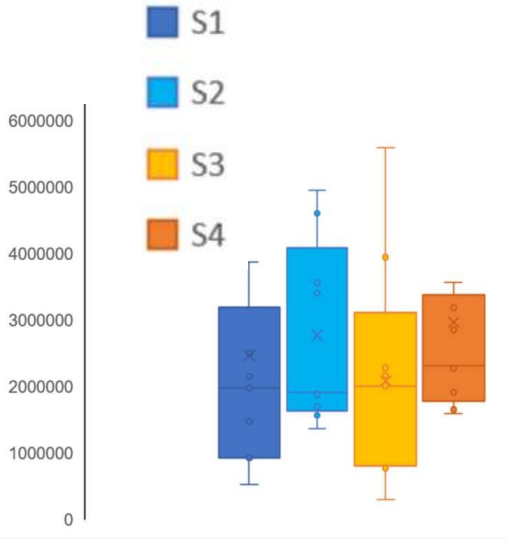
Zhang et al., Functional Ecology 2022

Few/large rainfalls *delayed* peak photosynthesis by ~1 month

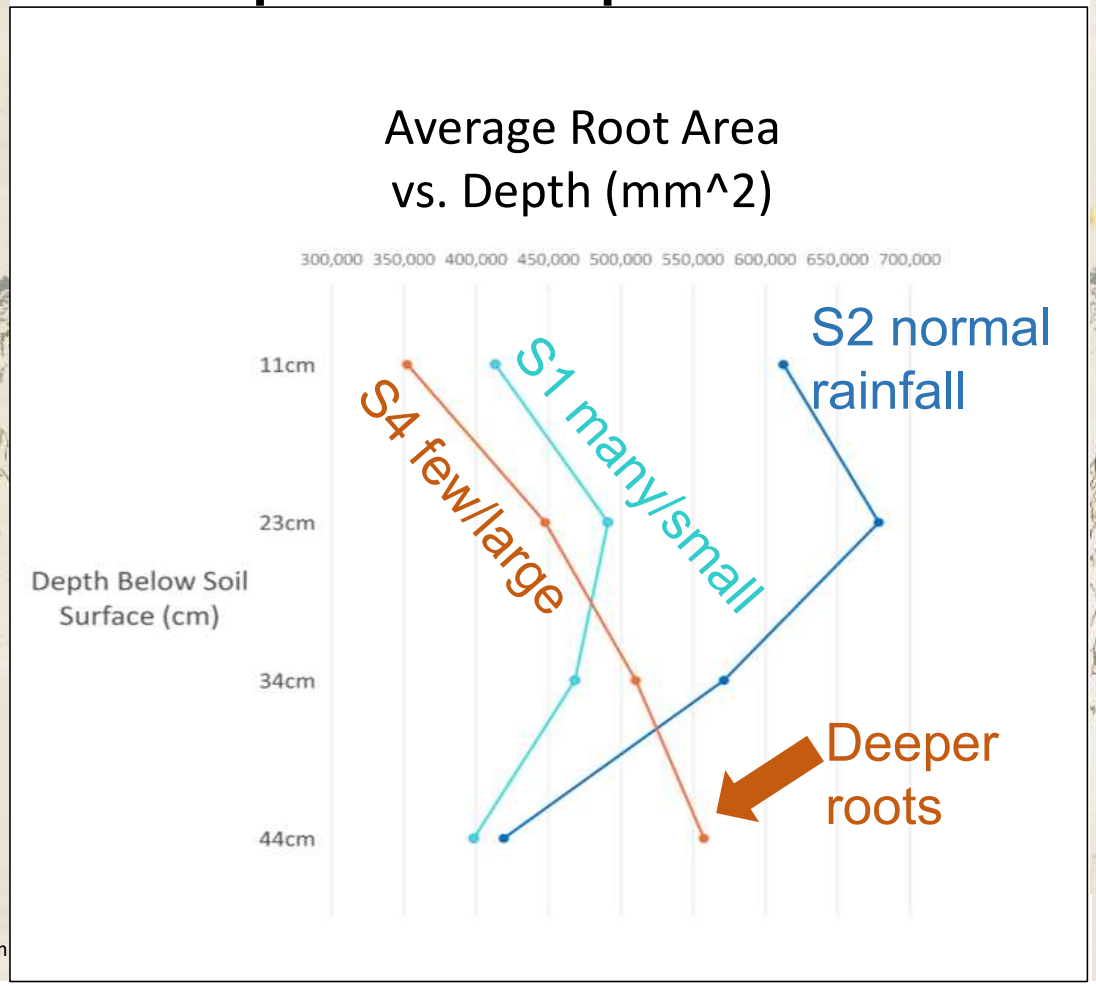


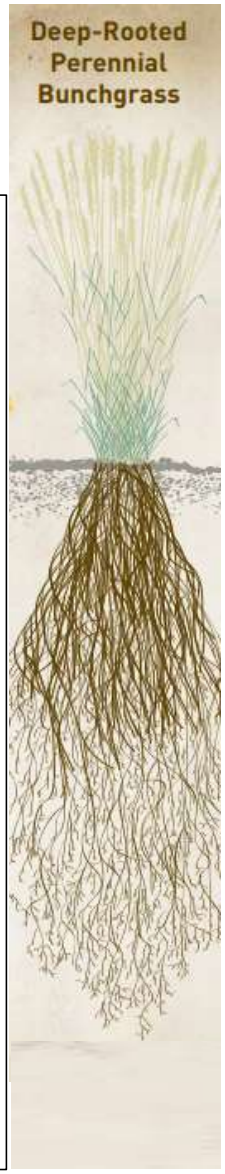
Zhang et al, Functional Ecology 2022

Few/Large rainfalls deepen root production

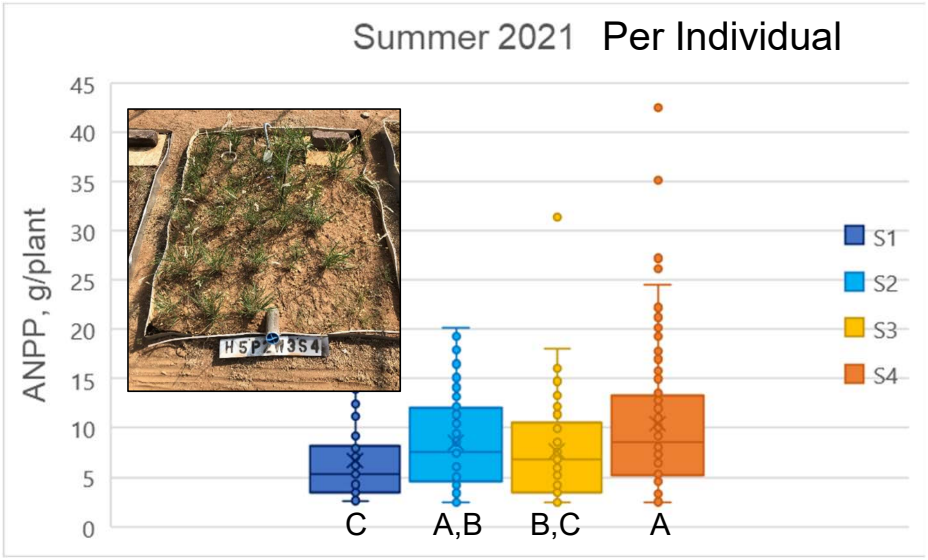


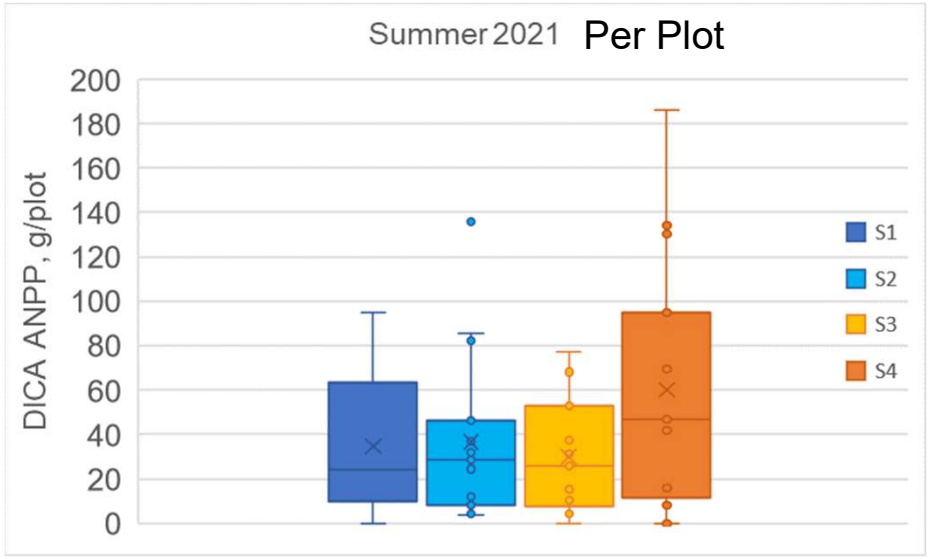
- No differences in total root area
- Different rooting depths





Perennial bunchgrass ANPP

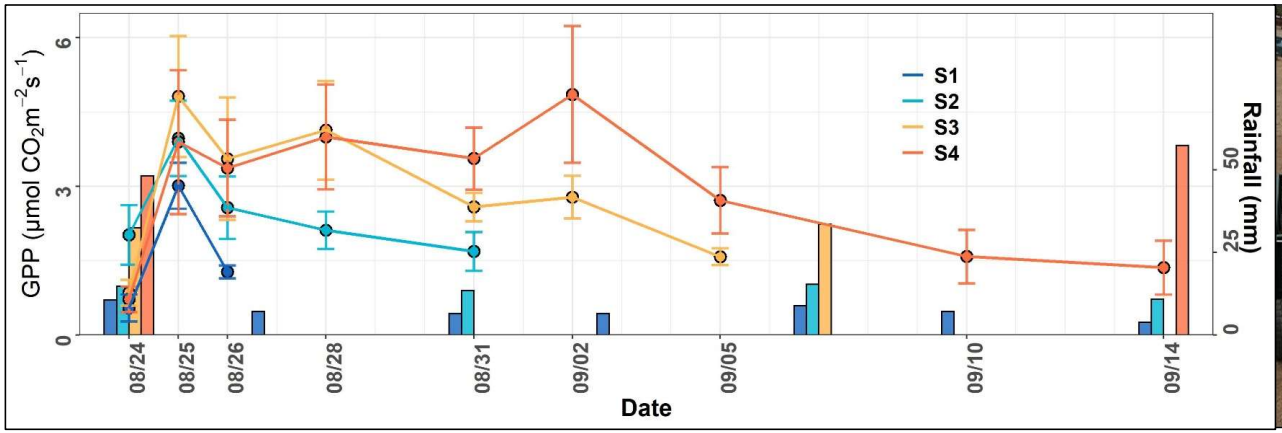


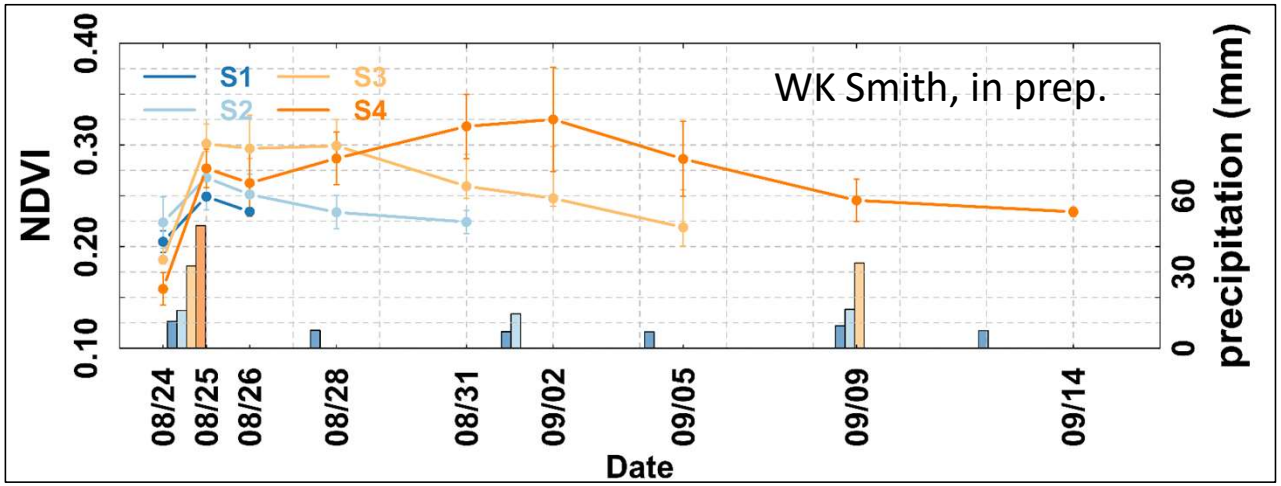


- Adjacent destructive sampling plots provide site-specific allometry: $Ht*BD^2$
- Biomass ~ Height * Basal Diameter^2
- Bigger individuals, no treatment effects at plot scale yet

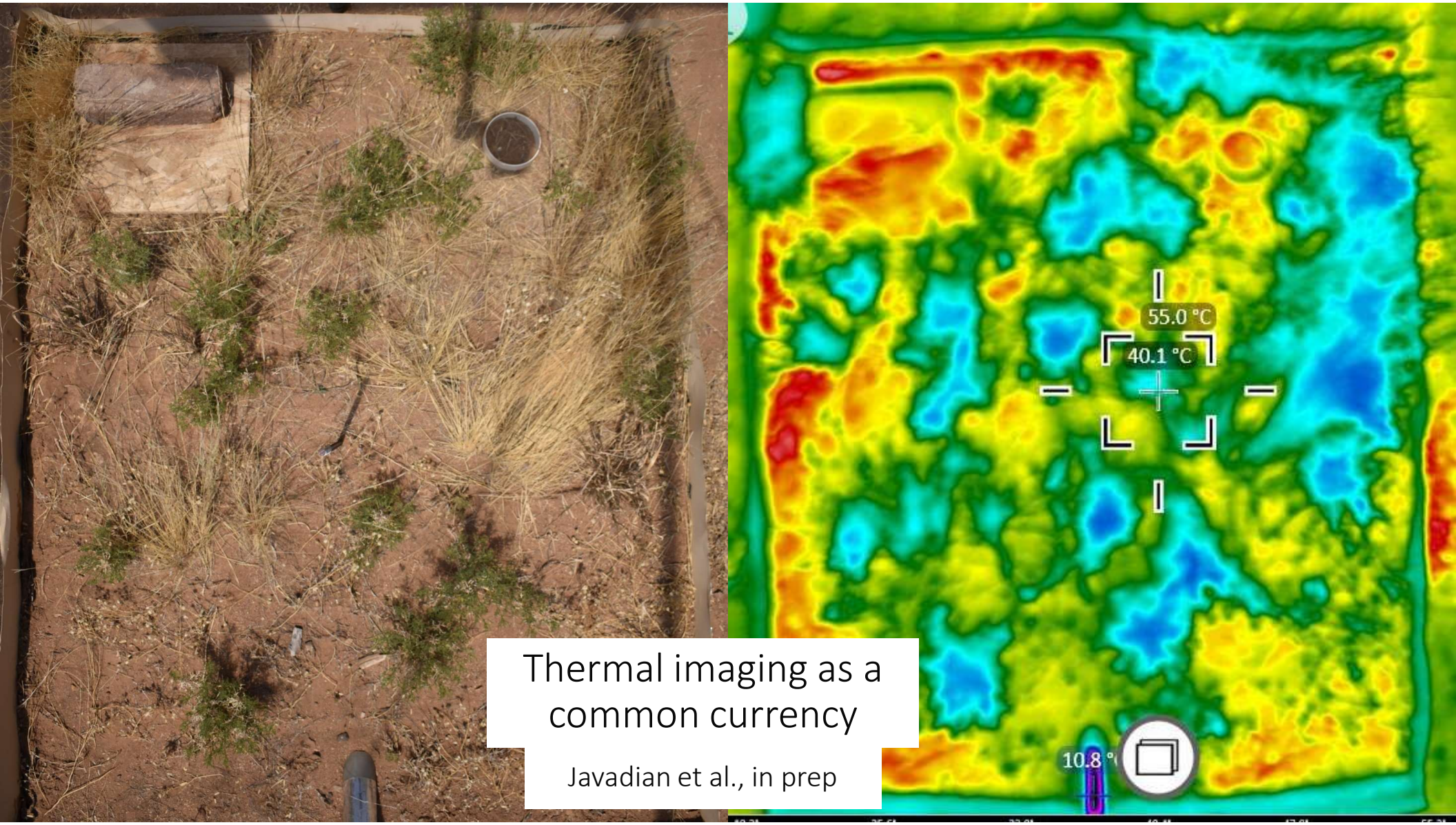
Pierce et al., in prep

NDVI tracks photosynthesis





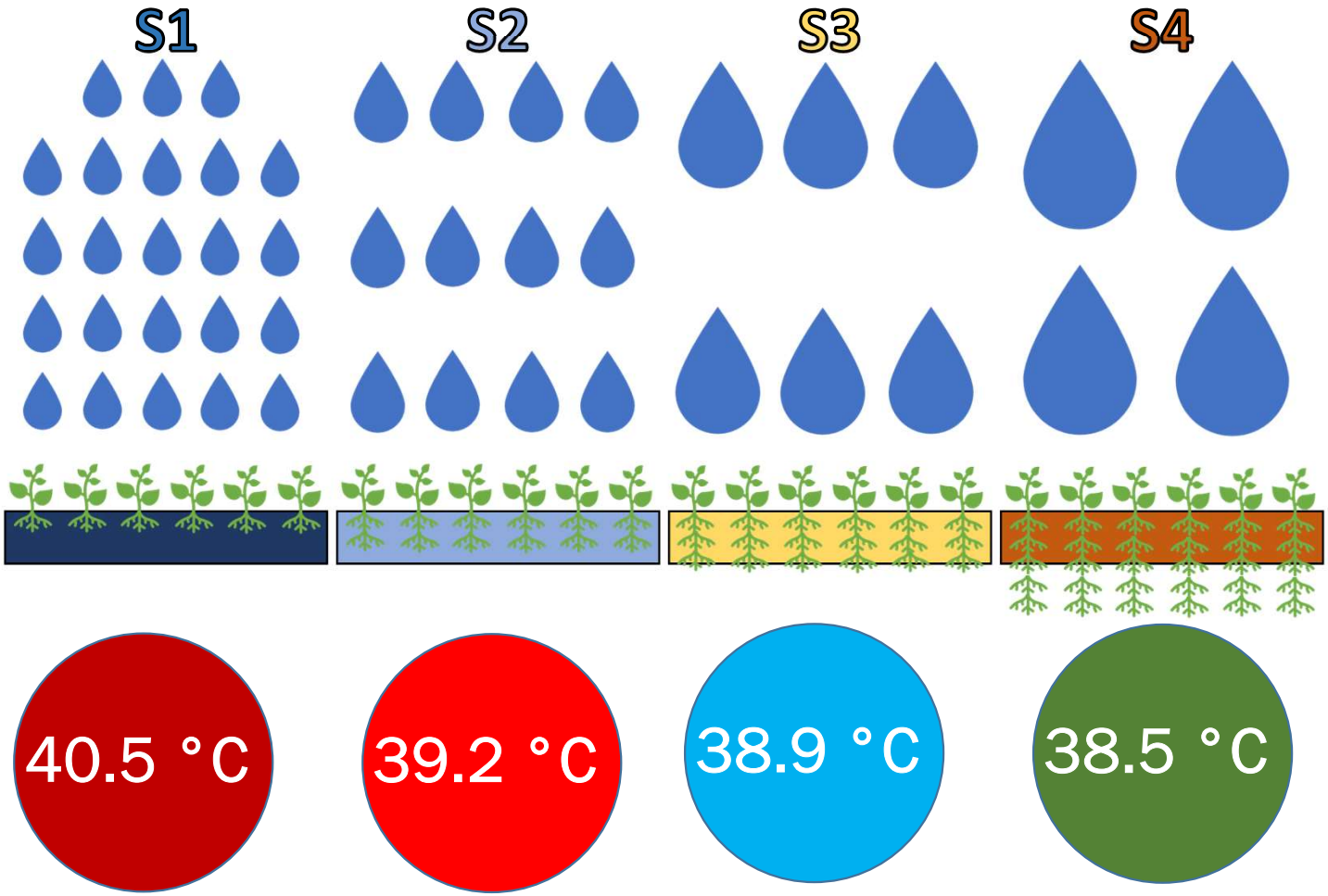
- NDVI is a common currency across time and space



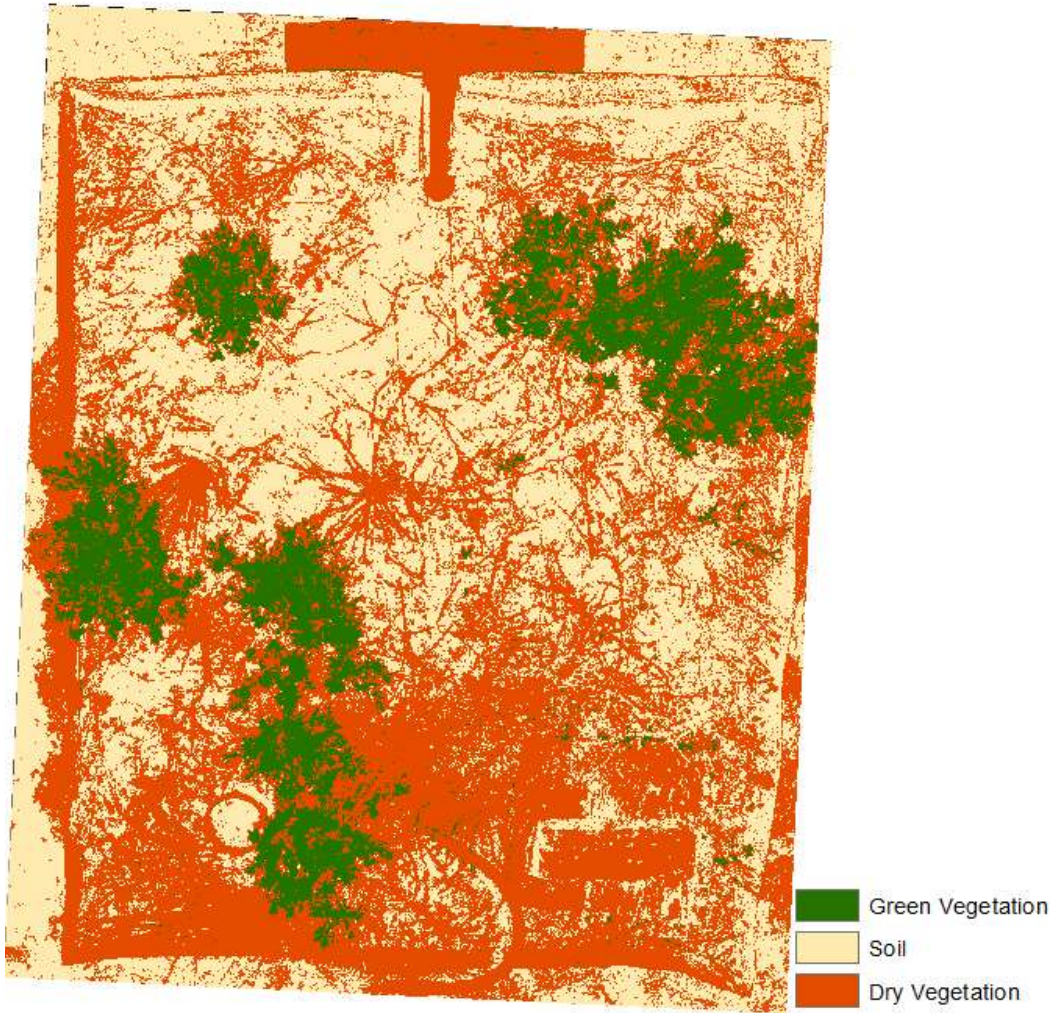
Thermal imaging as a common currency

Javadian et al., in prep

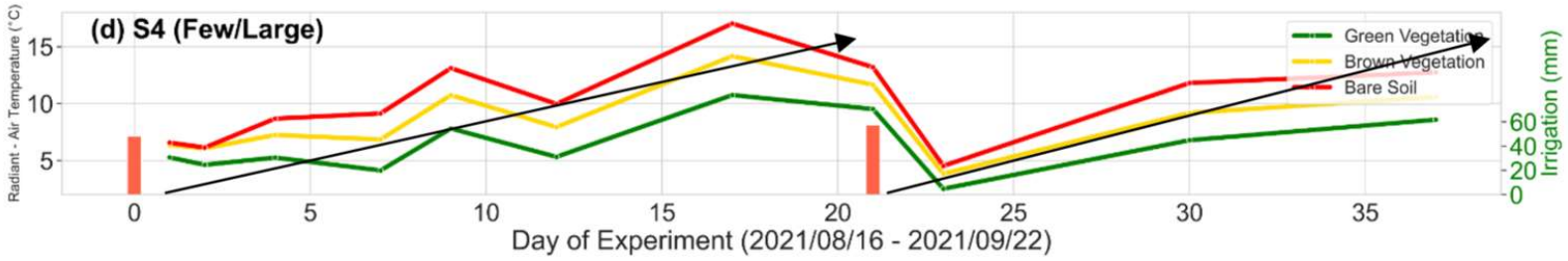
Few/Large rainfall plots stayed cooler

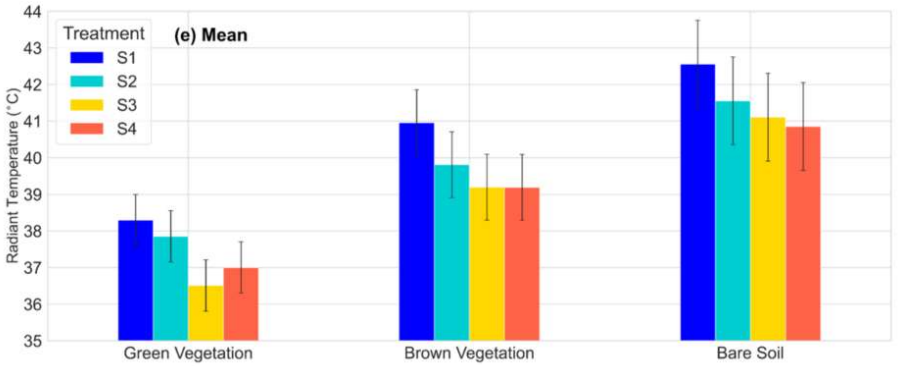


RGB cover classification



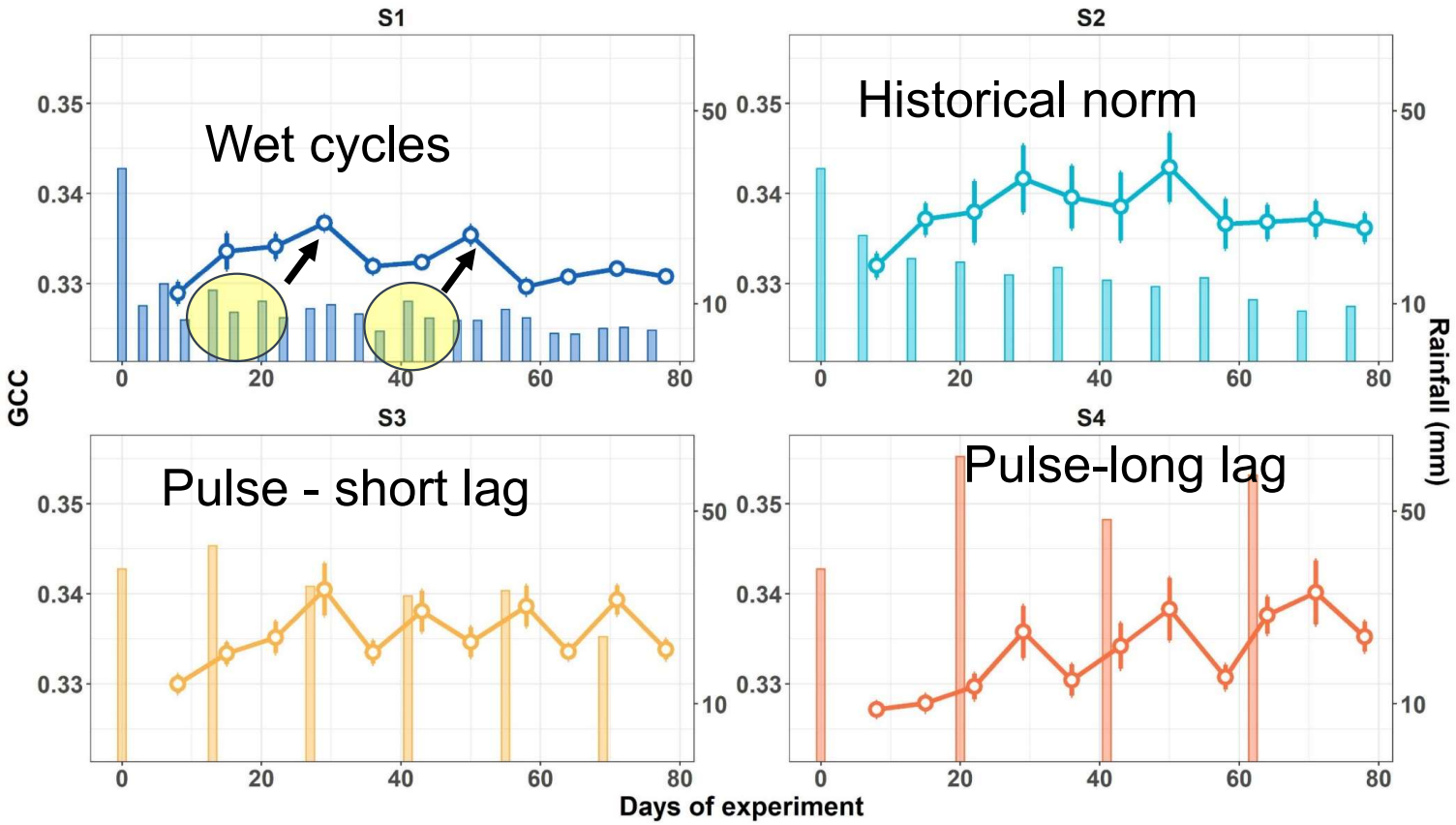
Thermal results by cover class & rainfall treatment





- 2-3 degrees between cover classes
- Differences grow with dry-down
- In all cover classes, few/large rainfalls=cooler
- Sustained access to root zone moisture

Variety of phenology across temporal repackaging
GCC = Greenness



Temporal repackaging into fewer/larger rainfalls:

- Increases time of root zone stress in shallow soils, relieves stress deeper
- Promotes deeper roots (and fewer shallow roots), no change in total root area
- Cools land surface by 1-2 degrees at midday
- Favors perennial plants with greater access to moisture (thermal)
- Delays peak productivity up to 30 days, no change in peak magnitude
- Bigger bunchgrass individuals, no change in ANPP
- Increases challenges with phenology models
- Increases importance of high-frequency measurements

Future Directions

- Temporal: Develop pulse-driven phenology models appropriate for drylands
- Quantify the impacts of temporal resolution with intensifying rainfall packaging
- Spatial: Link plot-scale heterogeneity in greenness & thermal to satellite RS
- Greenness ~ photosynthetic capacity
- Thermal ~ access to moisture/plant stress
- Hyperspectral ~ Functional traits