

Choice of Irrigated Corn or Sorghum and Center Pivot or Subsurface Drip in High Plains of Oklahoma

Selected paper presentation

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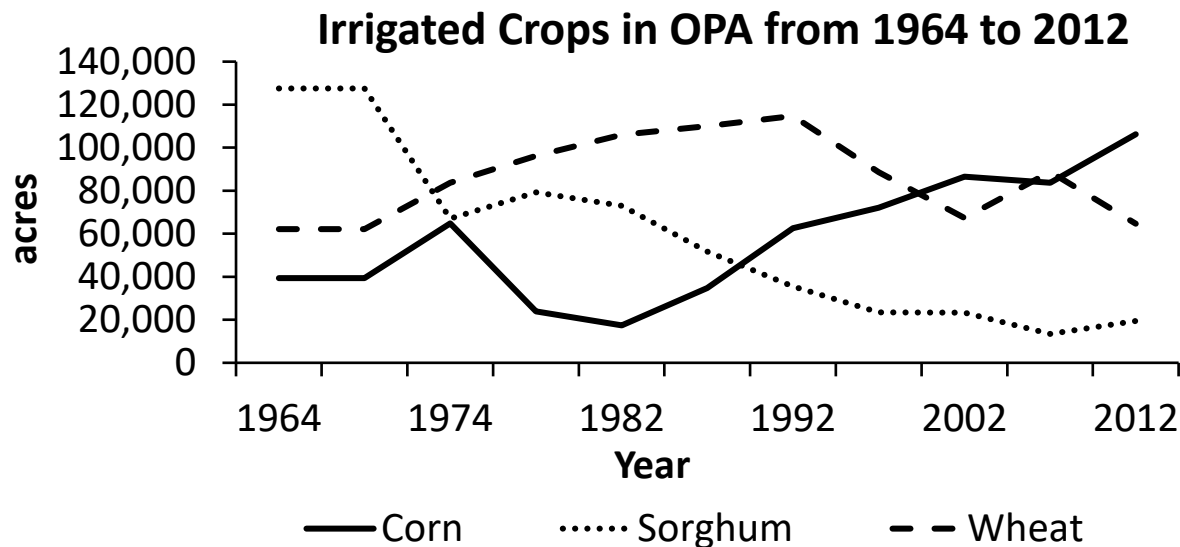
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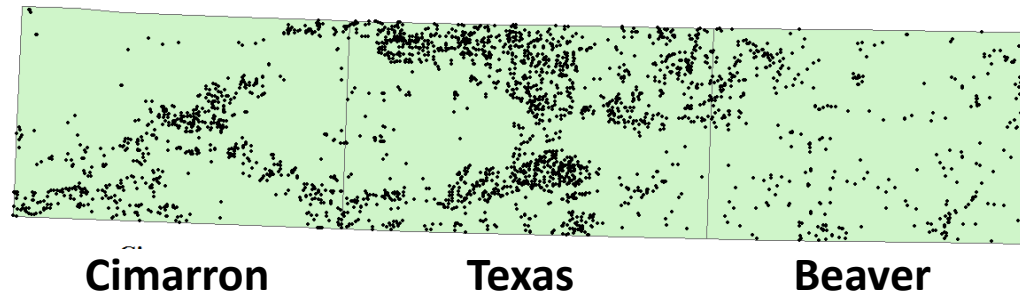
Background

- The Oklahoma Panhandle Area (OPA) irrigated crop production relies on groundwater.
- Census of Agriculture (2012) shows that, OPA has
 - 106,236 acres of irrigated corn,
 - 19,457 acres of irrigated sorghum,
 - and 64,671 acres of irrigated winter wheat

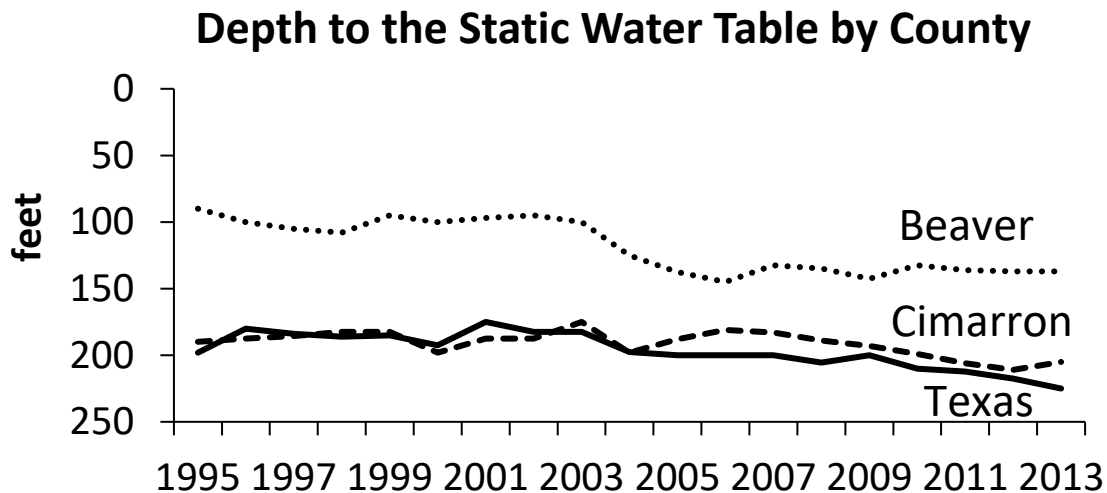


Background (cont.)

- There are 2,818 irrigation wells in OPA (OWRB, 2016)



- In 2012, USGS and OWRB monitoring wells showed that
 - recharge is 0.25 inches/year



County	Water level decline (ft/year)
Beaver	2.6
Cimarron	0.9
Texas	1.9

Irrigation Research at OPREC

- Irrigated variety trials at the OPREC compared performance of Corn and Sorghum (2005-2016)
- Compared Center Pivot (CP) and Subsurface Drip (SDI) irrigations to evaluate yield potential (2013-2014)
- Application frequencies simulated CP revolutions for well capacities 600, 400, 200, and 100 GPM to simulate irrigation of corn and sorghum on 125 acres
- The results from the OPREC verified that,
 - Sorghum had higher Water Use Efficiency (WUE) than corn
 - SDI had greater WUE than CP

Objective

- To maximize the Net Present Value (NPV) from the remaining groundwater by growing corn or sorghum by using either the CP or SDI system

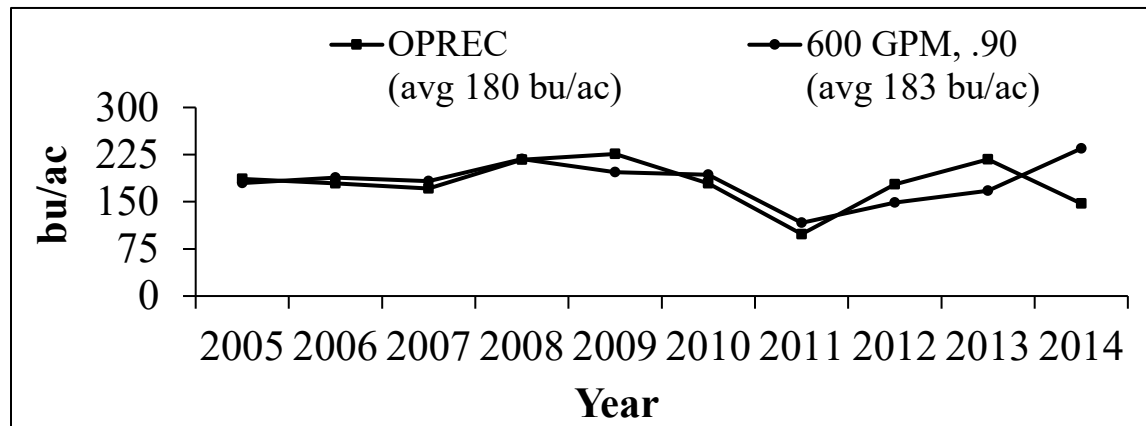
Research Problem

- How to extend limited research to provide yield and water use estimates under long-term conditions and deficit irrigation
- Develop budgets for corn and sorghum irrigated with CP and SDI for declining well yields and additional irrigation treatments

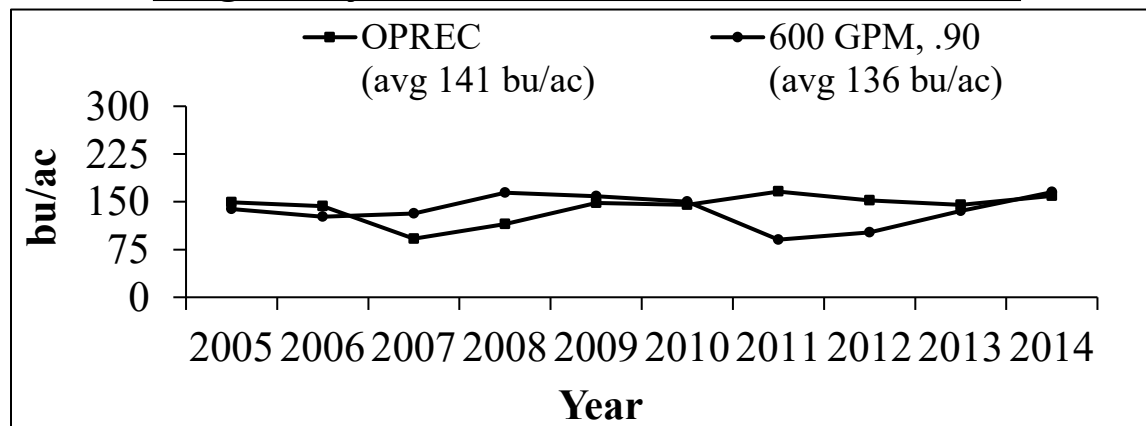
Methods

- Calibrate and validate EPIC¹ with experiment and variety results 2005-2014

Corn yield validated with OPREC results



Sorghum yield validated with OPREC results



¹Environmental Policy Impact Calculator (EPIC) is a crop simulation model

Methods

Validated EPIC used to

- Simulate corn and sorghum yields and water use by CP or SDI using 50 years (1965-2014) daily weather
- Simulate well capacities at 100, 200, ..., 800 GPM
- Simulate CP for 120 acre circle, and simulate SDI for 50, 75, ..., 150 acres
- Simulate possibility of deficit irrigation by delaying irrigation until soil moisture declined to 90, 80, ..., 30 percent of available soil water (ASW) capacity

Well drawdown used to

- Estimate the cost of pumping a unit water during 90 days of irrigation
- Estimate the remaining water available in the aquifer

Enterprise budgets used to

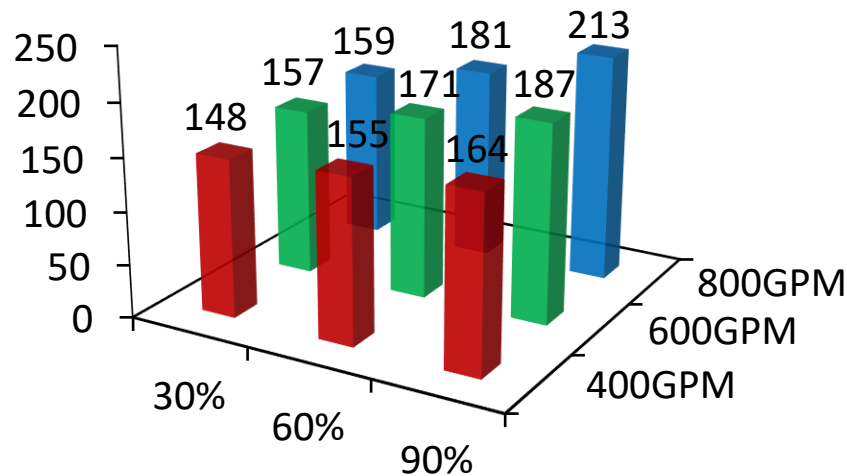
- Calculate the variable costs for CP and SDI irrigating corn and sorghum

Mixed-integer programming (MIP) used to

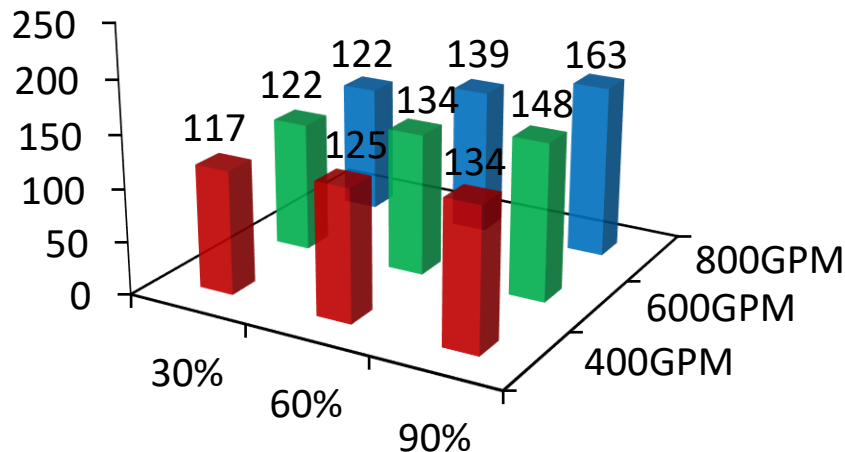
- Determine the optimal crop choice, irrigation system size, and aquifer life

CP Simulation results

CP irrigated CORN Yields (bu/ac)



CP irrigated SORGHUM Yields (bu/ac)



Corn irrigation (CP)

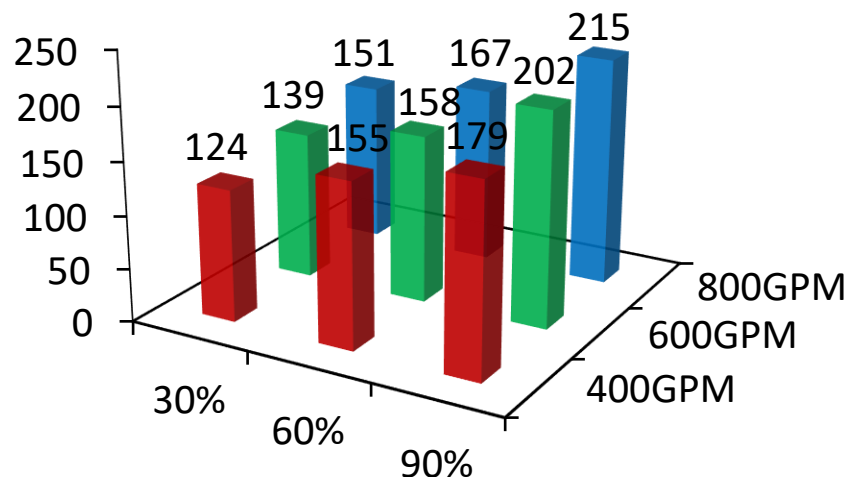
Well Capacity	Irrigation Frequency	Irrigation Stress Level		
		30%	60%	90%
GPM	Days	acre-inches		
800	4	14.6	18.8	22.5
600	6	14.6	17.2	21.6
400	8	13.5	15.0	17.6

Sorghum Irrigation (CP)

Well Capacity	Irrigation Frequency	Irrigation Stress Level		
		30%	60%	90%
GPM	Days	acre-inches		
800	4	8.3	10.0	15.6
600	6	8.2	9.2	12.6
400	8	7.7	8.6	10.4

SDI Simulation results

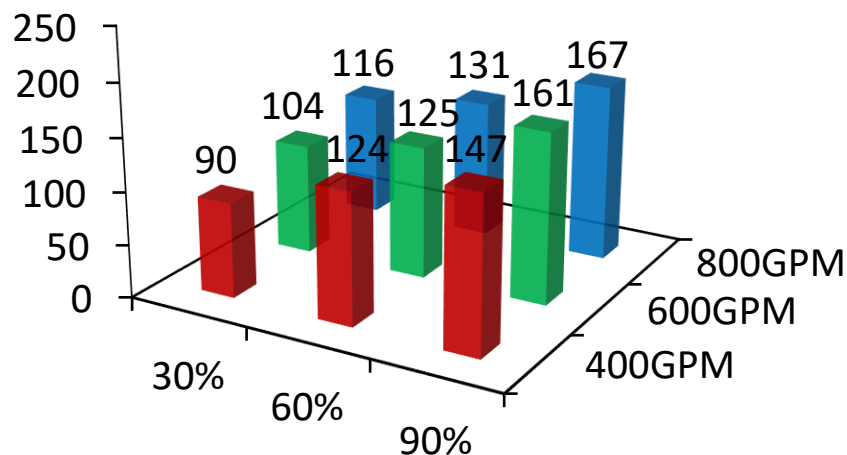
SDI irrigated CORN Yields (bu/ac)



Corn Irrigation (SDI)

Well Capacity	Irrigation Frequency	Irrigation Stress Level		
		30%	60%	90%
GPM	Days	acre-inches		
800	4	10.5	13.3	22.6
600	6	8.6	11.8	20.0
400	8	6.5	11.2	15.6

SDI irrigated SORGHUM Yields (bu/ac)

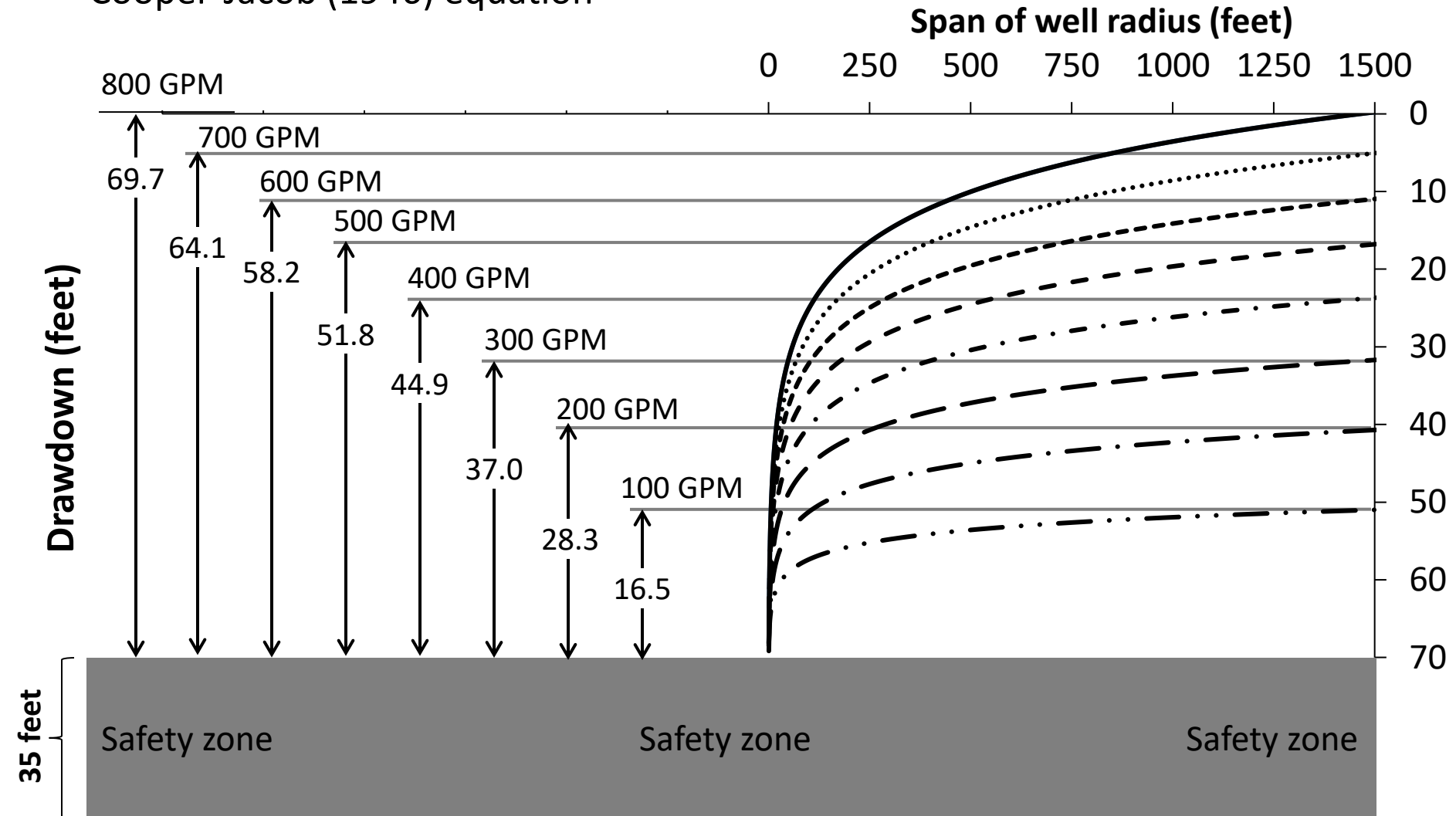


Sorghum Irrigation (SDI)

Well Capacity	Irrigation Frequency	Irrigation Stress Level		
		30%	60%	90%
GPM	Days	acre-inches		
800	4	5.7	7.2	12.7
600	6	4.7	6.5	11.4
400	8	3.6	6.2	9.0

Drawdown Calculation

Cooper-Jacob (1946) equation

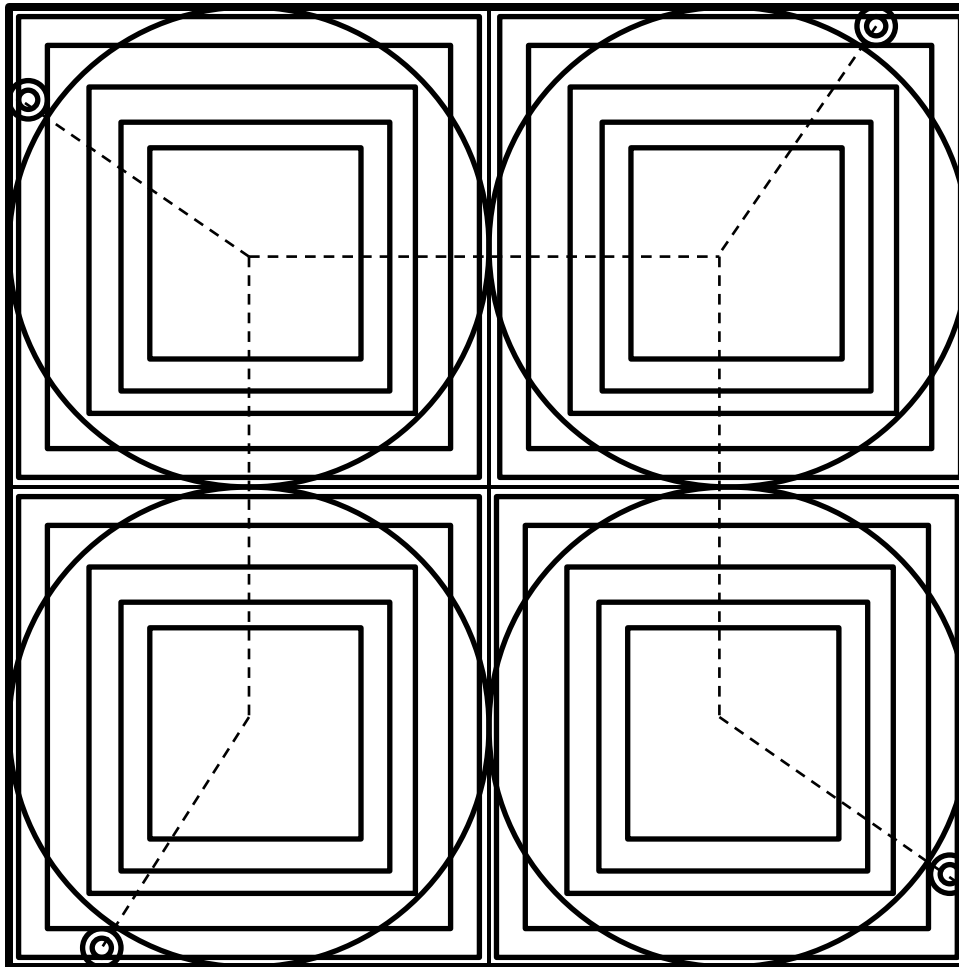


Budget Analysis

- Used 10-year (2005-2014) average crop prices,
 - Corn is \$4.50 per bushel
 - Sorghum is \$4.20 per bushel
- Used simulated 50-year average yields

	Crop, GPM	Yield	Net Rev	Cost	ac-ft	Pumping Cost/ ac-ft	Pumping Cost	Net returns
CP	Corn 600 GPM	187	\$837	\$549	1.8	\$65.0	\$117	\$172
	Sorghum 600 GPM	148	\$620	\$385	1.0	\$65.0	\$68	\$167
SDI	Corn 600 GPM	194	\$869	\$562	1.5	\$65.0	\$98	\$209
	Sorghum 600 GPM	155	\$649	\$395	0.9	\$65.0	\$56	\$198
CP	Corn 500 GPM	175	\$783	\$533	1.6	\$64.4	\$104	\$146
	Sorghum 500 GPM	141	\$590	\$375	0.9	\$64.4	\$61	\$154
SDI	Corn 500 GPM	181	\$811	\$550	1.3	\$64.4	\$84	\$177
	Sorghum 500 GPM	147	\$614	\$374	0.8	\$64.4	\$49	\$193

Hypothetical Representative Farm



- 640-acre field
- Four connected existing wells
- Initial well capacity is 600 GPM
- 120 acre CP
- 120 acre CP costs \$60,000
- 50, 75, ..., 150 acre SDI
- 50 acre SDI costs \$43,000
- 75 acre SDI costs \$58,000
- 100 acre SDI costs \$74,300
- 125 acre SDI costs \$90,700
- 150 acre SDI costs \$107,000
- Total water supply is 13,800 ac-ft

Long-term Profit Maximization: MIP

NPV maximization over a 60 year using Mixed-Integer Programming (MIP) can be expressed as,

15-year Irrigation System Investment Period

Discounted Irrigated Net Returns from Crop j , GPM g , at Year t

Discounted Investment Cost of Irrigation System at Period r

$$\max \text{NPV} = \sum_{r=1}^4 \left[\sum_{t=1}^{15} \left[\sum_{g=1}^m \sum_{j=1}^n (C_{gjtr} I_{gjtr}) + D_{tr} S_{tr} \right] - K_r P_r \right]$$

Discounted Dryland Net Returns at year t

Subject to: (784 rows)

Total Land: $\sum_g \sum_j I_{gjt} + D_t \leq 640$ for all t ,

Irrigated Land: $\sum_g \sum_j I_{gjt} - 120 \times P_r \leq 0$, $P_r \in \{0,4\}$ integer for all t, g, r ,

Water Supply: $\sum_t \sum_g \sum_j W_{gjt} I_{gjt} \leq WS_g$ for all t ,

j is the index of irrigated corn and sorghum activities at alternative stress levels, g is the index of aquifer level and well capacity, t is the index of the crop land allocation time period and r is the index of irrigation system purchase period 0-15, 15-30, 30-45 and 45-60,

C_{gjtr} is the present value of net revenue from irrigation in year t , (63,000 Columns)

I_{gjtr} is the acres irrigated at aquifer level g with GPM in year t ,

W_{gjt} is the water use for crop j from level g in year t ,

WS_g is the water supply from aquifer level g ,

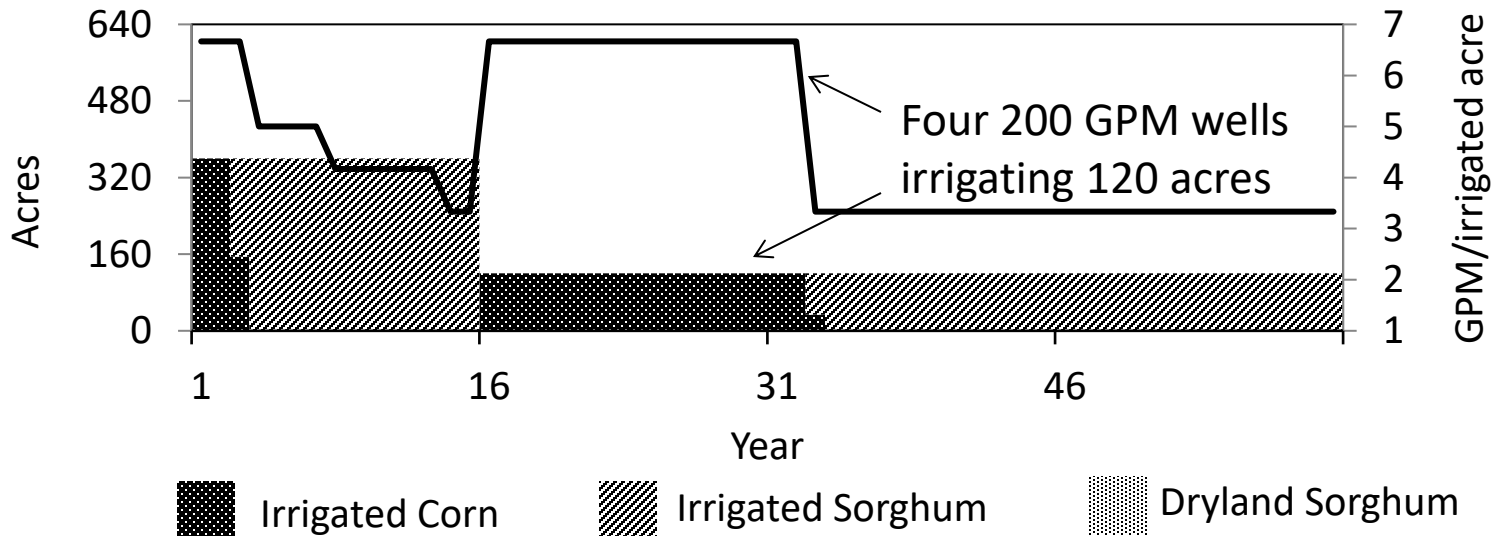
K_r is the present value of pivot investment in period r , (16 columns),

P_r is the irrigation system in investment period r ,

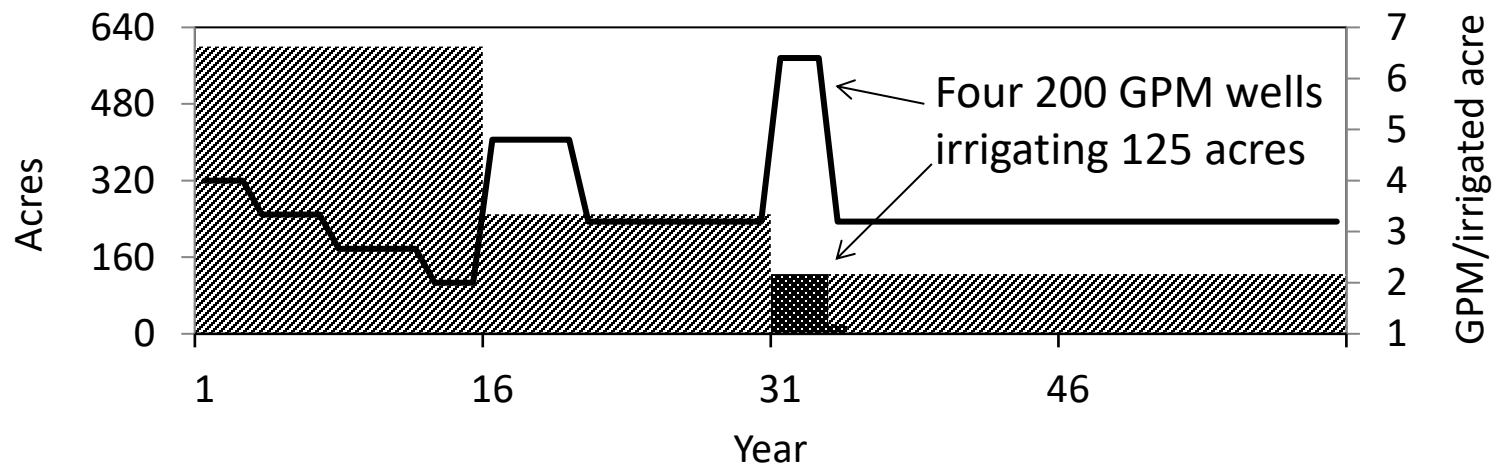
C_{gjtr}, K_r are discounted at 4 percent w.r.t year t .

MIP results: Crop allocation on a 640-acre

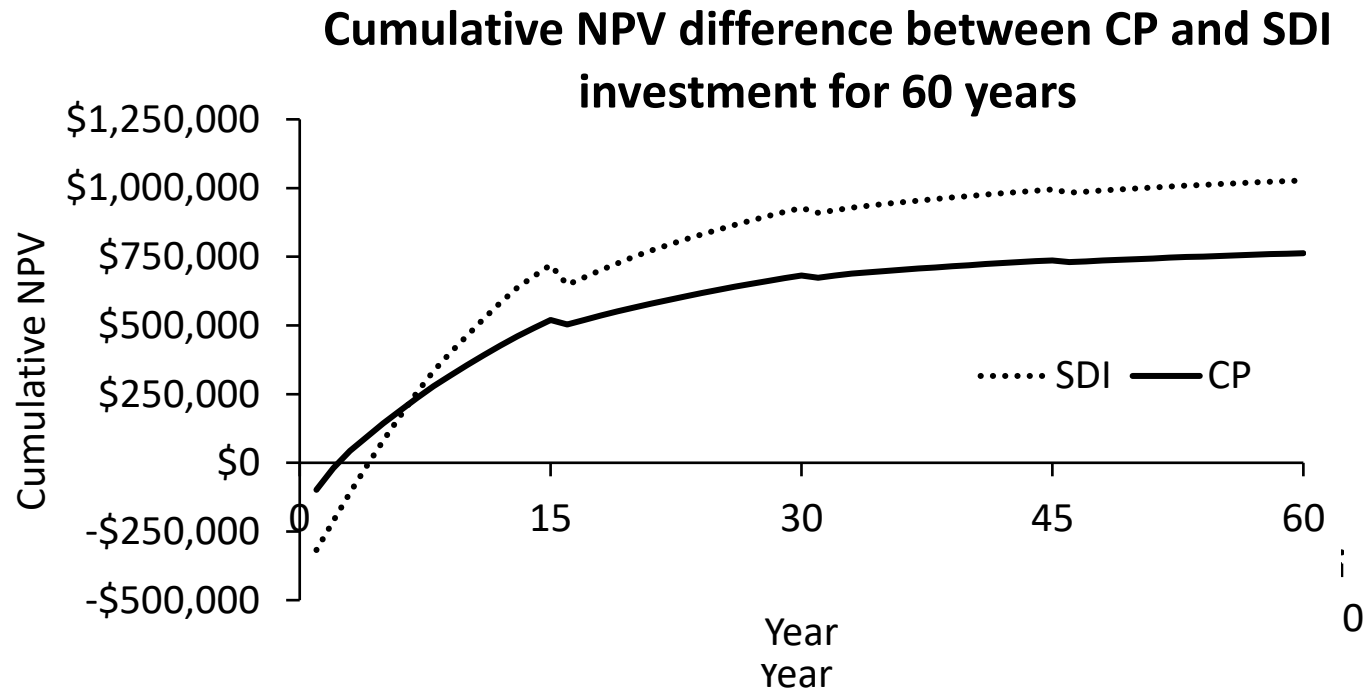
CP



SDI



Economic Results



Total Bushels of Grain Produced in 60 years using CP and SDI System

Irrigation Method	Irrigated		Dryland	Total
	Sorghum (bu.)	Corn (bu.)	Sorghum (bu.)	Grain (bu.)
CP	1,092,795	629,254	1,741,560	3,463,609
SDI	2,329,903	84,990	1,399,410	3,814,304
SDI-CP	1,237,108	– 544,264	– 342,150	350,695

Conclusion

- SDI generates greater NPV from the remaining groundwater in OPA than investing in CP
- SDI produces more grain and irrigates more acres than CP
- The limitations of this study are production risk and price risk were ignored
- Crop insurance premium may give advantage to choose irrigated corn over sorghum
- The current research on this project study the economics of groundwater interaction

THANK YOU

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