Final Report 2013

Title: Eastern redcedar encroachment and water cycle in tallgrass prairie

Start Date: 09/01/09

End Date: 12/31/14

Congressional District: Oklahoma Congressional District 3

Focus Category: ECL, FL, GW, HYDROL, INV, SW, WS, WU

Descriptors: baseflow, evapotranspiration, grassland, precipitation interception, sapflow, soil water dynamic, streamflow, water budget and water cycle

Principal Investigators:

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Supported Students:

Student Status	Number	Disciplines
Undergraduate	1	Engineering
M.S.	2	Natural Resource Ecology and Management
Ph.D.	1	Natural Resource Ecology and Management
Post Doc	0	
Total	3	

Publications

1. Articles in Refereed Scientific Journals

Zou, Chris B; Donald, Turton; Rodney, Will; Dave M, Engle; Samuel D, Fuhlendorf. 2014. Alteration of hydrological processes and streamflow with juniper (*Juniperus virginiana*) encroachment in a mesic grassland catchment. Hydrological Processes. DOI: 10.1002/hyp.10102

Caterina, Gulia L; Rodney E, Will; Donald, Turton; Duncan S, Wilson; Chris B, Zou. 2013. Water use of *Juniperus virginiana* trees encroached into mesic prairies. Ecohydrology. DOI: 10.1002/eco.1444.

Ge, Jianju; Chris B, Zou. 2013. Impacts of woody plant encroachment on regional climate in the Southern Great Plains of the USA. Journal of Geophysical Research – Atmosphere 118, 9093-9104. doi:10.1002/jgrd.50634, 2013

Wine, Michal L; Chris B, Zou. 2012. Long-term streamflow relations with riparian gallery forest expansion into tallgrass prairie in the Southern Great Plains, USA. Forest Ecology and Management 266: 170 – 179. doi: 10.1016/j.foreco.2011.11.014

2. Book Chapter

Zou, Chris B; Peli, Shi. 2009. Ecohydrological effects of woody plants encroachment into grassland and savanna in the USA. *In* Dong M and Werger JA (eds.), A Spectrum of Ecological Studies. Southwest University Press, Chongqing.

3. Dissertations & Theses

Caternia, Giulia. 2012. *Juniperus Virginiana* encroachment into mesic grasslands: rainfall interception and tree water use. 2012. MS Thesis. Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, Oklahoma, 107 Pages.

Hung, Jenny. 2012. Ecohydrological effects of eastern redcedar encroachment in tallgrass prairie. MS Thesis. Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, Oklahoma, 68 Pages.

4. Water Resources Research Institute Reports

N/A

5. Conference Proceedings

Zou, Chris B; Rodney E, Will; Elaine, Stebler; Lei, Qiao. 2014. Role of vegetation in modulating rainfall interception and soil water flux in ecosystems under transition from grassland to woodland. EGU General Assembly 2014, April 28 –May 2, 2014, Vienna, Austria

Qiao, Lei; Chris B, Zou. 2014. Eastern redcedar encroachment and change of water budget on lower Cimarron River basin. The 23rd OCWA Annual Meeting, Stillwater, April 2-3, 2014, Stillwater, OK;

Qiao, Lei; Joseph, Dale; Chris B, Zou. 2013. Streamflow and groundwater dynamics for a rangeland watershed under change in land surface conditions and climate in the south-central Great Plains. AGU annual Meeting, December 9-13, San Francisco, CA;

Zou, Chris B; Daniel, Turton; Elaine, Stebler; Rodney E, Will; David M, Engle. 2013. Streamflow responses after juniper (*Juniperus virginiana*) encroachment in previously cultivated mesic grasslands. Society of Range Management Annual Meeting, Feb. 2-8, 2013, Oklahoma City, OK

Caterina, Gulia; Rodney E, Will; Donald, Turton; Chris B, Zou. 2012. Water use of individual *Juniperus virginiana* trees: How much, how variable, and what factors affect it. The 97th Ecological Society of America Annual Meeting, August 5 -10, 2012, Portland, OR

Turton, Donald; Zou, Chris B; Rodney E, Will; Elaine, Stebler; Giulia, Caterina; David M, Engle; Samuel S, Fuhlendorf; Kim, Winton. 2012. Watershed research on the effects of redcedar encroachment on water quantity: Initial results. AAAS-SWARM. April 11- 13, 2012. Tulsa, OK

Caterina, Gulia; Rodney E, Will; Chris B, Zou. 2012. Water use of individual redcedar trees; How much, how variable, and what factors affect it. AAAS-SWARM. April 11- 13, 2012. Tulsa, OK

Zou, Chris B; Rodney E, Will; Donald, Turton, Bharat, Acharya; Amanda, West. 2012. Encroachment of redcedar into grassland - change in soil water and carbon. AAAS-SWARM. April 11- 13, 2012. Tulsa, OK

Hung, Jenny; Chris B, Zou; Tyson, Ochsner. 2012. A MATLAB tool for modeling evapotranspiration from soil moisture dynamics. 2nd Annual Student Water Conference, April 4 -5, 2012, Stillwater, OK

Hung, Jenny; Chris B, Zou; Rodney E, Will; David M, Engle; Samuel D, Fuhlendorf. 2011. Interactive effects of vegetation and soil types on soil water dynamics in woody-encroached grasslands. The 96th Ecological Society of America Annual Meeting, August 7 -12, 2011, Austin, TX

Engle, David M; Samuel D, Fuhlendorf; Brady W, Allred; Dwayne, Elmore; Chris B, Zou. 2011. Recoupling fire and grazing interactions to restore rangelands degraded by woody plant encroachment and climate change: a patch-burning approach to management. The 96th Ecological Society of America Annual Meeting, August 7 - 12, 2011, Austin, TX

Zou, Chris B; Donald, Turton; Rodney E, Will; Samuel D, Fuhlendorf; David M, Engle; Jenny, Hung. 2010. Estimating watershed level evapotranspiration using water budget method. The 95th Ecological Society of America Annual Meeting, August 1-6, 2010, Pittsburgh, PA

6. Other Publications

Zou, Chris B; Donald,Turton; David M, Engle; Rodney E, Will; Samuel D, Fuhlendorf; Kim, Winton. 2011. Eastern Redcedar Encroachment and Water: Update of 2010 Research. Water Research and Extension Center. WREC-101. Oklahoma Coop. Ext. Serv. Oklahoma State University, Stillwater

Zou, Chris B; Donald, Turton; David M, Engle. 2010. How eastern redcedar encroachment affects the water cycle of Oklahoma rangelands. Oklahoma Cooperative Extension Service. Fact Sheet NREM 2888

Problem and Research Objectives:

Land based water cycle and water supplies to streams and groundwater are heavily influenced by vegetation and vegetation change resulting from management. In the Great Plains, tallgrass prairie is rapidly transforming to woodland largely by the encroachment of eastern redcedar trees. Using Oklahoma as an example, of the 17 million acres of rangeland including prairie, eight million acres are currently overgrown with eastern redcedar. That number is increasing. Given the speed, magnitude and extent of the observed and projected encroachment, a logical question is: how and will increases in eastern redcedar cover modify streamflow and raw water supplies in the Great Plains states where water shortages are increasing? Our understanding of such effects is limited to somewhat inconclusive results from studies on semiarid savanna ecosystems. Therefore, a climate and site-specific investigation focusing on mesic prairies of the Great Plains is urgently needed considering long-term water planning is ongoing for most of these affected states.

The overall objectives are to develop an improved understanding of the effects of eastern redcedar encroachment in tallgrass prairie on ecohydrological processes and potential effect on basin water supplies if un-confined.

Methodology:

We directly quantified components of the water budget of small watersheds in tallgrass prairie with and without eastern redcedar encroachment. Specifically, we directly measured interception by tallgrasses and eastern redcedar woodland. Transpirational water loss by eastern redcedar trees was quantified using a sap flow technique and grassland transpiration was quantified using a USGS designed evapotranspiration chamber. Streamflow from each watershed was measured using appropriately sized flumes. We used the Soil and Water Assessment Tool (SWAT) model to simulate the impact of eastern redcedar encroachment into rangeland on water budget for the lower Cimarron River Basin. This simulation entails a land cover change scenario that current rangelands are completely encroached while other land use types remained unchanged over a time period of 22 years (1988-2009).

Principal Findings and Significance:

Except for days with maximum air temperature below -3 °C, eastern redcedar trees used water year round, reached a peak in late May, and exhibited reduced water use in summer when soil water availability was low. Overall daily average water use was 24 l (± 21.8 l s.d.) per tree. Trees in low-density stands used more water than trees with similar diameters from denser stands. However, there was no difference in water use between trees in different density stands when expressed on a canopy area basis. Approximately 50% of variation in water use that remained after accounting for the factors site, tree, and day was explained using a physiologically-based model that included daily potential evapotranspiration, maximum vapour pressure deficit, maximum

temperature, solar radiation, and soil water storage between 0 and 10 cm. Model suggested that an eastern redcedar woodland with a closed canopy is capable of transpiring almost all precipitation reaching the soil in years with normal precipitation, indicating the potential for encroachment to reduce water yield for streamflow and groundwater recharge.

The initial and steady-state infiltration rates under the eastern redcedar canopy were nearly triple to that of the grassland catchment and were intermediate in the intercanopy spaces within the encroached catchment. Soil water content and soil water storage on the encroached catchment were generally lower than on the grassland catchment, especially when preceding the seasons of peak rainfall in spring and fall. Frequency and magnitude of streamflow events were reduced in the encroached catchment. During the three water years from 1 October 2008 to 30 September 2011, annual runoff coefficients for the encroached catchment averaged 2.1%, in contrast to 10.6% for the grassland catchment. Annual streamflow duration ranged from 80 to 250 h for the encroached catchment compared with 600 to 800 h for the grassland catchment.

Modeling simulation indicated that up to 70 mm increase in annual ET and up to 80 mm reduction in annual water yield for heavily encroached subbasins of the lower Cimarron River Basin; Reduction in the water yield was mainly from surface runoff reduction with subtle increase in groundwater discharge. Effect of redcedar encroachment on reducing streamflow is associated with the climate. Runoff decreases linearly with increasing eastern redcedar cover for wet subbasins. Strong nonlinear and threshold type of response between streamflow reduction and increasing canopy cover was predicted in more aridity subbasins. Streamflow decreases throughout the year with acute reduction (up to 60%) in summer months. When conversion passes 60%, more arid watershed may completely run out of streamflow.

Encroachment of eastern redcedar trees into tallgrass prairie is transforming millions of hectares from warm season grasslands to evergreen forests. Rapid transformation of mesic grassland to a woodland state with eastern redcedar encroachment, if not confined, has the potential to drastically reduce soil water, streamflow and flow duration of ephemeral streams in the Southern-central Great Plains.

Our project have also led to a recent USDA/NIFA grant to OSU to study management options for eastern redcedar encroached rangeland for improving water yield and contributed to two multiple institutional, multiple million dollar NSF projects to study socio-ecological system resilience under increased climate variability. Our work has been reported in scientific oriented outlet such as Science magazine and management oriented outlets such as The Journal Records. Our work has also been reported by mass media such as OSU Sunup TV program and interviewed by regional TV channel.