Runoff mechanisms associated with woody plant encroachment in the mesic grassland of Oklahoma

Lei Qiao, Chris Zou, Elaine Stebler, and Rodney Will

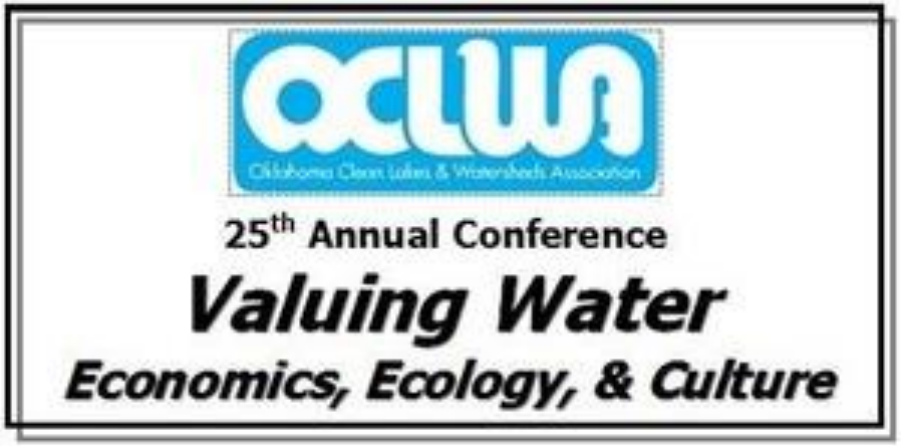
Department of Natural Resource Ecology and Management

Oklahoma State University

03/29/2016
Stillwater, Oklahoma

OKLAHOMA STATE UNIVERSITY
AGRICULTURE

The conference theme and our study

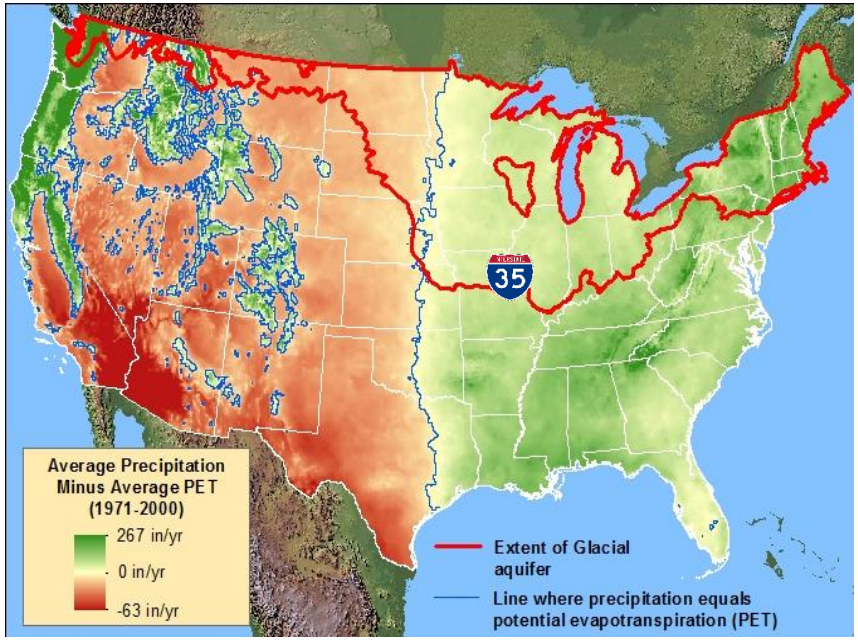


Encroached grassland in north-central Oklahoma

More water or more woods?

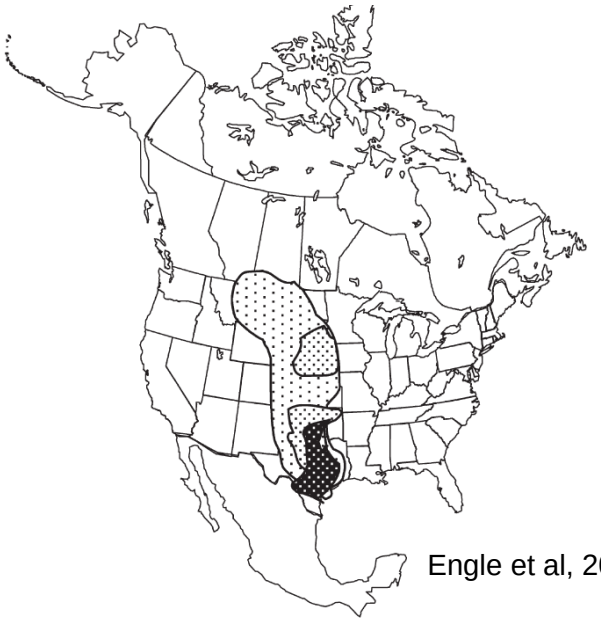
Great Plains in transition

1. Climate



http://mi.water.usgs.gov/projects/WaterSmart/background.html

2. Distribution of eastern redcedar



Engle et al, 2008

Why we care?

- Millions of acres of redcedar encroachment in Oklahoma (OSU E-947)
- Expansion of woody plants in SGP is 5- to 7-fold greater than that in other regions of the USA (Barger *et al*., 2011)
- Encroachment is degrading ecosystem services
- Demand for water is increasing

Impacts of woody encroachment on water budget

- Reduces streamflow or groundwater recharge
- Impairs water resources availability
- Great uncertainty in magnitude!!

OBS

Dugas et al., 1998: Bowen ratio-energy 35-85 mm/yr higher in ET

Huang et al., 2006: streamflow increased 46 mm/yr after removing juniper

Owens et al., 2006: canopy interception ~20% higher than grassland

Zou et al., 2013: 80 mm/yr runoff reduction

SIM

Wu et al. [2001]: (SPUR-91) model: 200 mm/yr increase of streamflow assuming woody cover being reduced by 40%

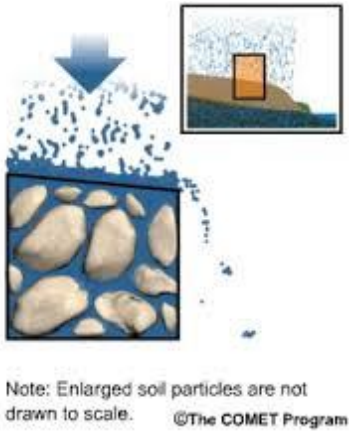
Afnowicz et al. [2005]: SWAT modeling within the Edwards Plateau. ET reductions ranged from 32 to 47 mm/year by removing juniper

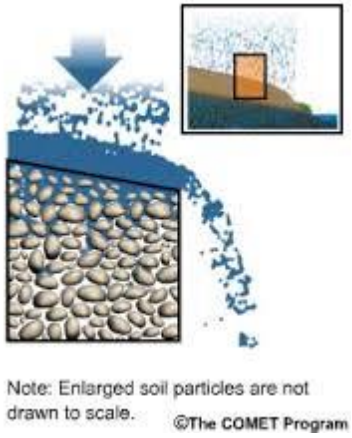
Bumgarner and Thompson [2012]: suggested water yield would increase by an average of 36 mm/yr by removing juniper

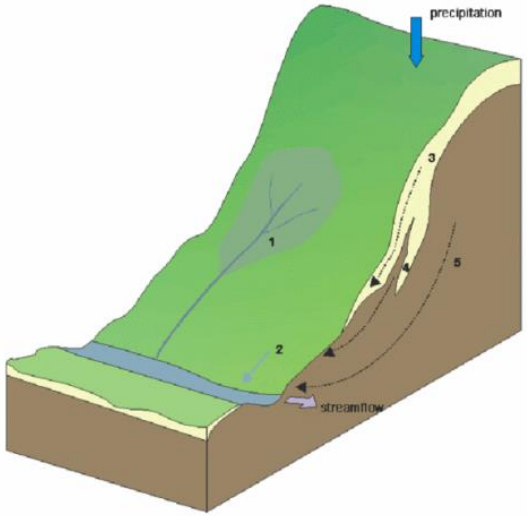
Runoff mechanisms: Unknown

Types of surface runoff:

- Saturation excess overland flow?
- Infiltration excess overland flow?
- Are these different between grasslands and redcedar woodlands?







Subsurface runoff contributions:

- Dominant in redcedar woodlands?
- Substantial contribution to total runoff?

http://daad.wb.tu-harburg.de/tutorial/flood-probability-assessment/hydrology-of-floods/characterization-of-floods/processes-acting-on-the-formation-of-surface-runoff/

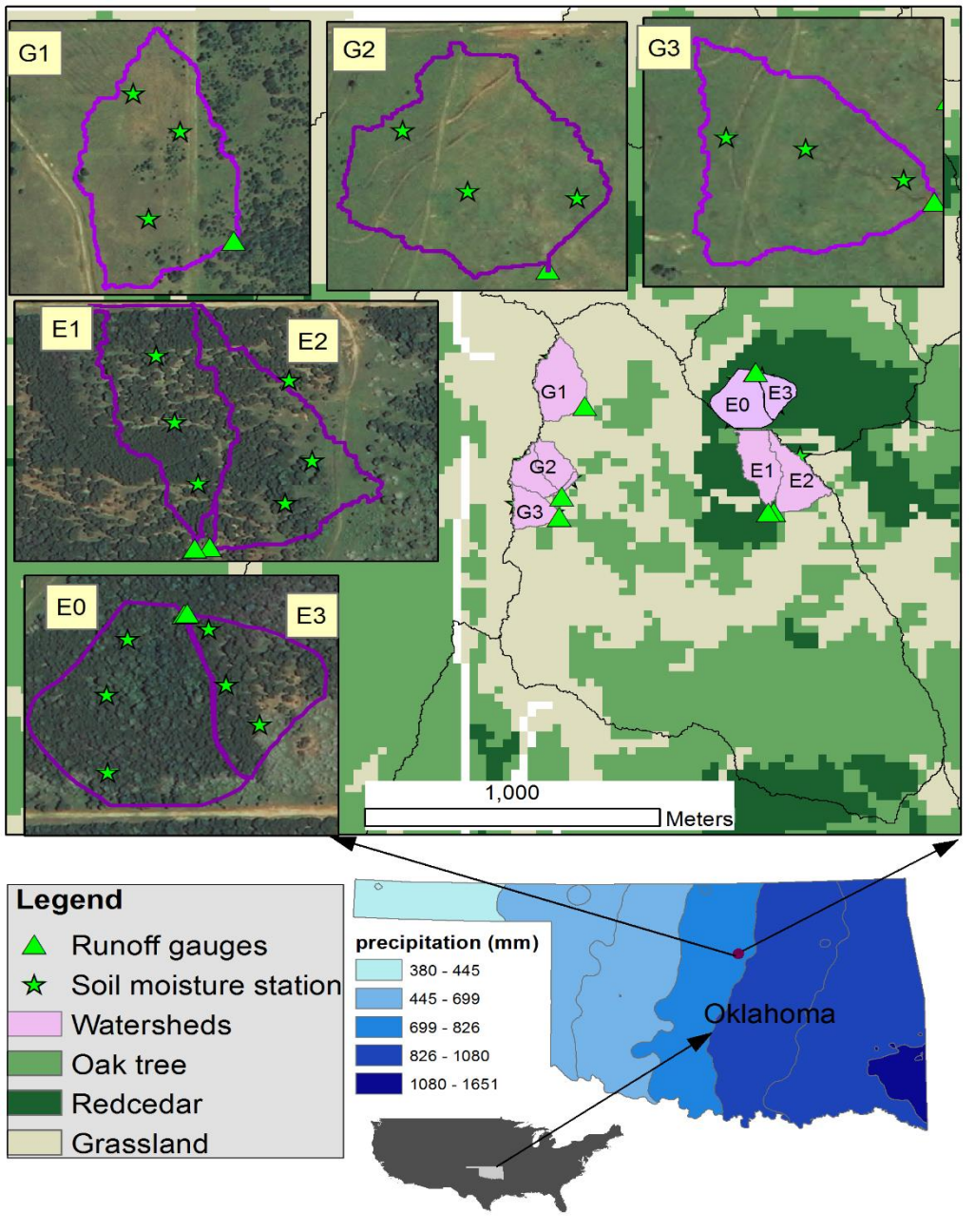
Objectives:

1). Analyze the soil moisture content and soil water storage dynamics between grassland and eastern redcedar encroached watersheds

2). Determine the dominant runoff mechanisms and illustrate underlying hydrological processes for each vegetation type

3). Statistically test the runoff difference between grassland and eastern redcedar encroached watersheds

Study area and measurements



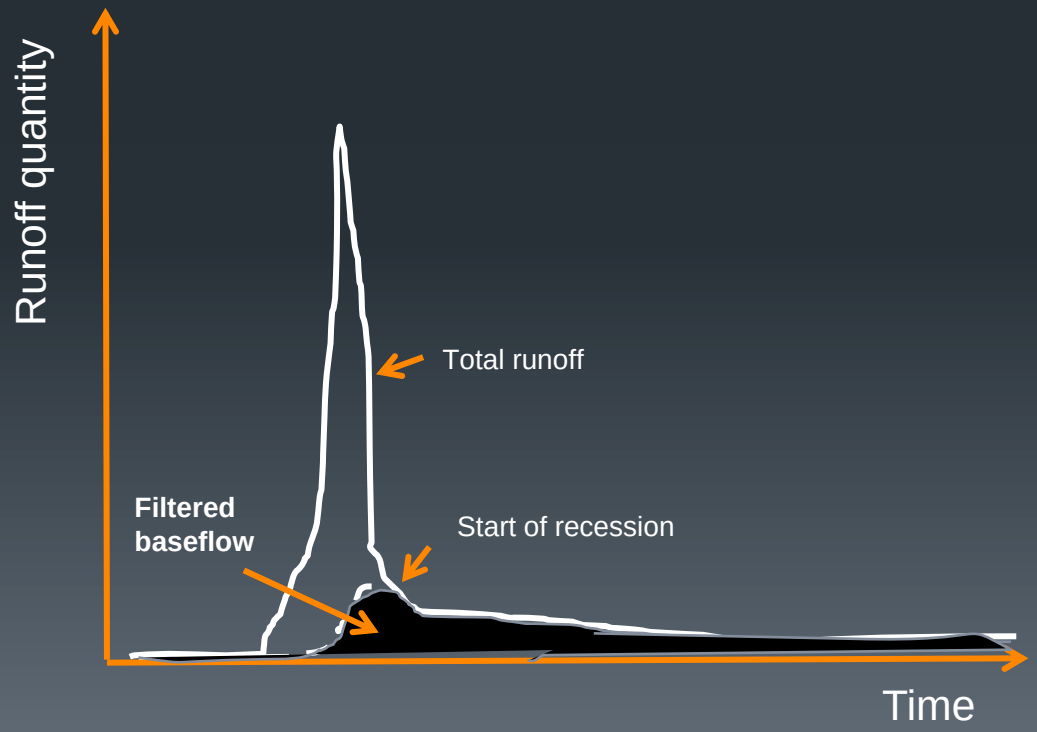
Water year: 2011-2014

5-minute intervals

15-minute intervals

Methods

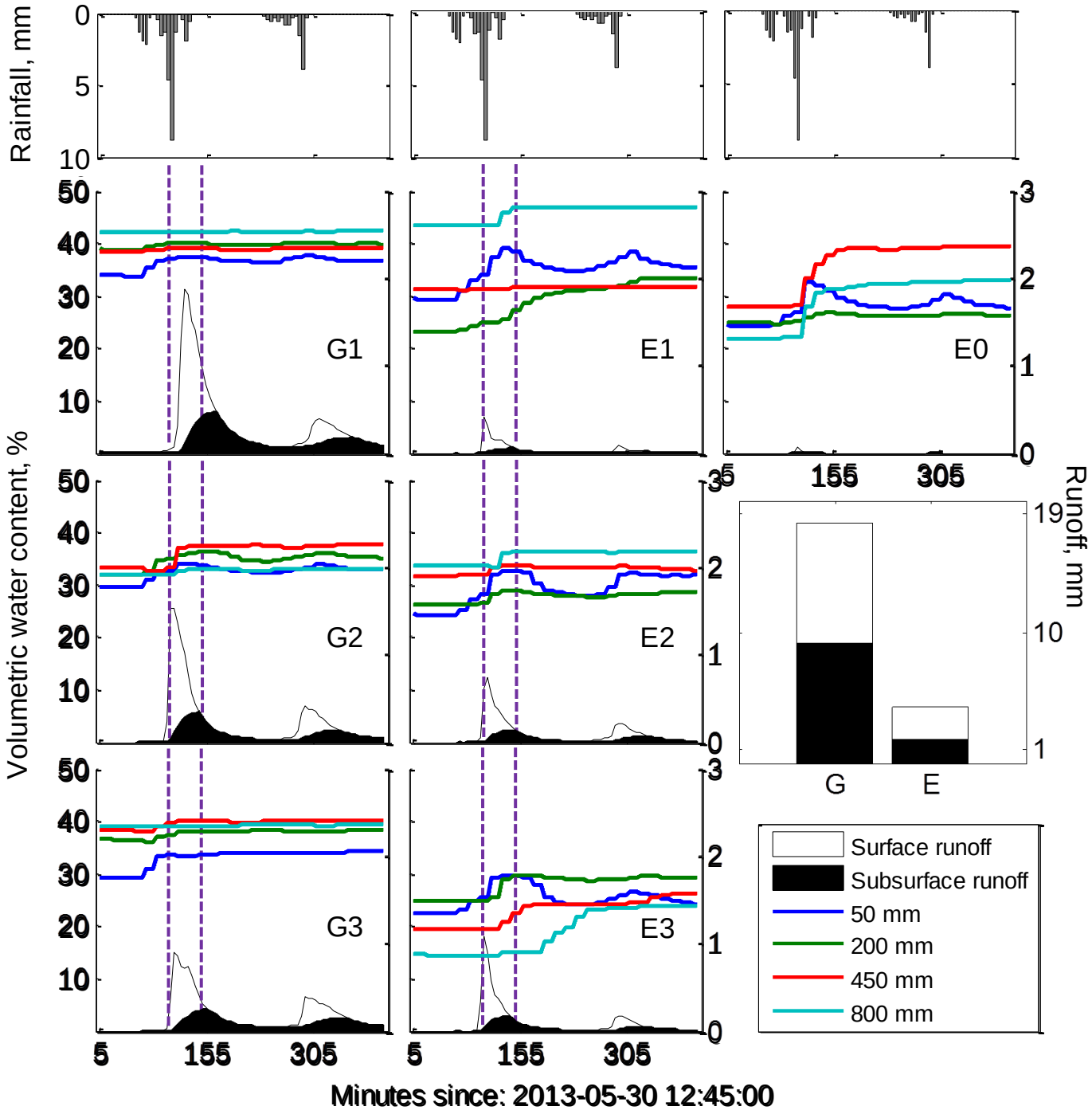
- Used a 6-hour gap to separate individual rainfall events
- Used the recursive digital filter method to separate baseflow from total runoff for each rainfall event
- Daily, monthly and yearly runoff accumulations were generated from the 5-minute runoff values
- A repeated measures analysis was conducted in Proc Mixed (SAS 9.3) to test for significance of Year*Runoff, Year*Cover, and Runoff*Cover interactions



Modified from Arnold et al., 1995

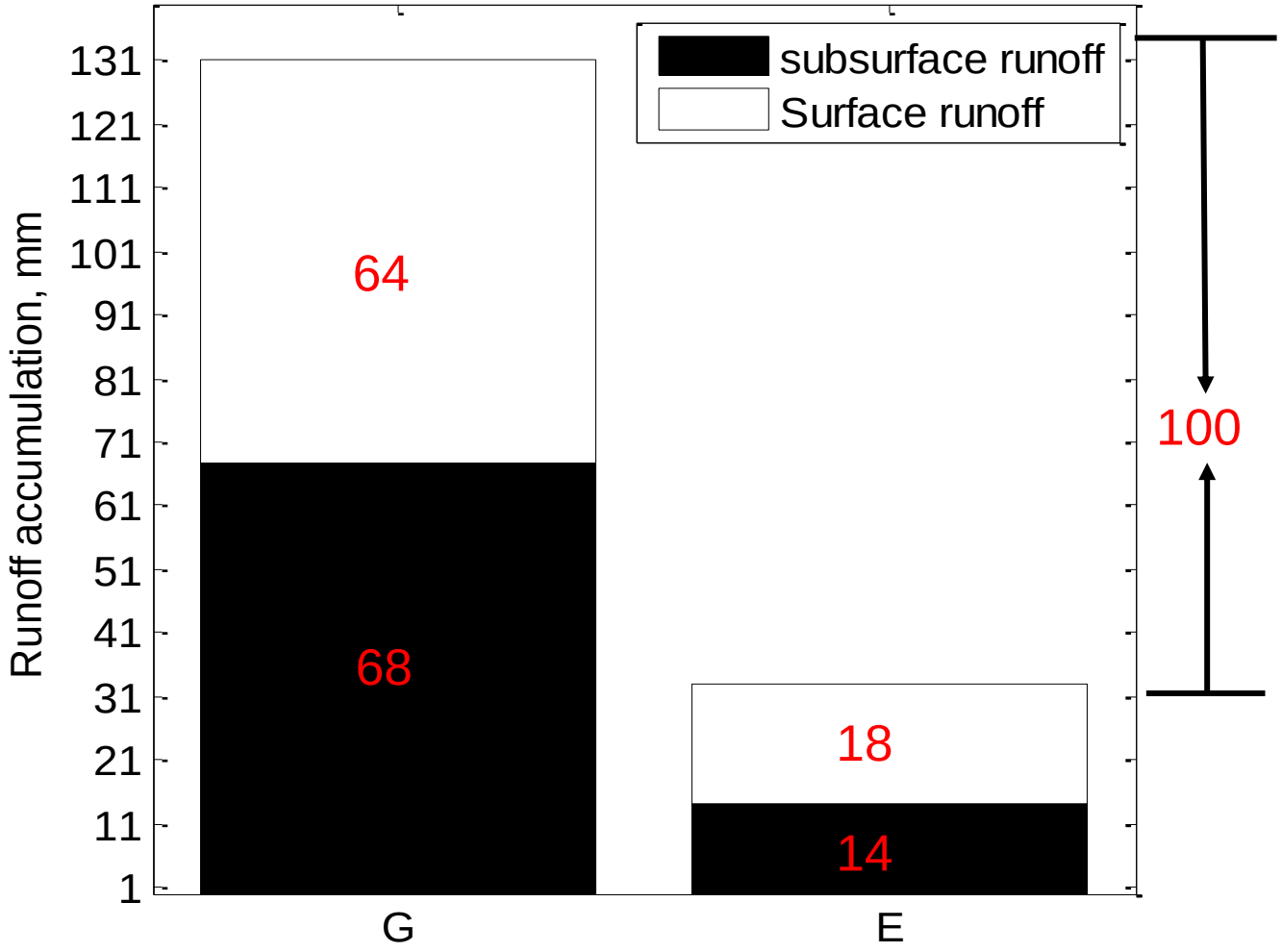
Results

1. Event-scale soil water dynamics and runoff responses



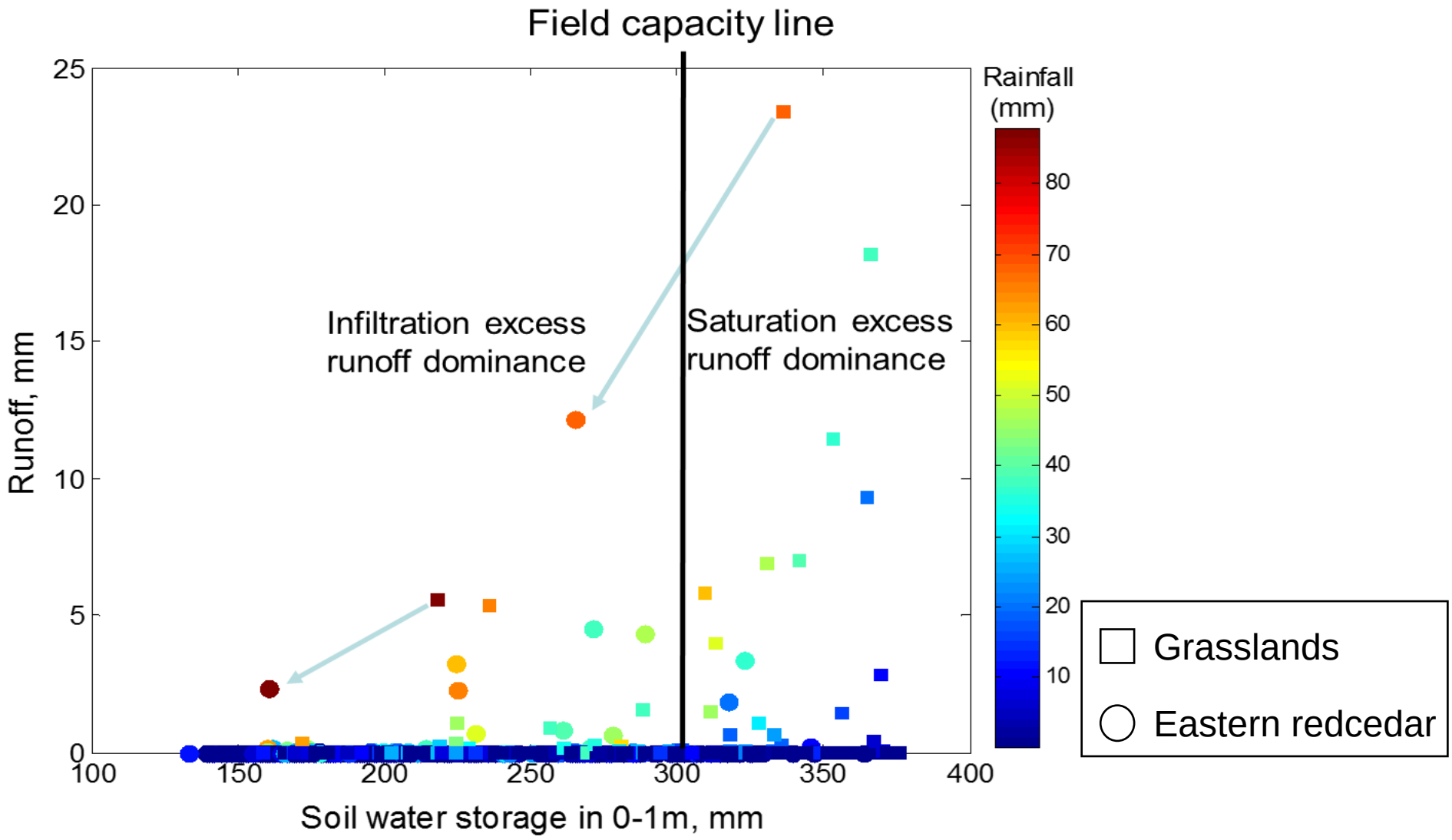
Results:

2. Runoff composition from all events during 2011-2014



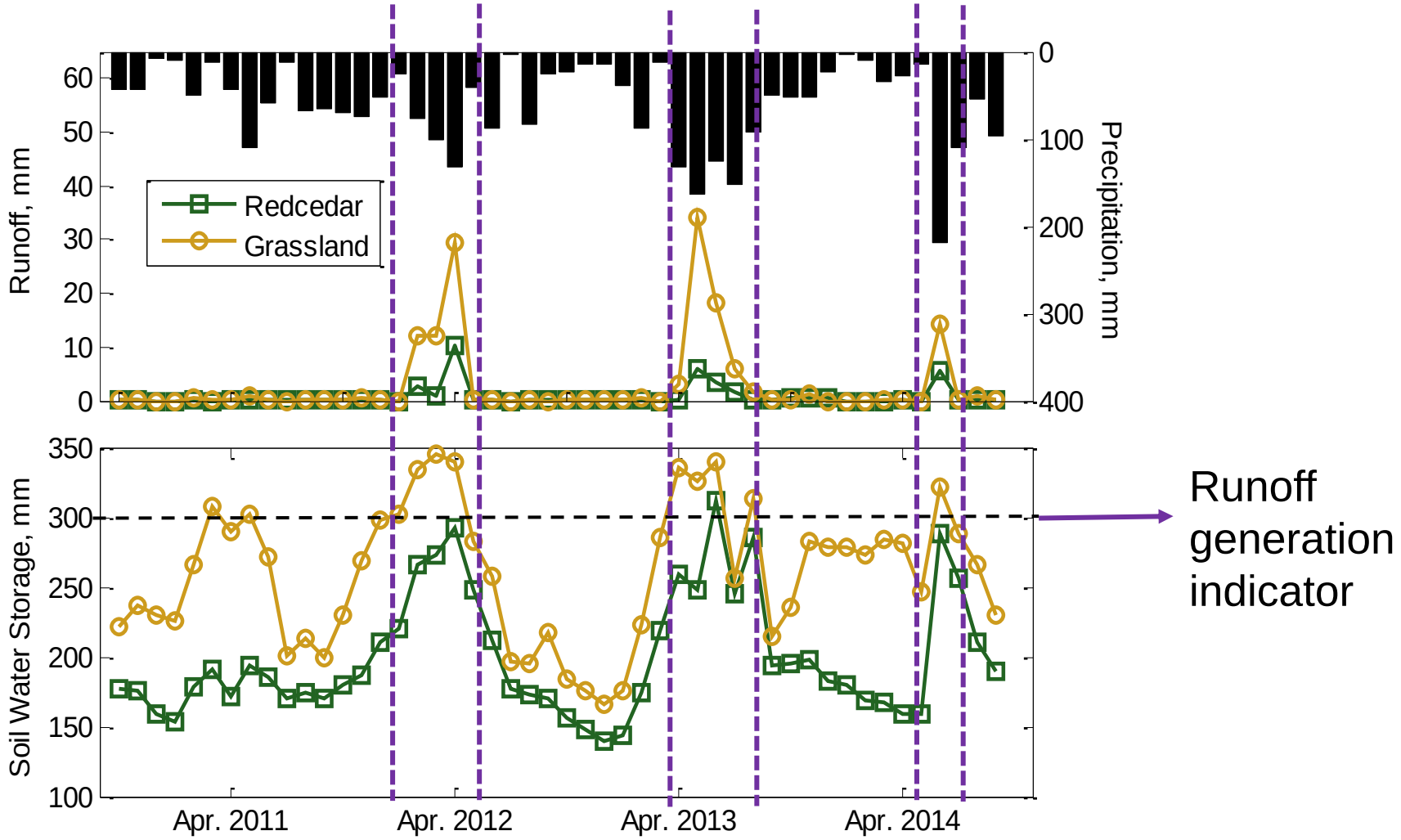
Results:

3. Runoff and antecedent soil water storage relationship



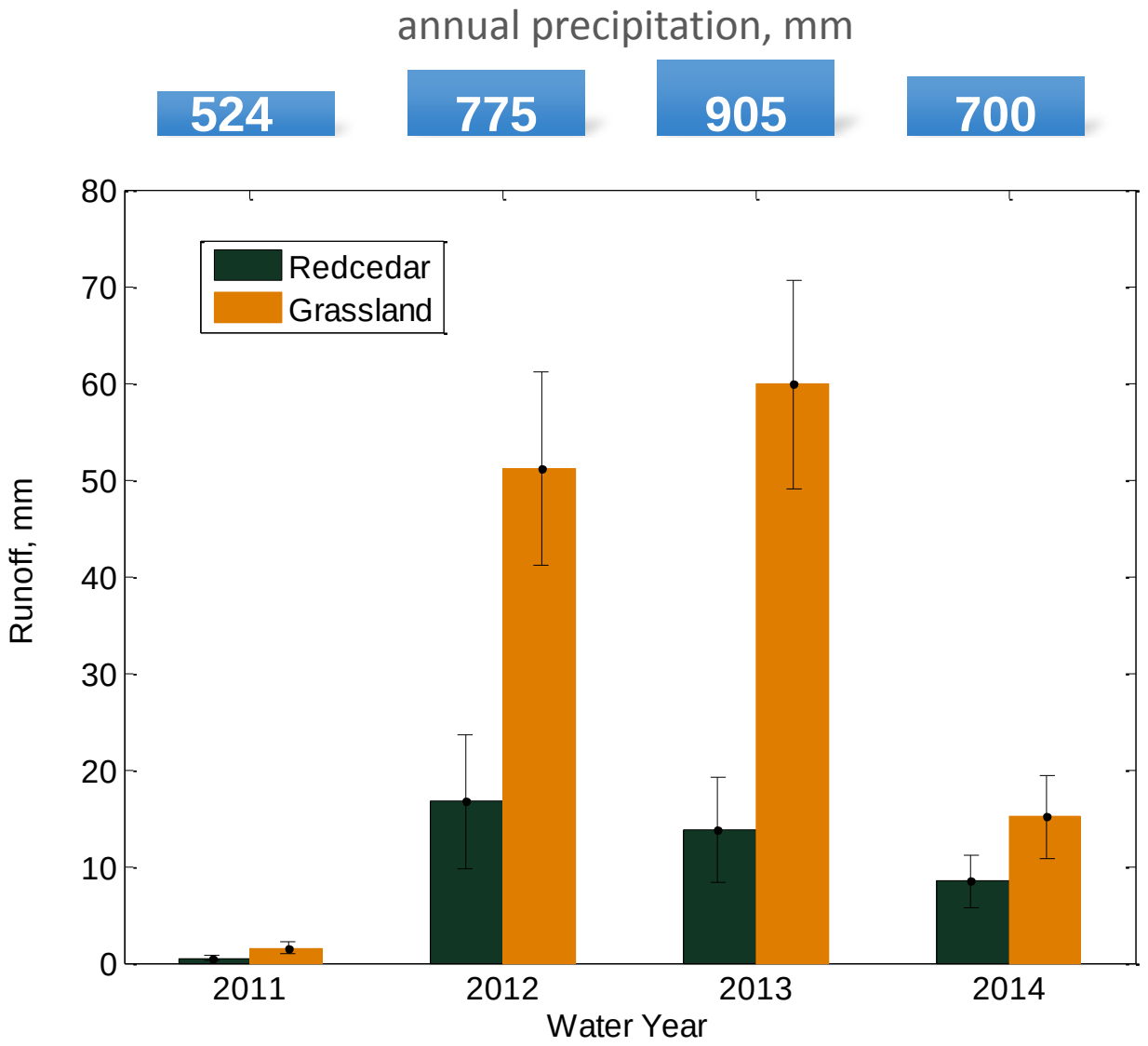
Results:

4. Monthly runoff and soil water storage fluctuations



Results:

5. Annual runoff mean and standard errors

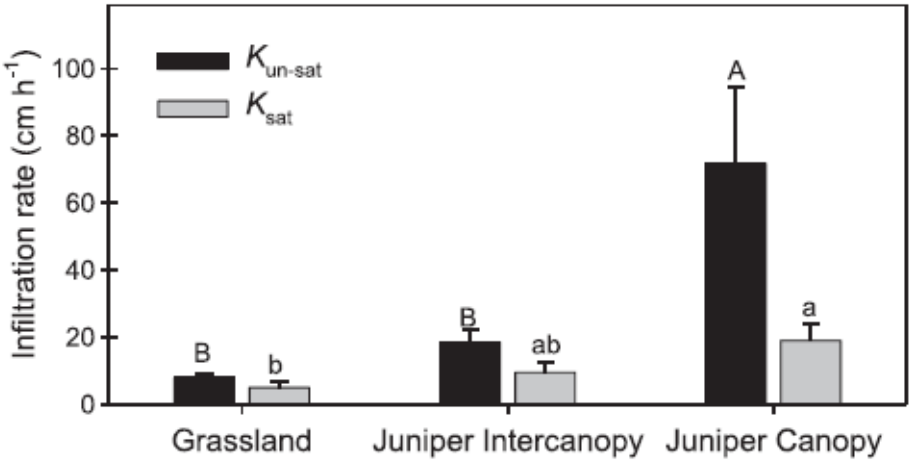


- Significant reduction in runoff for different years
- Nonsignificant date*vegetation type interaction (p= 0.48)

Discussion:

Closed-canopy forests are less likely to have infiltration excess overland flow.

Woody plant encroached grassland is different with more wide open inter-canopy spaces with less infiltration capacity.



Zou et al., 2014

Conclusions:

Grasslands:

- Saturation excess overland flow was a primary contributor to the surface runoff
- Subsurface runoff seemingly equally or slightly more contributed to total runoff

Eastern Redcedar:

- Soil water storage was less and the soils were rarely saturated
- Surface runoff was generated from infiltration excess overland flow during the few high intensity storms. This flow was likely generated from the grassy areas of the inter-canopy spaces
- Both surface and subsurface runoffs were reduced, and the reduction was higher in subsurface runoff component.

Conclusions:

Water budget impacts:

- Total runoff from the eastern redcedar watersheds was 100 mm less than from the grassland watersheds for 2011 to 2014
- The runoff difference was statistically significant between the two land covers

Acknowledgement

Funding sources

- South-central Climate Science Center
- Oklahoma Agricultural Experiment Station
- USGS/NWRI grant (G09AP00146)
- NSF DEB-1413900
- NSF EPSCoR (NSF-1301789)
- USDA-NRI Sustainable Bioenergy:2014-67010-21653