The feedback of Arizona Grassland to Longer Seasonal Droughts and its Implication for Dryland Carbon Cycling: Insights from Model-Experiment Integration

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November 26, 2022

Abstract

Dryland play a major role in the global carbon cycle. The US Southwest is experiencing fewer, larger precipitation events and longer dry intervals between rainfalls. These longer droughts are likely driving physiological, phenological, morphological, and community-level responses of dryland vegetation with unknown feedbacks to atmospheric CO_2. It remains unclear how seasonal drought intensity and duration affect the magnitude, duration, and direction of dryland vegetation carbon cycling and atmospheric feedbacks. To address this question, we integrated the measurements of soil hydrology, plant community, and carbon fluxes from a new rainfall manipulation experiment site (RainManSR) in the Santa Rita Experimental Range of Southeast Arizona, US into the Community Land Model (CLM5). This field experiment imposed four precipitation treatments (S1–S4), each with the same summer growing season total rainfall (205 mm) but packaged into a range of many/small to few/large rainfall events. This experiment enabled a comprehensive evaluation and parameterization of drought tolerance of semiarid grassland plant functional types (i.e. deep-rooted perennials and shallow-rooted annuals) and their effects on climate extreme-carbon cycles feedbacks. The ability of the improved CLM model to capture dryland productivity and carbon fluxes was then validated at larger scales with observed carbon fluxes from closeby AmeriFlux sites in the US Southwest, such as the semi-arid Kendall grassland site (US-WKG). Applying this model in the Arizona grassland sites indicated that high tolerances of dryland plants to relatively low soil water potential maintains the growing season length of the dryland ecosystem under drought conditions, whereas the acclimation of carbon assimilation and root dynamics to drought mitigate drought effects on vegetation productivity and interannual variability of carbon exchange.

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Dec. 14, 2021

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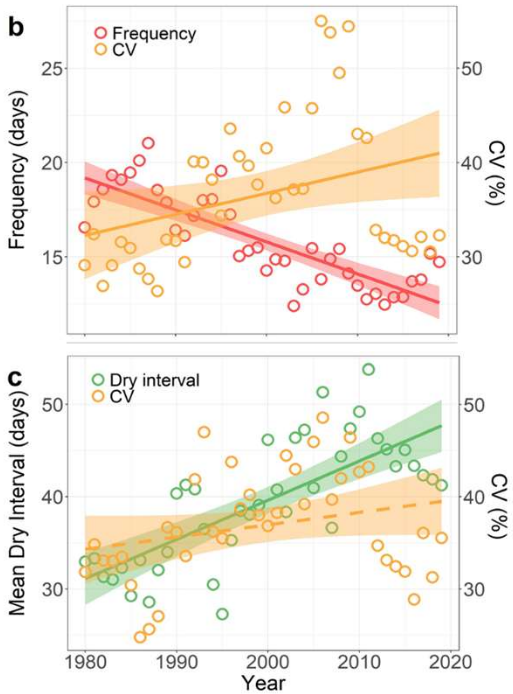
We acknowledge support for this work provided by TRIF/WEES AIR Resilience Grants
Dr. Nate Pierce and Dr. Fangyue Zhang for experimental data supports.

Better understand and predict the hydroclimate resilience of Arizona grassland

Fewer, larger precipitation events & longer dry intervals between rainfall

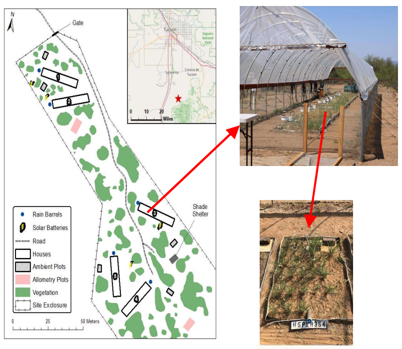


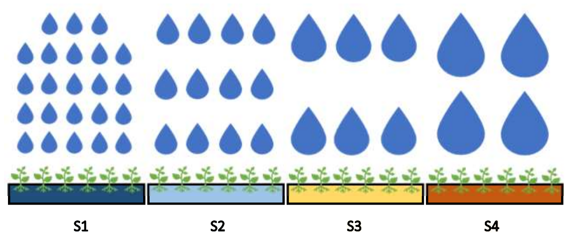
Zhang et al., 2021

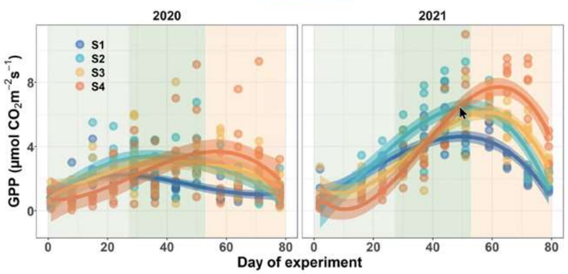
<u>Research Questions</u>

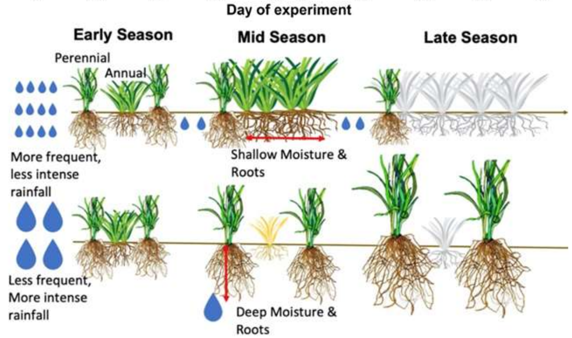
- **How does Arizona grassland acclimate to change in temporal variability of Precipitation?**
- **How does climate acclimation of Arizona grassland affect its ecosystem function ?**
- How does the climate resilience of Arizona grassland vary over the time ?

Rainman Precipitation Manipulation Experiment: Assessing the hydroclimate response of Arizona grassland









- Increased GPP
- Delayed peak productivity
- Changed community composition
- Deeper root depth

Plant moisture feedback

- Rubisco efficiency and mesophyll feedback
- Stomatal conductance feedback
- Leaf and root conductivity feedback
- Phenology feedback

CLM5.0 included feedback mechanisms

- Diverse drought tolerance capacity
- Root dynamics
- Carbon and nutrient allocation feedback

Not included in CLM5.0

Model experiment design

Control (CLM_c)

- General C3 and C4 grasses
- Rubisco efficiency and mesophyll feedback
- Stomatal conductance feedback
- Leaf and root conductivity feedback
- Phenology feedback

Drought-tolerant phenology ($CLM_{phenology}$)

- **Annual C3 and C4 grass, Perennial C3 and C4 grass**
- Rubisco efficiency and mesophyll feedback
- Stomatal conductance feedback
- Leaf and root conductivity feedback
- Phenology feedback

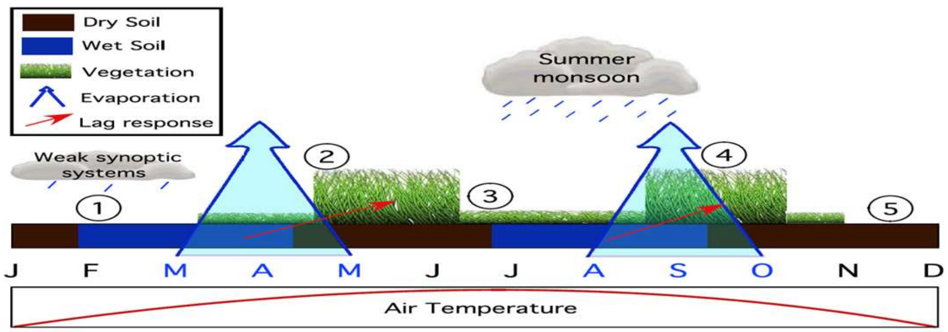
CLM Dynamic root ($CLM_{dynroot}$)

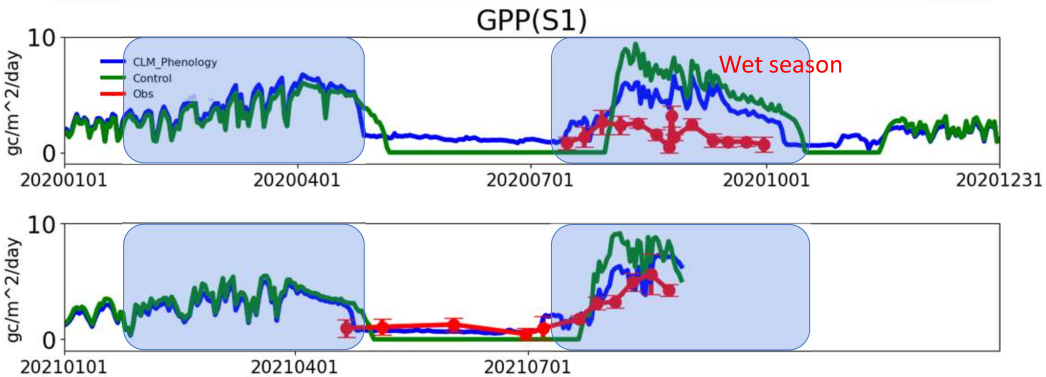
- **Dynamic root growth in response to water and nutrient availability.**
- Annual C3 and C4 grass, Perennial C3 and C4 grass
- Distinct drought tolerant of each plant functional types onset and offset of the growing season.
- Rubisco efficiency and mesophyll feedback
- Stomatal conductance feedback
- Leaf and root conductivity feedback
- Phenology feedback

Song Dynamic carbon allocation and root growth ($CLM_{dynallo}$)

- **Dynamic carbon allocation in response to water and light stress**
- **Vertical and horizontal root growth in response to water availability.**
- Annual C3 and C4 grass, Perennial C3 and C4 grass
- Distinct drought tolerant of each plant functional types onset and offset of the growing season.
- Rubisco efficiency and mesophyll feedback
- Stomatal conductance feedback
- Leaf and root conductivity feedback
- Phenology feedback

Drought-tolerant phenology is important moisture feedback mechanism of Arizona grassland (CLMphenology)

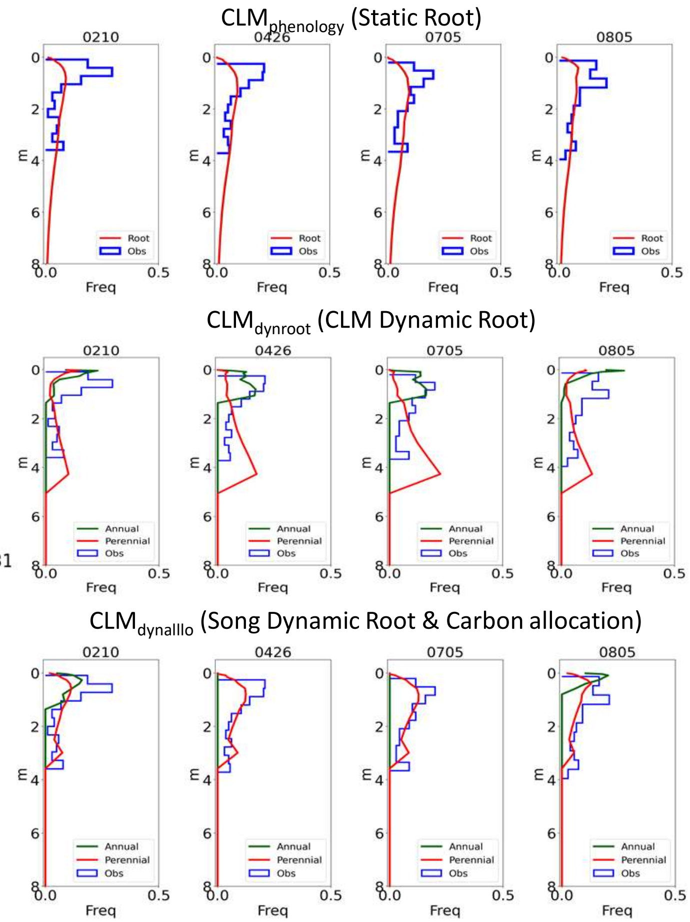




Drought-tolerant phenology better capture

- Earlier onset of grassland
- Maintained growth of perennial grasses and GPP during dry season
- Slower growth rates of grassland

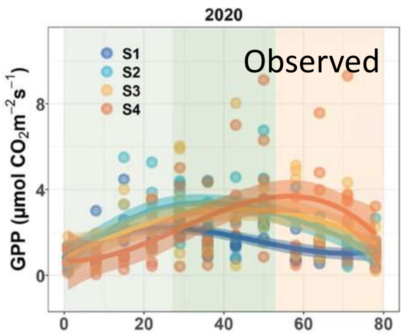
Dynamic root growth and carbon allocation better captures root profile of Arizona grassland

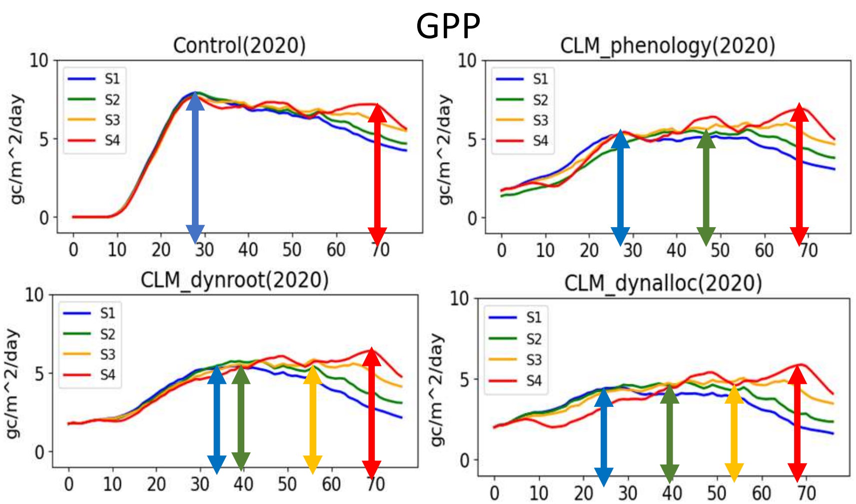


Dynamic carbon allocation and root growth

- Better capture seasonal change of annual grasses (e.g., root death).
- Better capture deep perennials root and shallow annuals root.

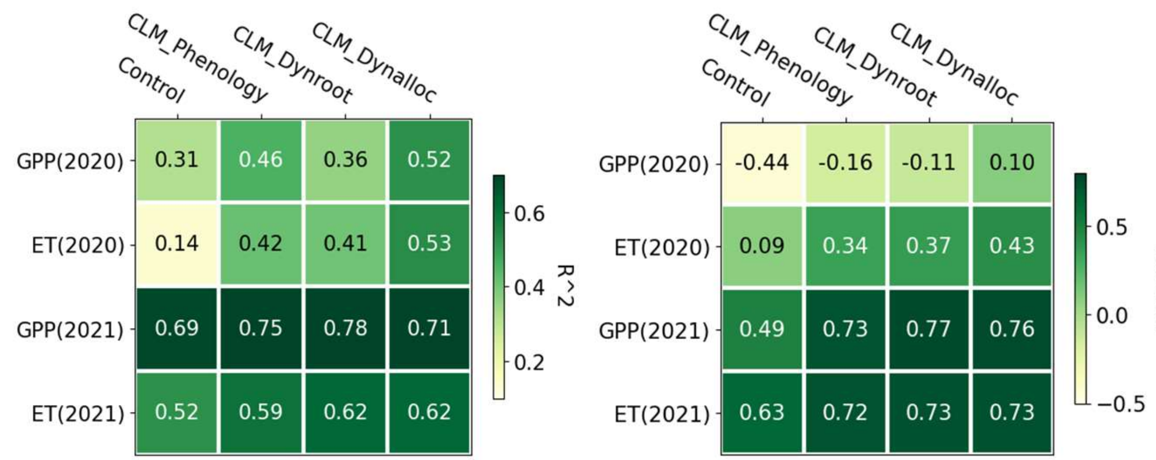
Dynamic carbon allocation and root growth is a useful scheme of Arizona grassland in response to less frequent and more intense rainfall





The increase in productivity and delayed peak is better Captured in dynamic root and allocation experiment.

Model overall performance



- Implementation of drought-tolerant phenology for annual and perennial grasses significantly improves simulation of carbon and water fluxes
- Implementation of dynamic root and carbon allocation further improves carbon and water fluxes simulation.

Take home message

- **Drought-tolerant phenology is important moisture feedback scheme of Arizona grassland.** Incorporation this scheme into the CLM better captures bi-model phenology feature, productivity and evapotranspiration of Arizona grassland.
- **Dynamic carbon allocation and root growth is also a useful scheme of Arizona grassland in response to less frequent and more intense rainfall.** Implementation of this scheme into the CLM better captures the delayed GPP peak.
- Current model-data integration have not calibrated the effect of N availability on GPP and ET fluxes. **Coupled aboveground-belowground model-data integration will be implemented** when the corresponding data is observed in the following step of our RainMan experiment.

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Acknowledgement

- We acknowledge support for this work provided by TRIF/WEES AIR Resilience Grants
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Thank You

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