Impact of Altered Precipitation Distribution and Warming on Tree and Grass Life Forms in Oak Savanna

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Project Overview

- Rationale
- Infrastructure
- Driver simulation
- Experimental results
- Conclusions
- Future research direction

Rationale / Approach

- Mechanistically evaluate leaf and root trait responses to warming and rainfall redistribution, complementing existing community level investigations.

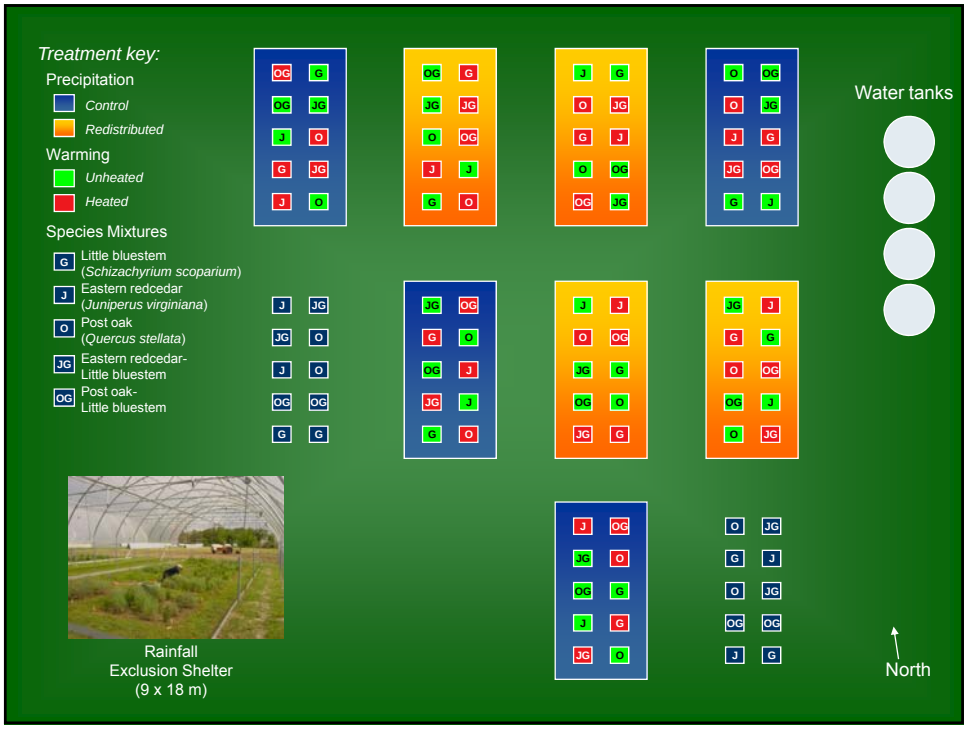
- Establish a physiological basis for the responses of three contrasting growth forms (C_4 grass, C_3 deciduous tree, C_3 evergreen tree) to these global change drivers.

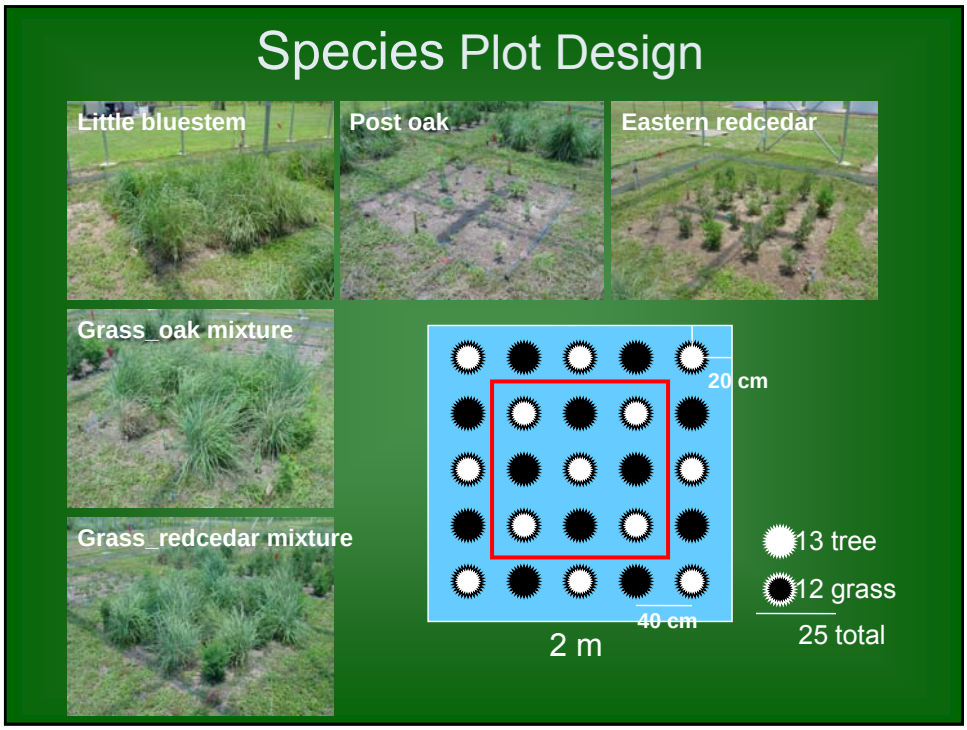
- Explore the potential for warming and rainfall redistribution to modify competition between dominant growth forms of southern oak savanna using mixed species plots.

Experimental Design

- Factorial combination of two rainfall patterns (long term mean / redistributed) and two temperature treatments (ambient / continuous warming (100 W m^{-2})).
- Each precipitation treatment is replicated in four rainfall exclusion shelters (eight shelters total).

- Infrared warming applied as a nested treatment to half of the 'species' plots within each shelter (2 warming treatments x 5 species combinations)
- Treatments initiated March 2004, 1 yr after the plants were established.


Treatment key:
Precipitation
Control
Redistributed
Warming
Unheated
Heated
Species Mixtures
G Little bluestem (Schizachyrium scoparium)
J Eastern redcedar (Juniperus virginiana)
O Post oak (Quercus stellata)
JG Eastern redcedar-Little bluestem
OG Post oak-Little bluestem
Water tanks
Rainfall Exclusion Shelter (9 x 18 m)
North


Species Plot Design
Little bluestem
Post oak
Eastern redcedar
Grass_oak mixture
Grass_redcedar mixture
20 cm
40 cm
2 m
13 tree
12 grass
25 total

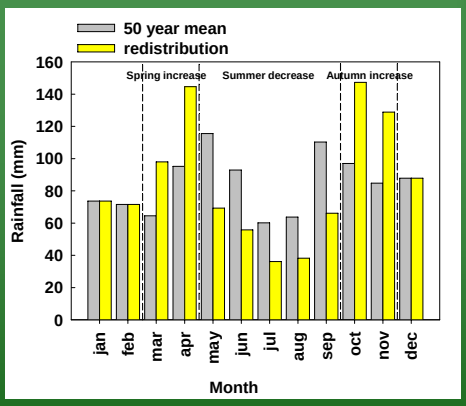
Simulated Rainfall Regimes

I. Long-term mean (50 year)

Simulated from event size and distribution of months that approached mean long-term monthly precipitation.

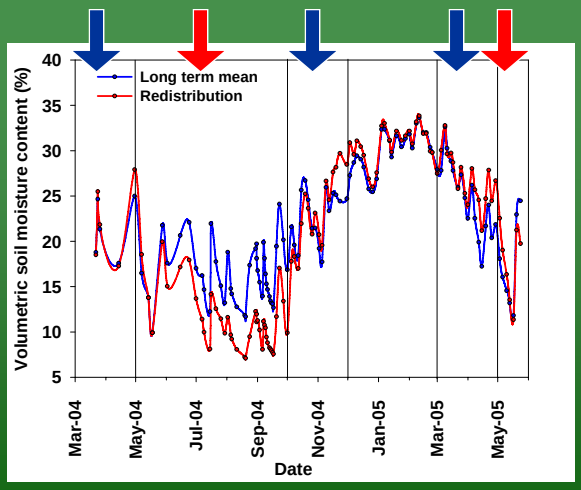
II. Redistribution

Reduce May – September precipitation by 40% and redistribute this amount to spring (March-April) and autumn (October-November)



Total annual precipitation (1018 mm) and the number and frequency of events are identical between the two rainfall regimes.

Dry Phase Effects on Soil Moisture



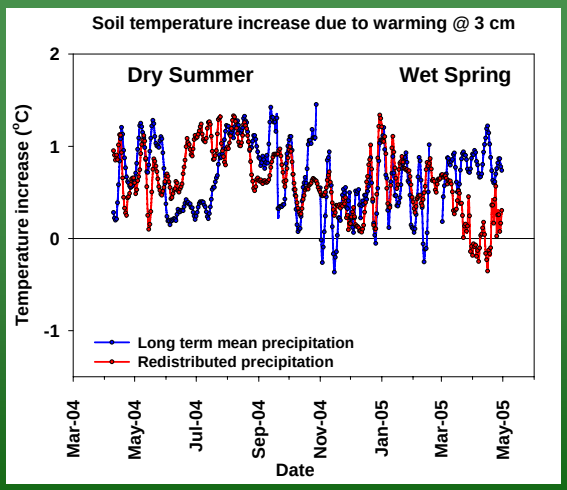
Redistributed plots receive 50% more water

Redistributed plots receive 40% less water

AV2

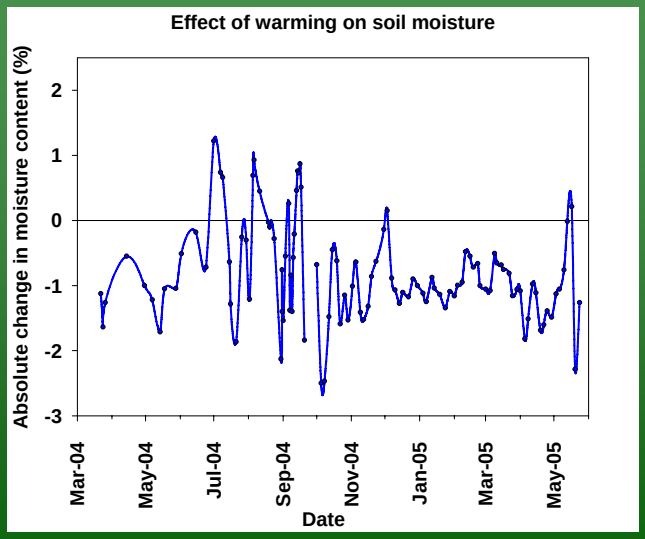
Soil Warming at 3cm Depth





Warming Reduces Soil Water Content





Slide 9

AV2 This new slide shows 5-day averages to smooth out some of the 'peaky-ness' of the earlier slide and to highlight the summer and spring effects. I have no good explanation for what is happening in the last 5 points.....

Astrid Volder, 6/7/2005

AV3

Post oak

Eastern redcedar

Little bluestem

Mechanisms

- Soil water acquisition mediates responses to warming and rainfall redistribution in addition to their direct effects on phenology and physiology.
- The growth forms least able to track and acclimate to these global change drivers will show the greatest negative effects on growth, function and competitive ability.

Slide 12

AV3 I inserted this slide to try to glue the various datslides together somewhat. Repeat the storyline and the thoughts behind the coming slides. What do you think?
Astrid Volder, 6/7/2005

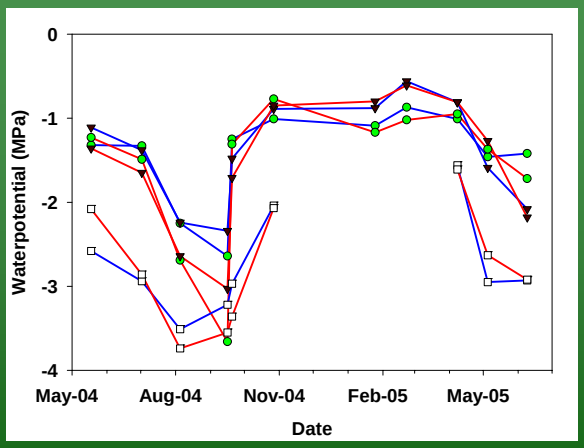
Data collection:

- Growth metrics
- Gas exchange
- Water relations
- Phenology
- Minirhizotron
- Root cores
- Soil water content
- Environmental

Plant Water Stress

- Does the C_4 grass exhibit reduced drought stress with intensified summer drought compared to the C_3 trees?
- Do all species recover equally after summer drought is temporarily relieved and does this response vary with precipitation treatment?

Plant Water Potentials

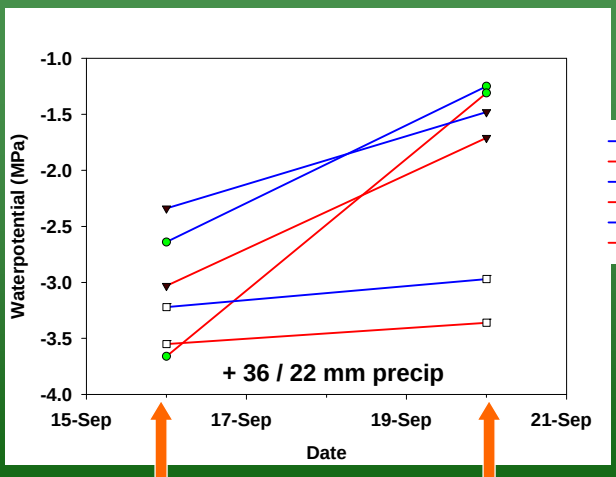


Less water stress

More water stress

Control Grass
Redist Grass
Control Juniper
Redist Juniper
Control Oak
Redist Oak

Drought Recovery



Control Grass
Redist Grass
Control Juniper
Redist Juniper
Control Oak
Redist Oak

Soil water 12.7 / 7.6%

Soil water 19.4 / 11.7%

Net gas exchange

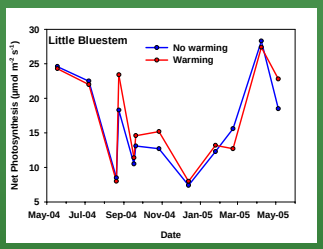


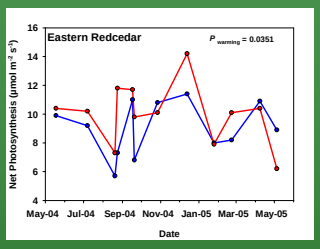
- Are there season x driver interactions, e.g. does winter warming have a larger effect than summer warming?
- Are there competitive interactions between the species in terms of net gas exchange, and are these consistent through time?

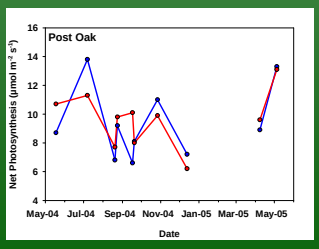
AV4

Warming and Gas Exchange





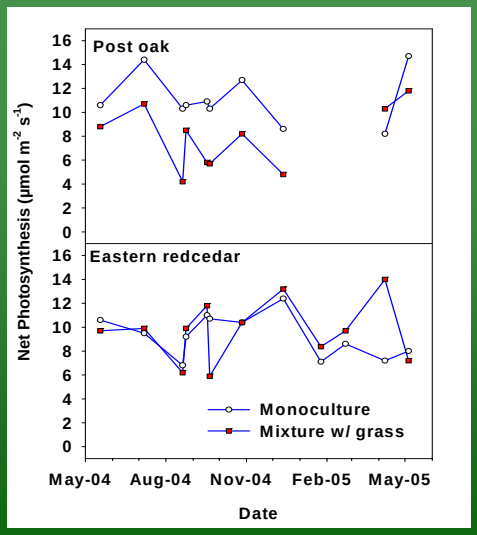




Slide 18

AV4 Note that we do have main driver effects (precipitation redistribution) throughout the summer on both gas exchange (for oak) and waterpotential (for all). This is the only warming effect though.
Astrid Volder, 6/7/2005

Tree-Grass Competition



Conclusions

- Treatments effectively simulated the global change drivers e.g., soil water was reduced 30% in summer and increased 3% in spring-autumn; top soil temperature increased by 0.6 ^{o}C.
- $\Psi_{mid\text{-}day}$ was most negative for oak and least negative for the grass. Grass presence increased water stress for both woody species in summer, but woody plants did not magnify water stress in the grass.
- Intensified summer drought increased water stress (more negative water-potential) for the C_4 grass and juniper, but less so for the oak. In spite of increased water stress, A_{area} was unaffected in both grass and juniper, but decreased in oak.

Conclusions

- In spite of reduced water stress after a summer rainfall event, all growth forms were relatively unresponsive to summer rainfall in terms of A_{area}.
- These data demonstrate that interactive effects of season, drivers and species composition will affect the response of southern oak savanna to climate change, rather than direct effects of the global change drivers *per se*.

Future Direction

- Our goal is to continue the current experiment to:
  - Evaluate cumulative driver effects as plants increase in size and competitive ability.
  - Initiate investigation of driver effects on ecosystem processes e.g., decomposition, N mineralization and soil respiration.
  - Explore potential feedback processes between plants and their environment e.g., litter composition and quality

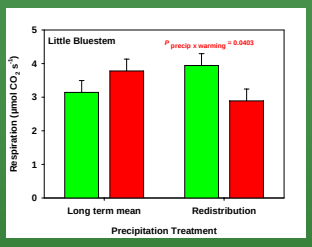
Soil Respiration

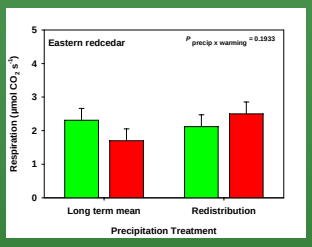


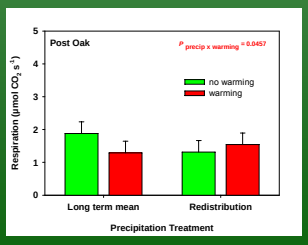
- Is soil respiration affected by species composition?
- Do warming and precipitation treatment affect soil respiration and are these responses affected by species composition?


Soil Respiration









$P_{mixture} < 0.0001$

$P_{mixture\ x\ precip\ x\ warming} = 0.0044$

Soil respiration in plots with C_4 grass responds opposite to warming and precipitation than in plots with tree monocultures

Synergistic Activities

Student training

- Undergraduate (7)
- Graduate
  - Oana Popescu (*soil respiration*)
  - Daniel Chmura (*canopy processes*)

Leveraged funding through Texas A&M University

- Technician salary support ($15,000 per year)
- Equipment purchases ($16,500)
- Electricity costs ($14,000 per year)

News coverage

- *Earth, sky tapped in unique global climate change study* (Agriculture Program News Release, May 11, 2004).
- Texas A&M University *Lifescapes* Vol. 4(3), Fall 2004.

Publications & Abstracts

Atkin OK, MG Tjoelker. 2003. Thermal acclimation and the dynamic response of plant respiration to temperature. *Trends in Plant Science* 8, 343-351.

Briske DD, MG Tjoelker, A Volder. Experimental warming and rainfall redistribution in southern oak savanna: infrastructure, design and plant growth responses. Meeting of the Ecological Society of America, Montreal, Canada, August 7-12, 2005 (poster & abstract).

Tjoelker MG, A Volder, DD Briske. Experimental warming and altered rainfall distribution in southern oak savanna: leaf-level gas exchange. Meeting of the Ecological Society of America, Montreal, Canada, August 7-12, 2005 (poster & abstract).

Volder, A, MG Tjoelker, DD Briske. Experimental warming and altered rainfall distribution in southern oak savanna: plant-soil water relations. Meeting of the Ecological Society of America, Montreal, Canada, August 7-12, 2005 (poster & abstract).

Acknowledgements



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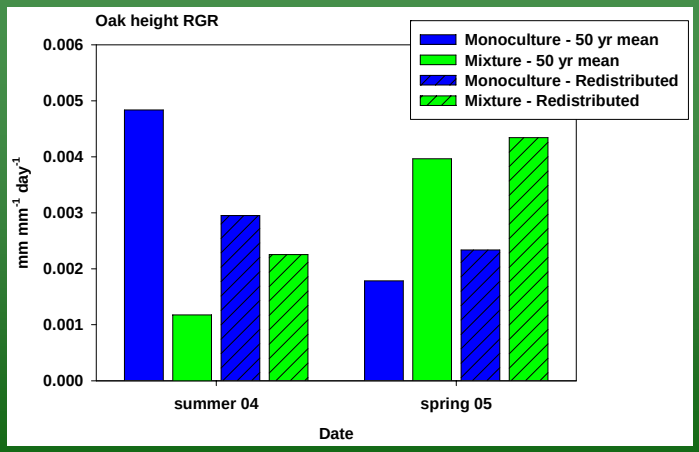
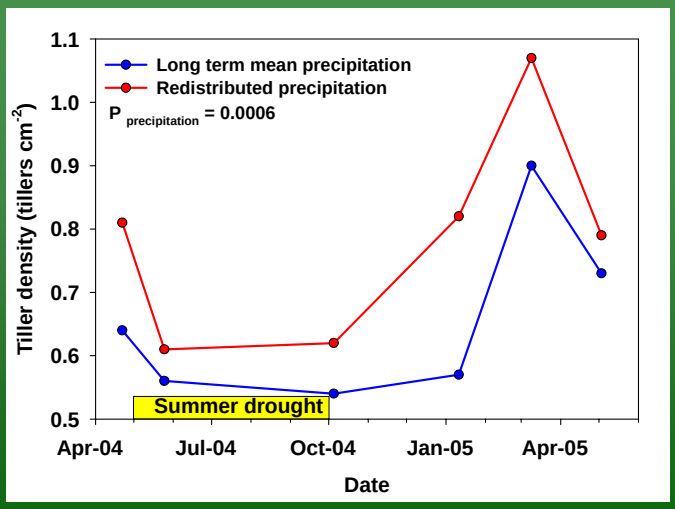
Precipitation Regime, Mixture, Season and Oak RGR





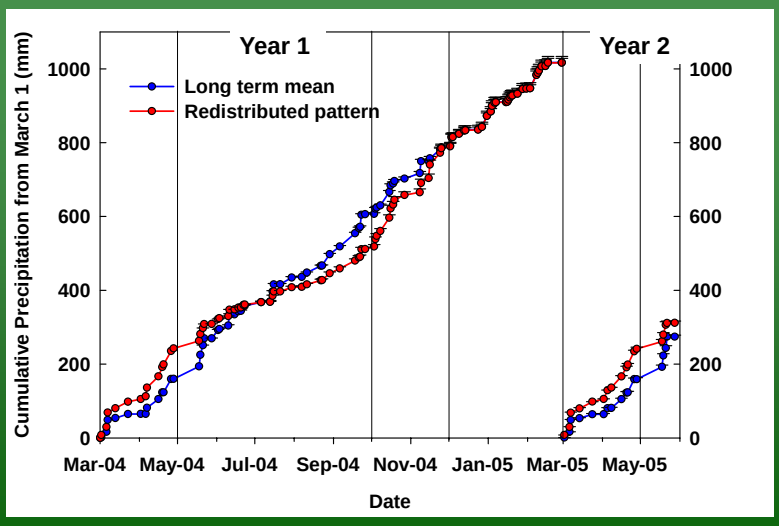
Grass Tiller Density





Event Size and Frequency





Oak Canopy Cover (%)