Simulating the Impacts of Social Coordination on Groundwater Sustainability and Agricultural Resilience

Phillip D. Alderman[1]

Uvirkaa Akumaga[1], Ron Miller[2] and Brandon A. Vaverka[1]

[1]Department of Plant and Soil Sciences
[2]Department of Biosystems and Agricultural Engineering
Oklahoma State University

April 7, 2017

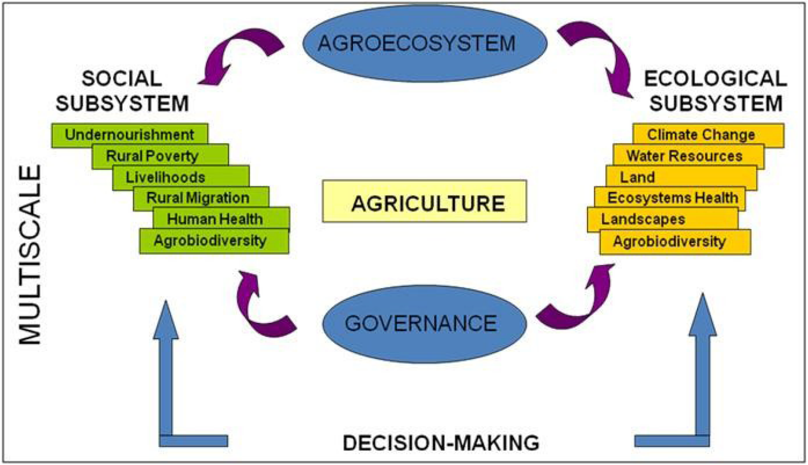
Overview

- Setting the Stage
- Modeling Approach
- Discussion of Future Directions

Setting the Stage

- Agriculture as a Socio-ecological System
- Oklahoma's Climate Variability
- Tragedy of the Commons

Agriculture as a Socio-ecological System

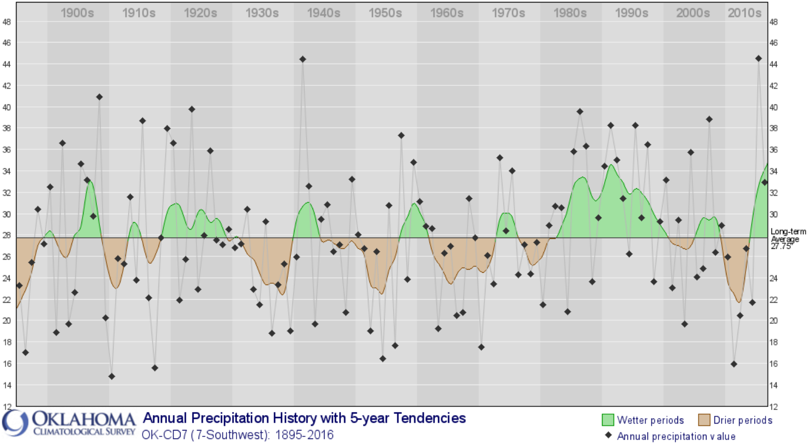


(Rivera-Ferre et al., 2013)

DEPARTMENT OF Plant & Soil Sciences

OKLAHOMA EPSCoR

Oklahoma's Climate Variability



DEPARTMENT OF
Plant &
Soil Sciences

OKLAHOMA EPSCoR

Tragedy of the Commons

DEPARTMENT OF
Plant &
Soil Sciences

OKLAHOMA EPSCoR

Some Socio-ecological Research Questions

How does the interaction between the duration and intensity of drought affect the sustainability of groundwater as an irrigation source?

What is the relationship between water conservation measures and the sustainability of groundwater and agricultural production?

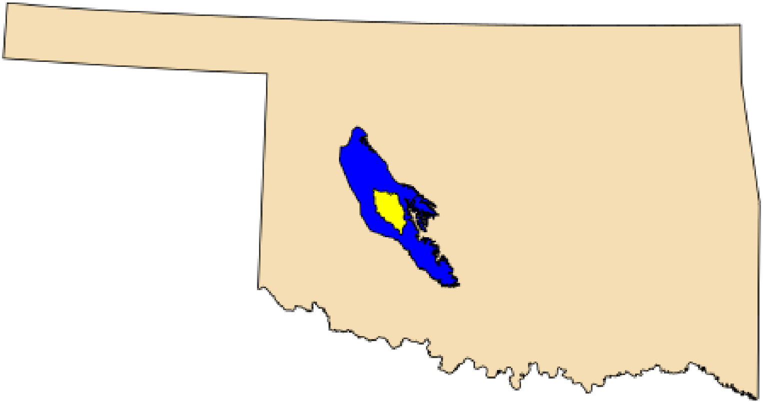
To what extent does agricultural drought risk exposure differ across socio-ecological gradients?

Modeling Approach

- Ft Cobb Study Area
- Bucket Aquifer Model
- DSSAT Cropping Systems Model
- Drought Scenarios

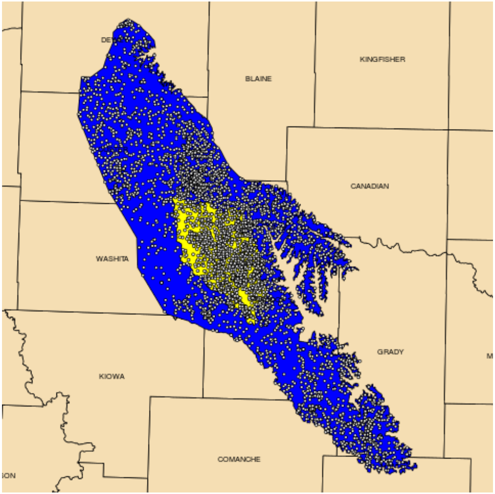
DEPARTMENT OF
Plant &
Soil Sciences

Ft Cobb Study Area



DEPARTMENT OF
Plant &
Soil Sciences

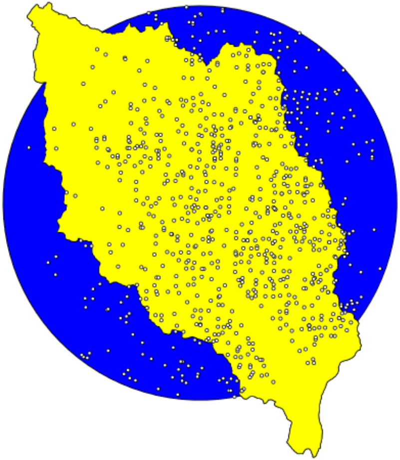
Ft Cobb Study Area



DEPARTMENT OF
Plant &
Soil Sciences

OKLAHOMA
EPSCoR

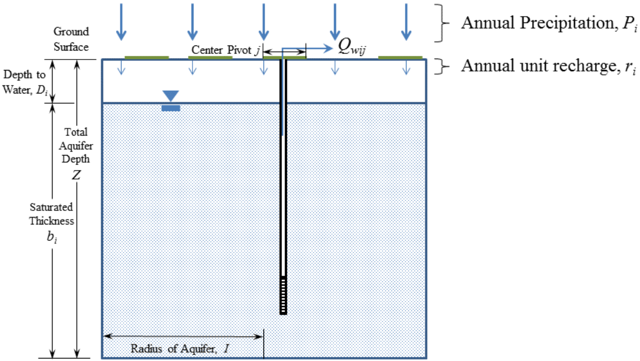
Ft Cobb Study Area



DEPARTMENT OF
Plant &
Soil Sciences

OKLAHOMA
EPSCoR

Bucket Aquifer Model



Q_{wij} = *DSSAT irrigation output*

$V_{wi} = V_{wi-1} - \Sigma Q_{wij} + R_{ri}$

$b_i = V_{wi}/S_y \pi I^2$

$D_i = Z - b_i$

$r_i = 0.077 P_i - 3.88$

$R_{ri} = (r_i \cdot 0.001) I^2 \pi$

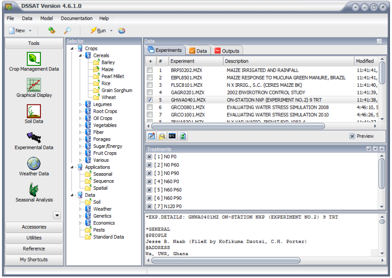
V_{wi} – Volume of water in aquifer at year i

S_y – Specific yield of aquifer material (related to porosity)

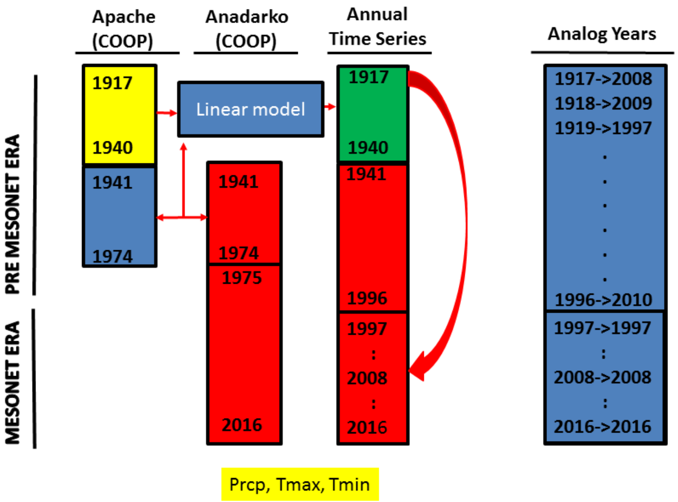
R_{ri} – Annual volume of recharge to aquifer (m^3)

DSSAT Cropping Systems Model

- Decision Support System for Agrotechnology Transfer
- Began in 1983
- Most widely utilized crop model system
- 42 crops in version 4.6.1
- 100 countries
- >7,000 publications

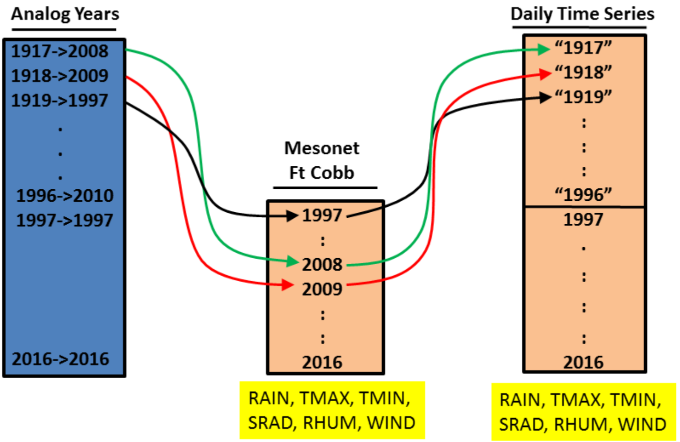


Climate Analog Years

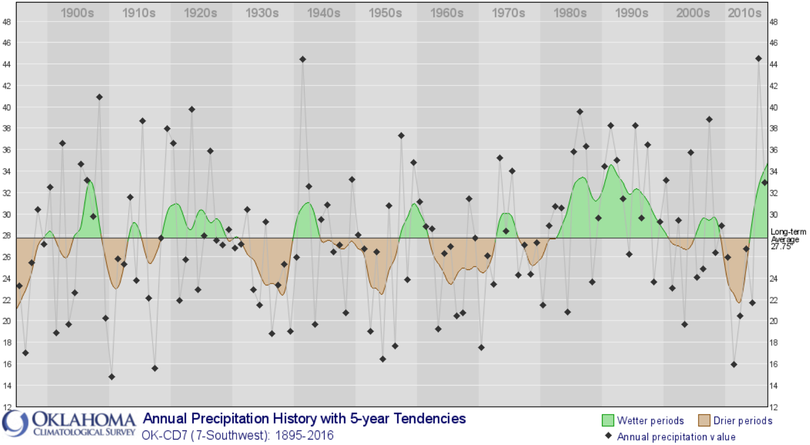


DEPARTMENT OF Plant & Soil Sciences

Climate Scenario Data



Drought Scenarios



DEPARTMENT OF Plant & Soil Sciences

OKLAHOMA EPSCoR

Drought Scenarios

Drought Period	Begin Year	End Year
1	1930	1940
2	1944	1957
3	1962	1972
4	1976	1982
5	2000	2006
6	2010	2015

Future Directions

- Refine socio-ecological research questions and scenarios in collaboration with social scientists
- Consider non-agricultural (e.g. municipal) water use?
- Add more detail to groundwater model or link to more detailed groundwater model?
- Consider surface-groundwater relationships?
- Revise climate analog approach?

Questions?

http://www.proginosko.com/wordpress/wp-content/uploads/question-mark.jpg

Bucket Model Documentation

Reported values:

S_y – Specific yield of aquifer.

Model value: 0.25

Published range (highly utilized area)[1, 2]

0.18-0.33

Z – Total depth of aquifer.

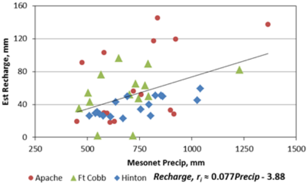
Model value: 300'

Published range (highly utilized area)[1,3]

150'-300'

Calculated value:

r_i – Recharge per annual rainfall per unit area. Linear regression of annual precipitation and estimated annual recharge data pairs 1998-2014 for Mesonet sites located on Rush Springs aquifer ($r^2 = 0.20$)[4].



[1] Becker, M.F. and D. L. Runkle. 1998. Hydrogeology, water quality, and geochemistry of the Rush Springs aquifer, western Oklahoma. USGS WRIR 98-4081.

[2] Ketchum, Q. J. 2015. Development of digital groundwater models and simulation of groundwater flow of the Rush Springs aquifer in west central Oklahoma. Master's thesis. Oklahoma State University, 2015. ProQuest Dissertations Publishing .

[3] Tanaka, H.L. and L.V. Davis. 1963. Ground-water resources of the Rush Springs sandstone in the Caddo County area, Oklahoma. OGS Circular 61.

[4] Wyatt, B.M., T.E. Ochsner, C.A. Fiebrich, C.R. Neel, and D.S. Wallace. 2017. A simple method for estimating drainage through long-term soil moisture monitoring. *In Review at Vadose Zone J.*

Variety Selection & Panting Dates

- Previous field trial results
- Used best area match for varities
- "Usual Planting and Harvesting Dates for U.S. Field crops" (USDA 1997)
- Range of planting dates
- Set model for automatic planting

Soil

- Created a representative soil profile
- Based on a Pond Creek Fine Sandy Loam
- Soil Survey
- Web Soil Survey Soil Explorer
- Used DSSAT S Build to calculate missing values

DEPARTMENT OF
Plant &
Soil Sciences