Estimating Groundwater Recharge Using the Oklahoma Mesonet

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Introduction

- Effective water resource management and planning requires accurate information about groundwater recharge rates.
- Information about groundwater recharge rates in Oklahoma is limited, and the last state-wide study used data from the years 1970-1979 (Pettyjohn et al., 1983).
- By estimating drainage rates across the state using soil moisture data from the Oklahoma Mesonet, we may be able to approximate groundwater recharge rates.

Objective

- The objective of this research is to determine the level of agreement between drainage rates calculated using Mesonet soil moisture data and independent estimates of groundwater recharge rates for several aquifers across Oklahoma.

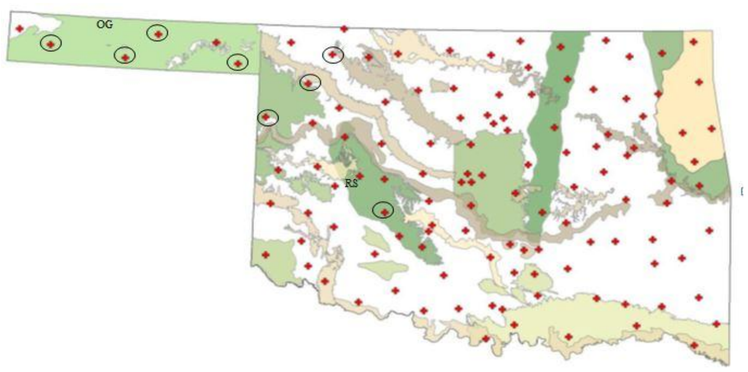

Figure 1. Major aquifers of Oklahoma (shaded regions) and Mesonet site locations (red dots). The Ogallala (OG) and Rush Springs (RS) aquifers are identified and coring locations are circled. Adapted from OWRB publication.

Materials and Methods

- Soil moisture data from Mesonet sites were converted to matric potential by (Illston et al., 2004):

$$\Psi_m = -c\exp(a\Delta T_{ref}) \quad (1)$$

- Using site-specific soil hydraulic properties, matric potential values were converted to normalized soil volumetric water content (effective saturation) for each site by (van Genuchten, 1980):

$$S_e = \left[1+(-a\Psi_m)^n\right]^{-m} \quad (2)$$

- Daily normalized volumetric water content at the 60cm depth was used to determine daily hydraulic conductivity values by (Schaap et al., 20010):

$$K(S_e) = K_0 S_e^L\{1-[1-S_e^{n/(n-1)}]^{1-1/n}\}^2 \quad (3)$$

- Assuming gravity-driven flow, the daily drainage rate at 60 cm was set equal to the hydraulic conductivity.
- The unsaturated zone chloride mass balance method (CMB_{uz}) was applied to soil cores taken at eight Mesonet focus sites (Dec. 2013-May 2014).
- HYDRUS 1-D software was used to simulate free drainage at 60 cm and 300 cm over ~15 years at each Mesonet focus site using site-specific soil properties.
- Groundwater chloride data was analyzed using the saturated zone chloride mass balance method (CMB_{SZ}) to estimate recharge over 5 Oklahoma aquifers (Table 3).

Results and Discussion

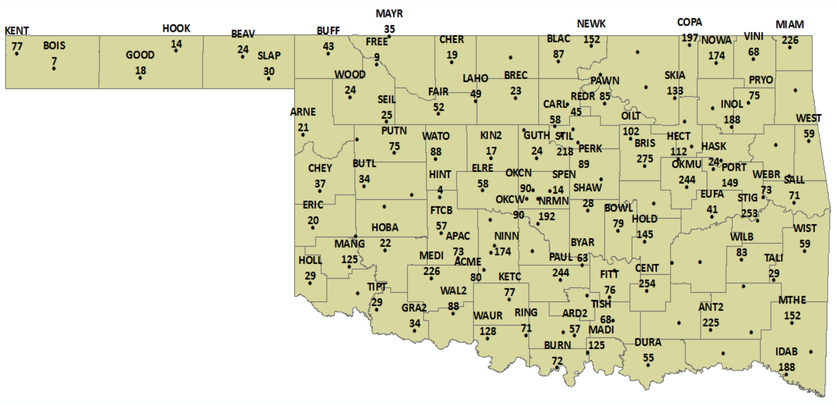

Figure 2. Mean annual drainage rates for the years 1996-2012.

- Median state-wide drainage rate for the years 1996-2012 was found to be 61 mm yr^{-1}.
- Drainage throughout the state tends to follow the pattern of precipitation, decreasing from southeast to northwest.

Table 1: Mean annual precipitation, mean pore water chloride concentrations below the active root zone, and recharge estimates based on CMB_{uz}.

Mesonet Site	Precip.	Chloride	Recharge
	mm yr^{-1}	ppm	mm yr^{-1}
Fort Cobb	712	961	0.27
Freedom	655	1529	0.16
Arnett	561	81	2.5
Slapout	530	516/75	0.20/1.4
Hooker	436	687	0.13
Goodwell	410	39	2.0
Boise City	386	624	0.12
Woodward	630	127	1.8

- Recharge rates from CMB_{uz} analysis range from 0.12 mm yr^{-1} at Boise City to 2.5 mm yr^{-1} at Arnett.
- Recharge rates using the CMB_{uz} method were 7.2 to 57 mm yr^{-1} lower than Mesonet drainage rates.

Table 2: Average annual drainage at 60 cm and average annual flux values at 60 and 300 cm found using HYDRUS1-D.

Mesonet Site	Mesonet Drainage- 60 cm	HYDRUS flux- 60 cm	HYDRUS flux- 300 cm
	mm yr^{-1}	mm yr^{-1}	mm yr^{-1}
Fort Cobb	57	145	21
Freedom	9.3	64	0.8
Arnett	21	54	0.2
Slapout	30	90	0.5
Hooker	14	9.9	1.3
Goodwell	18	7.5	0.1
Boise City	7.3	15	0.3
Woodward	24	55	0.7

- Flux values below the root zone (300 cm) found using HYDRUS 1-D were 7.0 to 36 mm yr^{-1} lower than Mesonet drainage rates .
- However, at 6 of 8 sites, Mesonet drainage at 60 cm was lower than HYDRUS 1-D flux values at 60 and 300 cm.

Table 3: Median annual drainage at 60 cm for Mesonet sites above selected Oklahoma aquifers from 1996-2012. For comparison, prior published estimates of groundwater recharge for these aquifers are also shown.

Aquifer	Sites	Drainage	Recharge	No. Sources
		mm yr^{-1}	mm yr^{-1}	
Boone	3	235	2.3-254	4
Arkansas River	5	171	127	1
Garber-Wellington	3	121	7.6-203	4
Rush Springs	5	74	4.9-99	4
Antlers	4	70	8.1-152	4
Ogallala	8	21	1.5-54	4

- Median aquifer-scale Mesonet-based drainage rates exhibit good agreement with prior recharge estimates, falling within the range of previous recharge estimates in all but two cases.

Table 4: Mean annual precipitation for Oklahoma aquifers sampled by the GMAP program in 2013 along with groundwater chloride concentrations and recharge estimates based on CMB_{SZ}.

Aquifer	Precip.	GW chloride	Recharge
	mm yr^{-1}	ppm	mm yr^{-1}
Gerty Sand	894	11	25
Canadian River	770	52	4.8
Rush Springs	714	31	7.6
Elk City	683	9	25
Ogallala Northwest	587	11	18

- CMB_{SZ} analyses yielded recharge rates ranging from 25 to 4.8 mm yr^{-1}, with a median of 18 mm yr^{-1}.
- The recharge rate found for the Ogallala aquifer using the CMB_{SZ} method compares well with the median Mesonet-based drainage rate for the same aquifer, with rates of 18 and 21 mm yr^{-1}, respectively.

Summary

- Mesonet-based drainage rates generally reflect the precipitation gradient of the state, but some sites' drainage rates are significantly different than those of surrounding sites.
- Mesonet-based drainage rates are shown to lie near the upper end of published ranges of recharge rates, in most cases.
- Mesonet-based drainage estimates may be considered an indication of "potential recharge," as these rates are higher than independent recharge estimates in many cases.
- Additional quality control is needed to determine the cause of unrealistic drainage rates at certain sites.
- This novel and unique drainage calculation method may provide Oklahomans with a powerful tool for groundwater recharge estimation, and work to improve the method is ongoing.

Acknowledgements

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