Irrigation Water Fluxes in an Agricultural Watershed in Central Oklahoma

Sumon Datta¹, Saleh Taghvaeian¹, Mukesh Mehata¹, and Daniel Moriasi²

¹ Dept. Biosystems & Agricultural Engineering, OSU, Stillwater, OK

² USDA-ARS Grazinglands Research laboratory, El Reno, OK

**2019 ASABE International Meeting, Boston, MA
July 7-10, 2019**

Background

- ✓ Irrigation accounts for 41% of water withdrawal in OK (OWRB)
- ✓ In the Fort Cobb Reservoir Experimental Watershed (FCREW), Irrigation is practiced widely.
- ✓ The Rush Springs Aquifer is the main source of water (7 ft W.L. decline from 2011 to 2015 during drought).
- ✓ Major crops: peanuts, cotton, soybean, corn, etc. (long history of fertilizer, insecticides application).

Problem statement

- ✓ Water availability, especially during droughts
- ✓ Soils are medium- and coarse-textured, highly erodible
- ✓ Applied chemicals combined with irrigation return flows may be conveyed to downstream land & water resources.
- ✓ If infiltrated deep enough, groundwater quality may be impaired.

Solutions

- ✓ Risk may be assessed by estimating the water fluxes in agricultural fields.
- ✓ Need to estimate or measure important water fluxes: irrigation (I), precipitation (P), runoff (RO), deep percolation (DP), and evapotranspiration (ET)

Study Sites

- FCREW, Central Oklahoma
- 8 commercially irrigated fields in 2017 and 2018
- 3 crops: peanut (PN), Soybean (SB), and Cotton (CT)
- Irrigation system: Center Pivot

Flux estimation

- ✓ Fluxes are estimated using simple water balance approach:
 - ✓ $DP = (P - RO) + I - ET_{c \text{ adj}} - D_r$ (root zone depletion)
- ✓ Combination of measurement and modeling
 - ✓ Irrigation and precipitation data from rain gages installed below center-pivot nozzles
 - ✓ ET_o from Oklahoma Mesonet Weather Data
 - ✓ FAO-56 dual crop coefficient method
 - ✓ HYDRUS-1D

Modeling Framework

- ✓ Two Oklahoma Mesonet stations
 - ✓ ET_o : ASCE-PM (Short crop)
- ✓ FAO-56 dual crop coefficient method for estimating adjusted ET_c (Allen et al. 1998)
 - ✓ $ET_{c \text{ adj}} = (K_s K_{cb} + K_e) ET_o$
 - ✓ Actual Transpiration (T_a) = $K_s K_{cb} ET_o$
 - ✓ Actual Evaporation (E_a) = $K_e ET_o$

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	
Spreadsheet for Calculating Dual Crop Coefficients and an Irrigation Schedule based on FAO-56												Green-highlighted cells require user input. Other cells are automatically calculated.																		
Crop: Soybean_Roland				Table 11				Table 17 Adjusted				Computed																		
				L_{ini}	20	$K_{cb\ ini}$		0.15	0.15	$K_{e\ min}$		0.15			J_{plant}	165					$f_w\ (irr)$	1.0								
Planting: Month 6				L_{dev}	30	$K_{cb\ mid}$		1.10	1.09	h_{max}		1.14	m			J_{dev}	185					REW	8	mm						
Day 14				L_{mid}	60	$K_{cb\ end}$		0.30	0.30					J_{mid}	215							TEW	18	mm						
				L_{late}	25									J_{late}	275							$D_e\ ini$	18	mm						
				Mid-season Wind								2.62	m/sec			J_{harv}	300					$f_w\ ini$	1.0							
				Mid-season RH _{min}								56	%																	
												← Evaporation Calculation →																		
Month	Day	Year	J	T _{max} °C	Wind m/sec	T _{dew} °C	ET _o mm/d	e° T _{dew} kPa	e° T _{max} kPa	RH _{min} %	I+P mm	Date	K _{cb}	Height m	K _{e max}	Net I/f _w mm	f _e	f _w	f _{ew}	D _{e,i start} mm	K _r	K _e	E mm/d	DP _e mm/d	D _{e,i end} mm	K _e	ET _e mm/d	T mm/d		
6	14	2018	165	36.5	4.5	16.4	9.4	1.87	6.11	31	0.0	06/14/18	0.15	0.16	1.26	0.0	0.01	1.00	0.99	18.0	0.00	0.00	0.0	0.0	18.0	0.15	1.4	1.4		
6	15	2018	166	35.2	5.6	17.7	9.7	2.03	5.69	36	25.4	06/15/18	0.15	0.16	1.27	0.0	0.01	1.00	0.99	0.0	1.00	1.12	10.8	7.4	10.9	1.27	12.2	1.4		
6	16	2018	167	34.1	6.0	19.0	8.9	2.20	5.35	41	0.0	06/16/18	0.15	0.16	1.26	0.0	0.01	1.00	0.99	10.9	0.71	0.79	7.0	0.0	18.0	0.94	8.4	1.3		
6	17	2018	168	33.5	5.4	19.2	8.4	2.22	5.17	43	0.0	06/17/18	0.15	0.16	1.25	0.0	0.01	1.00	0.99	18.0	0.00	0.00	0.0	0.0	18.0	0.15	1.3	1.3		
6	18	2018	169	33.3	4.4	20.7	6.9	2.44	5.12	48	25.4	06/18/18	0.15	0.16	1.23	0.0	0.01	1.00	0.99	0.0	1.00	1.08	7.4	7.4	7.5	1.23	8.4	1.0		
6	19	2018	170	32.1	4.3	20.0	5.8	2.34	4.78	49	0.0	06/19/18	0.15	0.16	1.22	0.0	0.01	1.00	0.99	7.5	1.00	1.07	6.3	0.0	13.8	1.22	7.2	0.9		
6	20	2018	171	31.6	2.2	18.2	5.3	2.09	4.65	45	0.3	06/20/18	0.15	0.16	1.20	0.0	0.01	1.00	0.99	13.6	0.44	0.47	2.5	0.0	16.1	0.62	3.3	0.8		
6	21	2018	172	35.0	2.0	16.1	6.9	1.83	5.62	33	0.0	06/21/18	0.15	0.16	1.22	0.0	0.01	1.00	0.99	16.1	0.19	0.21	1.4	0.0	17.5	0.36	2.4	1.0

Modeling Framework

- ✓ HYDRUS-1D (Simunek et al. 2006):
 - ✓ Used E_a and T_a from FAO-56
 - ✓ Executed model and estimated other fluxes
- ✓ Model Validation
 - ✓ Used observed soil moisture data from a locally tested sensors: Acclima TDR315/310S (Datta et al. 2018)
 - ✓ Installed at 4 depths (10, 30, 51, 71 cm)

Water Fluxes – Cotton (CT) Fields

CT17

CT2-18

Water Fluxes – Soybean (SB) & Peanut (PN) Fields

SB1-18

PN18

Validation results

Summary of Cumulative Fluxes

Summary

- Most fields were under deficit irrigation
- DP was less than 4% of total water application (<2% for most fields)
- Actual irrigations applied were smaller than what should have been applied to maintain stress-free conditions
- Deficit irrigation management by farmers in FCREW
- Continuance of this project to collect more data during different climatic conditions in 2019

Acknowledgment

Funding was provided by

- U.S. Geological Survey 104(b) program, administered by the Oklahoma Water Resources Center
- Agricultural Research Service, U.S. Department of Agriculture, Agreement No. 58-3070-5-007

Oklahoma Water
Resources Center

References

Datta, S., Taghvaeian, S., Ochsner, T., Moriasi, D., Gowda, P., & Steiner, J. (2018). Performance Assessment of Five Different Soil Moisture Sensors under Irrigated Field Conditions in Oklahoma. *Sensors*, 18(11), 3786.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). *FAO Irrigation and drainage paper No. 56*. Rome: Food and Agriculture Organization of the United Nations, 56(97), e156.

OWRB. Water Facts (Oklahoma Water Resources Board). Available on <https://www.owrb.ok.gov/util/waterfact.php>

Simunek, J., Van Genuchten, M. T., & Sejna, M. (2006). *The HYDRUS software package for simulating the two-and three-dimensional movement of water, heat, and multiple solutes in variably-saturated media*. Technical manual, 1.

THANK YOU

DP Estimates