Soil moisture impacts of redcedar encroachment in the Cross Timbers ecoregion

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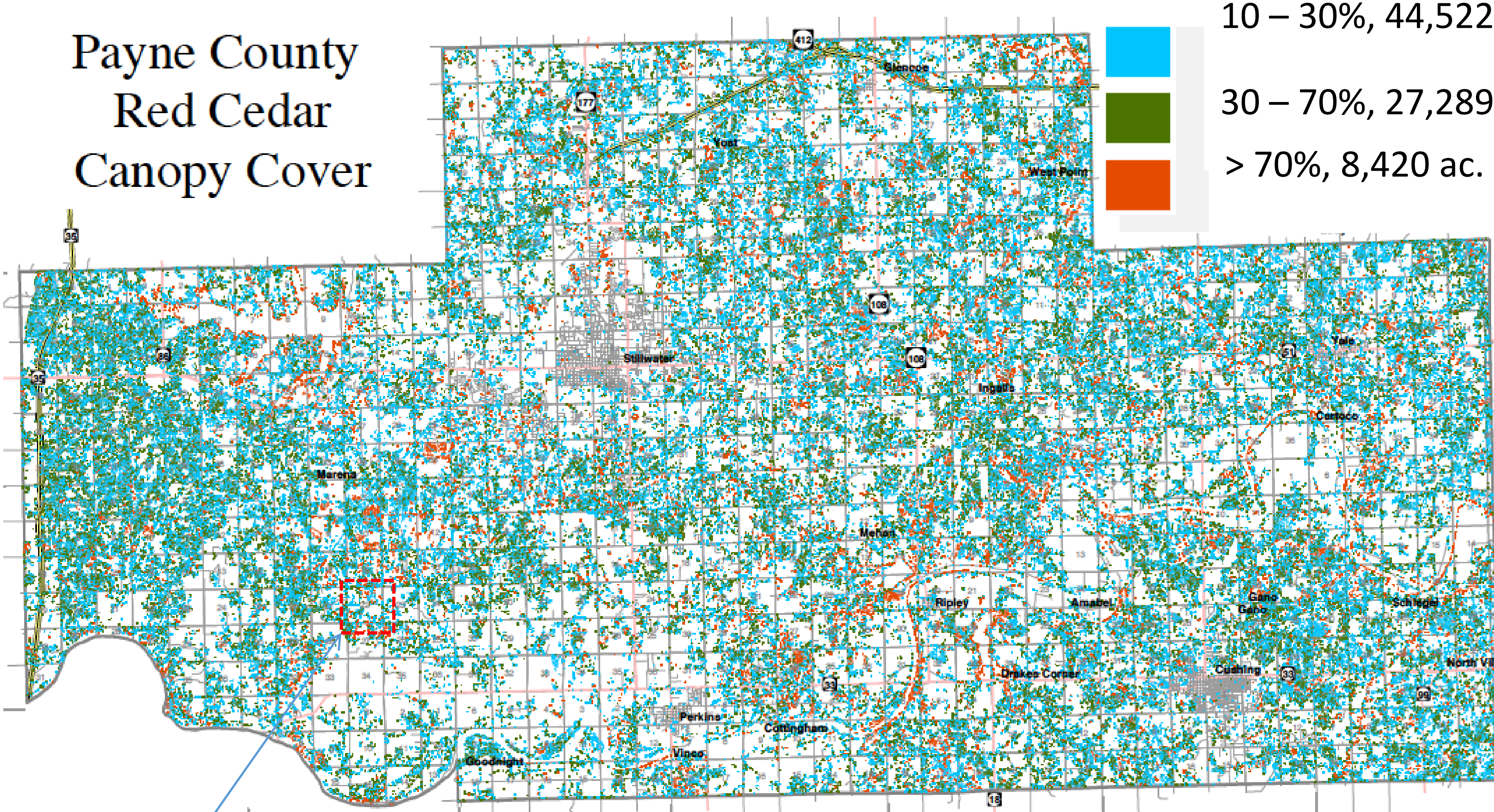
Multiple million acres of redcedar encroachment in
Oklahoma

Payne County Red Cedar Canopy Cover

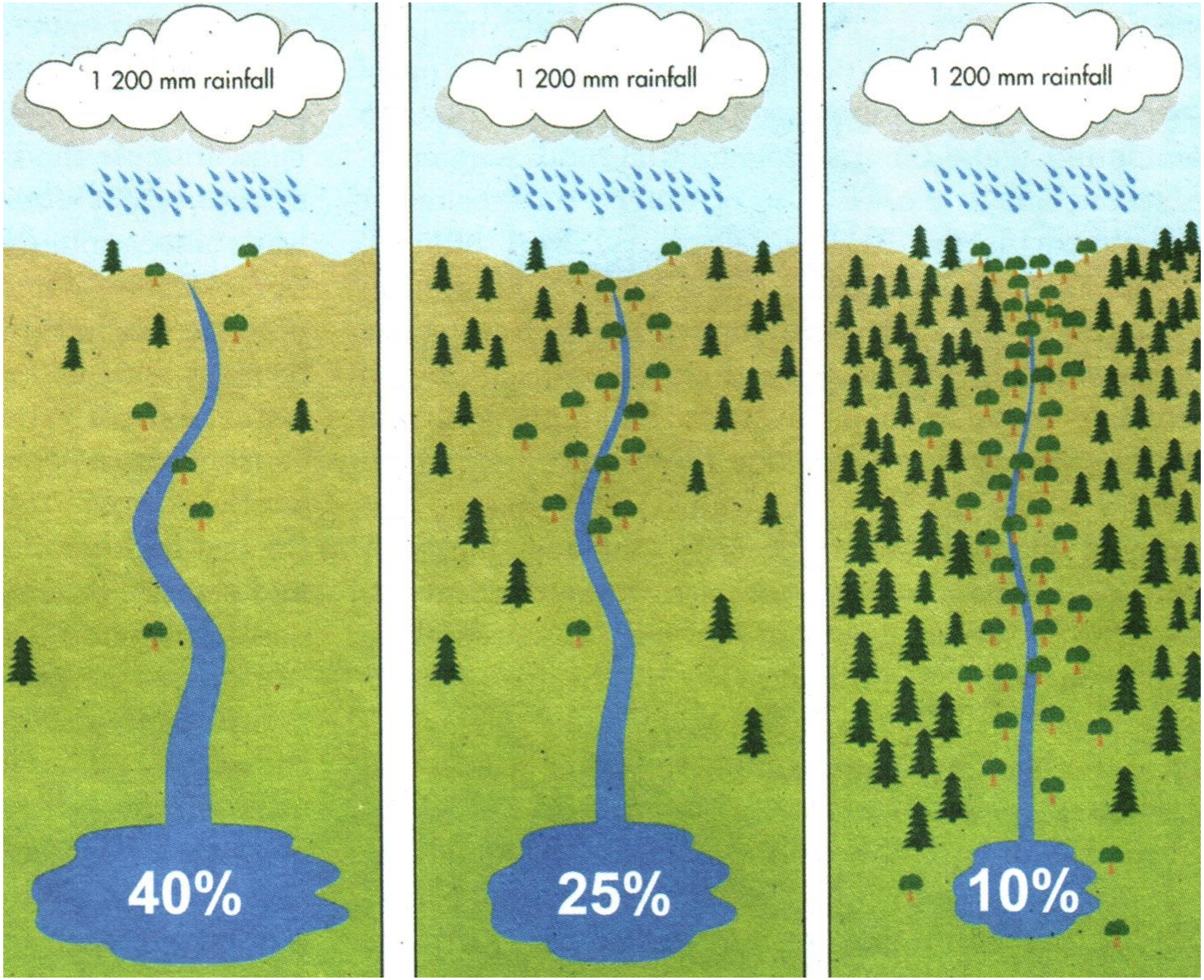
10 – 30%, 44,522 ac.

30 – 70%, 27,289 ac.

> 70%, 8,420 ac.



OSU Rangeland Research Station (OSURRS)



Modified from Mark & Dickinson 2008 *Frontiers in Ecology and the Environment*

ECOLOGY

When Juniper and Woody Plants Invade, Water May Retreat

Dense plants are taking over grasslands in many areas; researchers in the U.S. Southwest are studying how they tap into water supplies—and how to keep them in check

AUSTIN—The day is hot and humid, as Robert Jackson descends into the mouth of Powell Cave and down a ladder that drops into the limestone bedrock of the Edwards Plateau about 240 kilometers west of Austin. He follows an ancient streambed through several large caverns and a few tight crawl spaces, until he arrives at a point about 18 meters below the surface, where a crystal-clear stream bubbles out of the rock.

Several thick tree roots burst out from the limestone, reach down, and suck moisture from the water. Some of them have been wired with electronic probes. Applying pulses of heat, Jackson and his lab can gauge water flow by how fast that heat dissipates. Jackson, a biologist at Duke University in Durham, North Carolina, is investigating how roots transfer water from this depth up to the surface. "A single taproot can provide a third or more of the tree's water during a drought," says Jackson.

His study aims to determine what enables juniper to survive in these arid environments and how much ground water they are using. Funded by the U.S. National Science Foundation, the U.S. Department of Agriculture, and the Andrew W. Mellon Foundation, this research indicates that wildlife and water management would benefit from fewer of these trees.

Woody shrubs and trees like juniper have in recent decades replaced arid and semiarid grasslands and savannas throughout much of the western United States, from the Great Plains to the Gulf Coast. "Encroachment of woody plants limits the amount of forage available to livestock, alters the natural landscape for native wildlife, impedes the flow of water available at the surface, and creates conditions for more catastrophic fires," Jackson says.

With global warming predictions calling for increased droughts, expansion could continue. And it's not just a U.S. problem: The shrubs and trees are proliferating in grasslands and savannas in South America, Africa, and Australia.

Depleted streams

The effect of expanding woodlands on water flow can be dramatic. Kathleen Farley of San Diego State University in California and Jackson reviewed data sets from efforts to establish new forests in Africa, New Zealand, Australia, and Europe and found that increased tree and shrub growth typically resulted in the loss of one-third to three-quarters of stream flow. "In areas where natural runoff is less than 10% of mean annual precipitation, afforestation can result in complete loss of runoff," says Farley. As a consequence, some say, afforestation efforts that have been proposed as carbon offsets need close scrutiny.

The same types of growth appear to be draining water from the Swiss-cheese structure of the limestone bedrock, known as karst, on the Edwards Plateau. Such systems cover one-fifth of Texas and 7% to 10% of the globe's land surface. This area in Texas gets about 63.5 centimeters of rain a year, yet there are few aboveground streams. Jackson's research shows that the drinking habits of these trees may be partly responsible.

One hundred and fifty years ago, this area was comprised of grasslands and savanna where oak trees dotted the landscape. They were more frequently swept by wildfires, one of several factors that kept woody plants at bay. "There is likely no single driver" of the change to denser growth, says Steve Archer, a professor at the School of Natural Resources at the University of Arizona, Tucson. Fire suppression, overgrazing, droughts, and climate change have all played a part in helping woody plants succeed, he says.

Juniper is the dominant woody invader throughout much of the Great Plains and the West, but mesquite plays a role in the southern Great Plains and the Southwest, creosote in the Southwest, and Chinese tallow in the Gulf Coast Prairies. Juniper and mesquite have invaded the plateau, forming dense monocultures in which birds and wildlife don't do well. Black-capped vireos and golden-cheeked warblers, two Texas birds that are both endangered, are among those that require a mixed-forest habitat to thrive.

Large mammals are affected as well. The bighorn sheep of New Mexico, already endangered, are increasingly threatened by attack from mountain lions, which are moving into wooded mountaintops that were bald in the past. According to Eric Rominger, a bighorn sheep biologist at the New Mexico

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"In areas where natural runoff is less than 10% of mean annual precipitation, afforestation can result complete loss of runoff."

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Published online 4 March 2010 | Nature | doi:10.1038/news.2010.107

News

Woody shrubs don't slurp up water

Clearing encroaching plants from savannah might make drought worse.

Erik Vance

Most Texans know that ranchers don't like shrubs. That's because of an assumption that when woody plants move into an area, they greedily horde water and drain nearby rivers. That assumption is the driving force behind efforts from Texas to South Africa to clear shrubs from drought-prone land.

Trees and shrubs may help to keep water flowing in arid areas. The degraded area on the left of this picture could struggle to hold water in the same way. *Charles Taylor*

However, there is one problem — according to a study by researchers at Texas A&M University in College Station, that assumption may not be true. Hydrologist Bradford Wilcox and his colleague Yun Huang examined water levels going back to 1925 for four of Texas's biggest rivers near the parched Edwards Plateau in the west of the state. What they found shocked them.

"Rivers on the Edwards Plateau not only are not disappearing, but they are increasing in flow," says Wilcox, who is first author on the study, to be published in *Geophysical Research Letters*[1]. "By a lot. I mean, it's doubled. That's really big."

The landscapes that Wilcox is describing are karst savannahs that are fed by groundwater and the occasional rain storm. A century ago, the Edwards Plateau was heavily populated by massive herds of cows, goats and sheep. However, as Texas developed, the number of herds diminished and left wastelands of eroded soil and rock. These 'degraded' landscapes slowly recovered and, eventually, aggressive woody shrubs such as juniper and mesquite blanketed what had once been prairie. Such plants today are demonized as greedy water drinkers, and ranchers are asking for government help in removing them. Yet, when Wilcox examined water records, he found an increase in water flows that he attributes to increased land cover by woody plants. Rain patterns in the area haven't changed drastically and there has been little urbanization.

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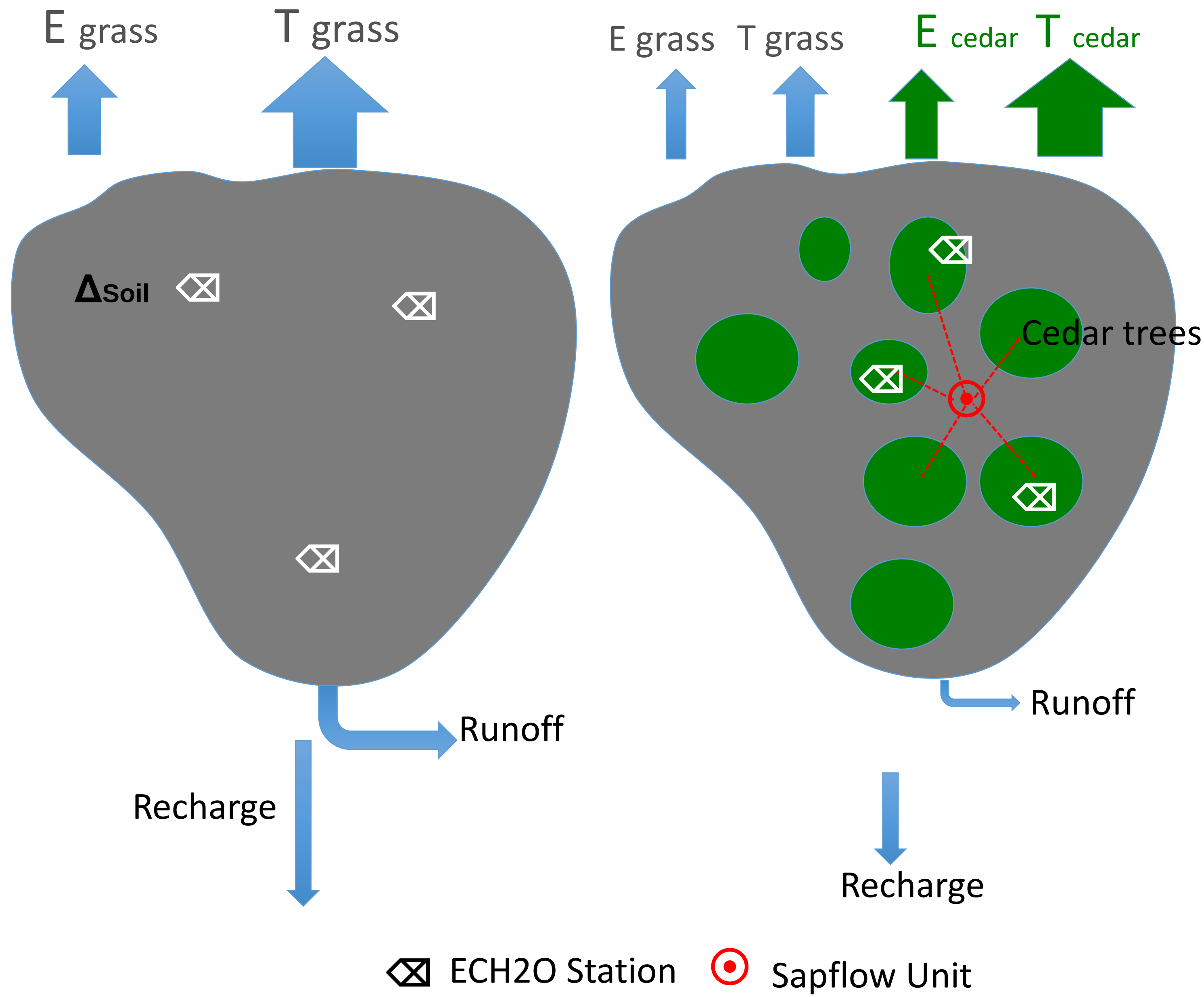
- Bradford Wilcox
- Texas Parks and Wildlife Department: Edwards Plateau Ecological Region

"Water levels going back to 1925 for four of Texas's biggest rivers" revealed "Rivers on the Edwards Plateau are not disappearing, but they are increasing in flow."

Wilcox and Huang 2010 *Geophysical Research Letter*


E grass
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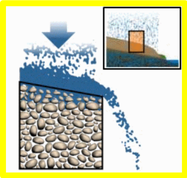
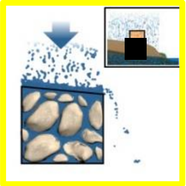
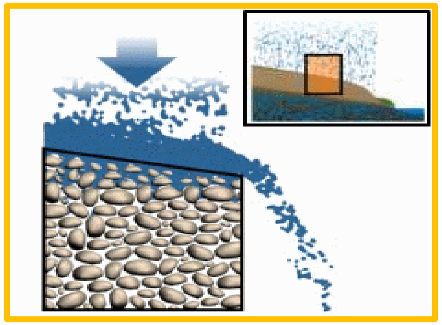


Use of temporal soil moisture data to interpret streamflow responses

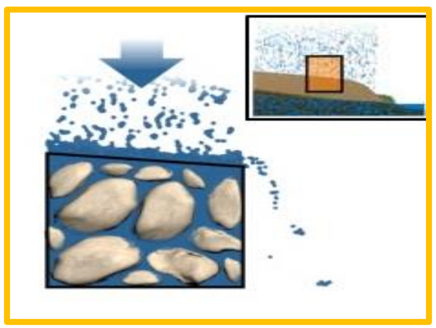


High resolution soil moisture data to constraint and parameterize hydrological model

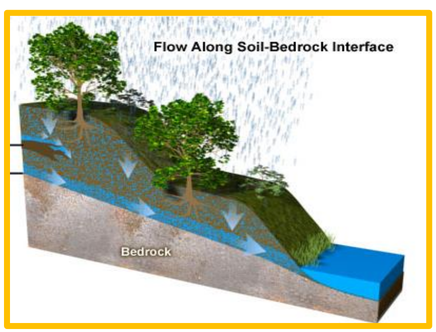
Streamflow generation in rangeland



Infiltration excess overland flow



Saturation excess overland flow



Subsurface runoff

- 3 grassland watersheds and 4 redcedar watersheds;
- 3 EC-5 swc arrays for each watersheds (a total of 21 stations);
- Add 9 stations in oak watersheds in 2015 from NSF EPSCoR

Soil water content (SWC) and Water Depth

- Grassland watersheds (n = 9)
- Encroached watersheds (n = 12)
- Water content at 4 depths every 15 min
- Soil water storage (1 meter soil)

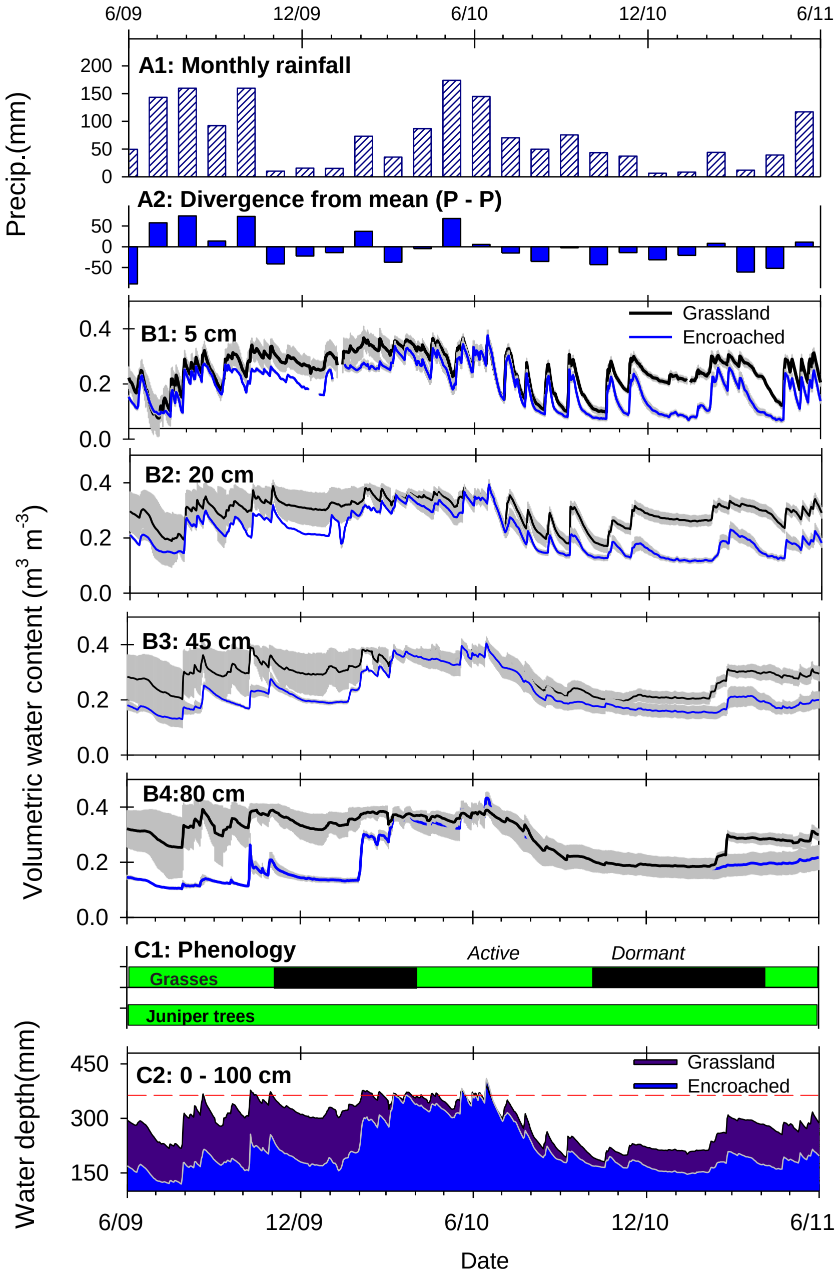
$= SWC_5 * 0.1 + SWC_{20} * 0.2 + SWC_{45} * 0.3 + SWC_{80} * 0.4$

Streamflow

Construction of flumes and weirs

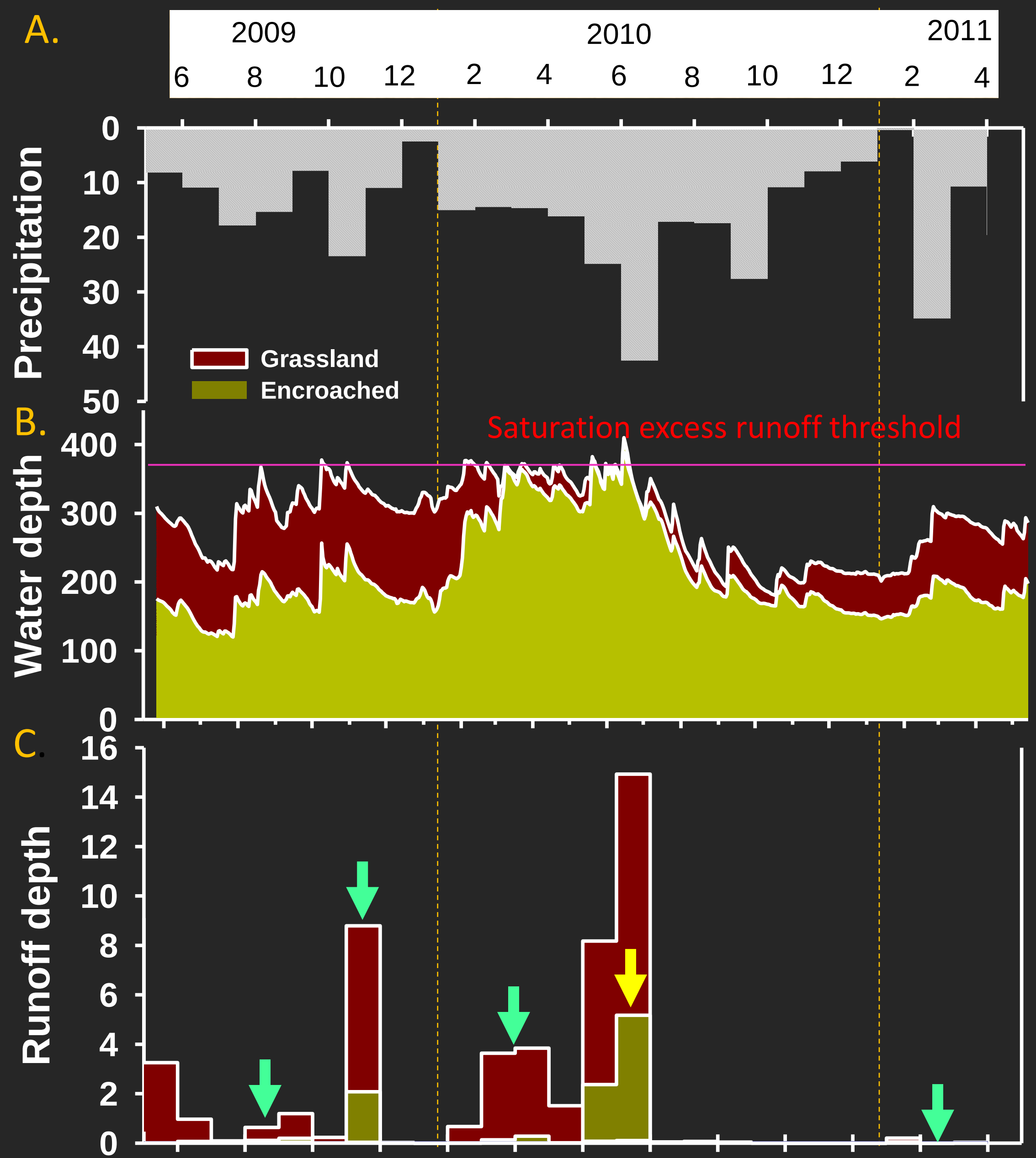
Grassland watersheds

Redcedar watersheds

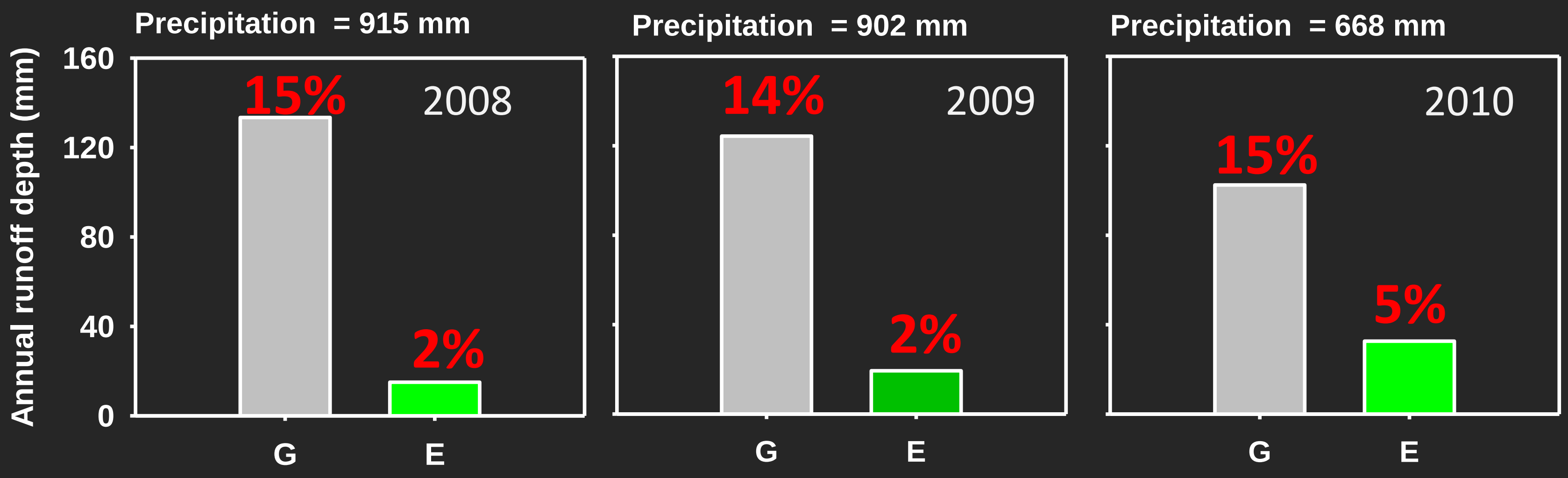


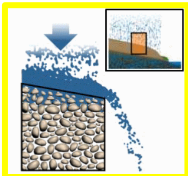
Zou *et al.* 2014. *Hydrological Process*

Coupling of runoff and soil water storage



Do water retreat when redcedars move in?





Use of temporal soil moisture data to interpret streamflow response

High resolution soil moisture data to constraint and parameterize hydrological model

Challenges in simulating redcedar impact on streamflow

- Models mostly developed for cropland, grassland or forest
- Lack of species specific parameter for eastern redcedars
- Lack of long term streamflow data from large eastern redcedar watersheds for calibration and validation
- Limited runoff events from experimental watersheds

Woody encroachment impacts on water budget: Uncertainty

SIM.

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

Afnowicz et al. [2005]: SWAT modeling within the Edwards Plateau. ET reductions ranging from 31.94 to 46.62 mm/yr by removing juniper.

Bumgarner and Thompson [2012] suggested water yield increase by an average of 36 mm by removing juniper.

High resolution soil moisture data to constraint and parameterize hydrological model

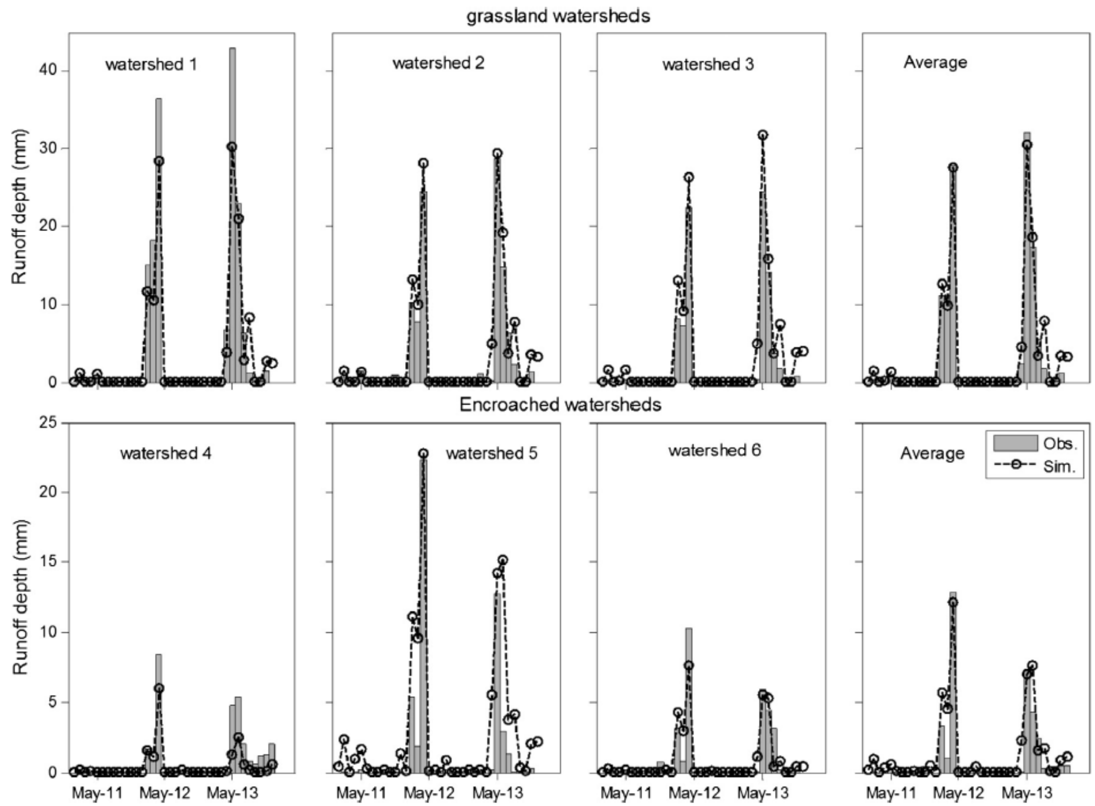
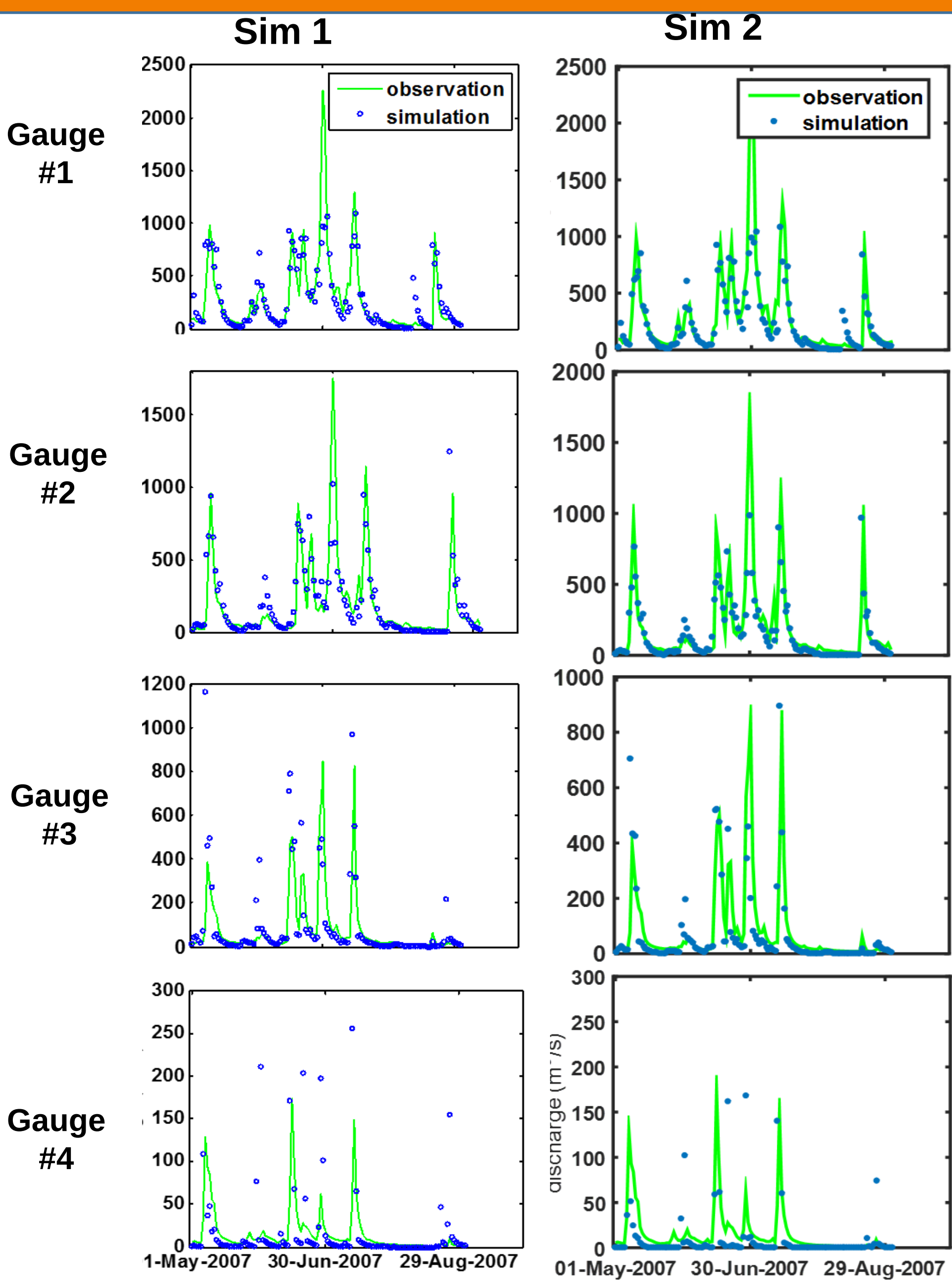


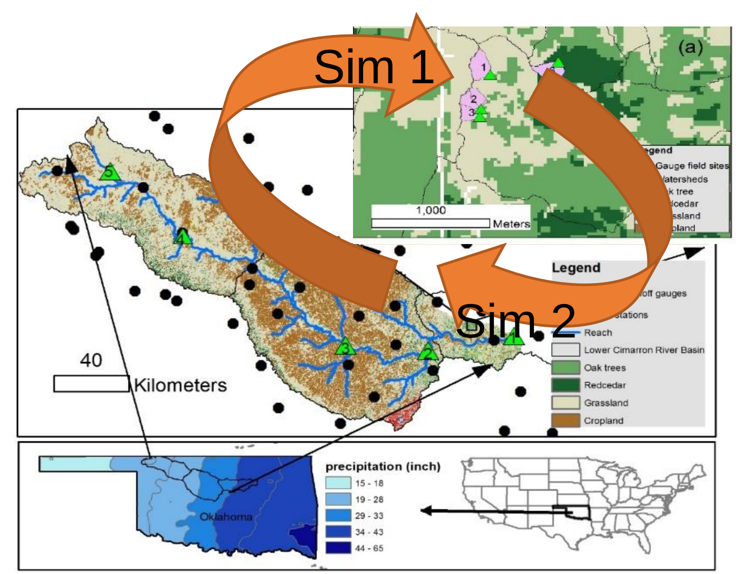
Fig. 3. Comparison of observed versus simulated monthly runoff depth from the grassland (upper panel, watersheds 1–3) and eastern redcedar encroached (lower panel, watersheds 4–6) watersheds.

Model Validation in lower Cimarron River Basin

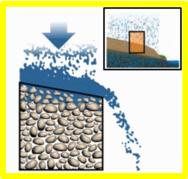


Daily Stats

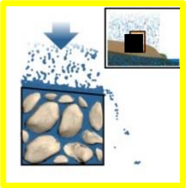
R^2	Sim1	0.79	0.77	0.58	0.54
	Sim2	0.84	0.81	0.64	0.56
Pbias (%)	Sim1	28.1	32.3	51	117.8
	Sim2	-2.25	-2.68	4.42	20.49



Summary and future research opportunities



Spatial and temporal swc data holds the key to interpret streamflow response, especially in water-limited system



Local swc network is effective in improving hydrological models

Summary and future research opportunities

Subsurface flow and recharge

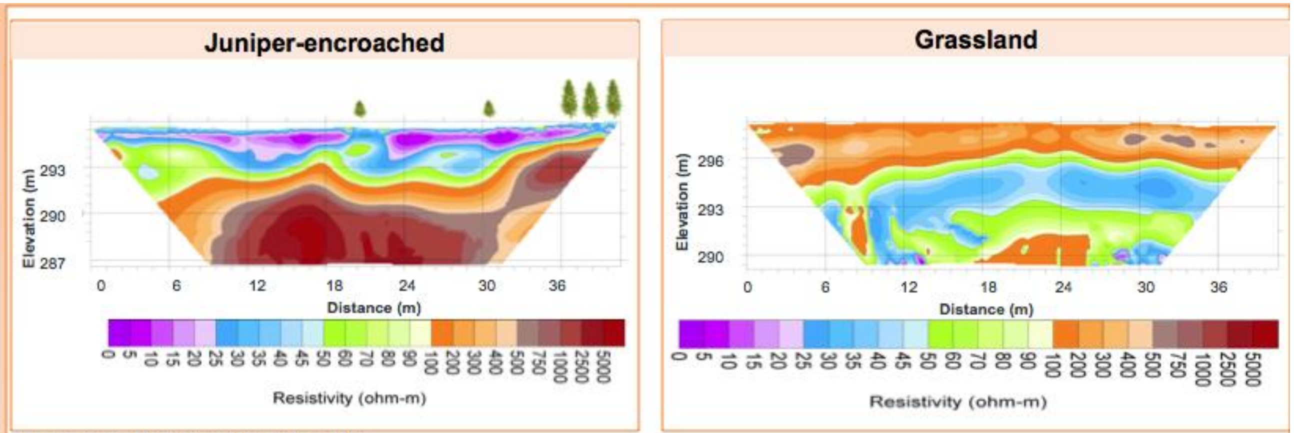


Figure 4: Background ERI 13 June 2014

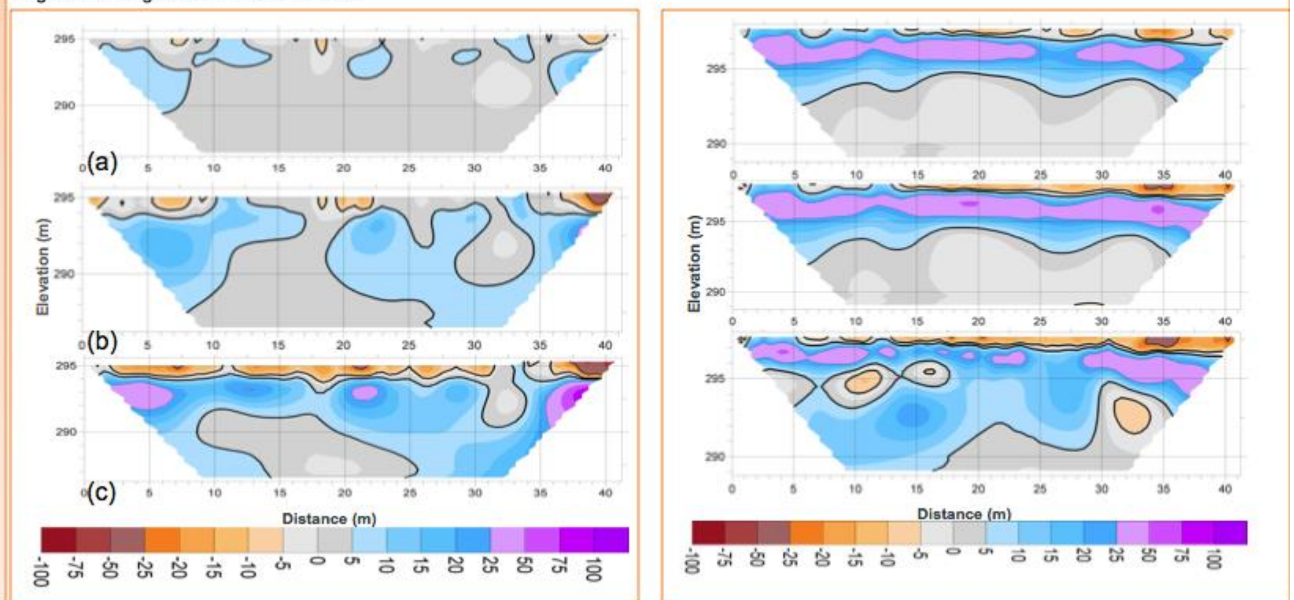


Figure 5: Transient images showing percent change in conductivity (a) 13 June - 24 June (b) 13 June – 3 July (c) 13 June - 1 August, 2014

- Integration of local, regional swc network (such as Oklahoma Mesonet) with COSMOS, SMAP, AirMOSS should provide new opportunity to improve or build ecohydrological models