

Optimal Long Term Choice of Crop and Irrigation System with Limited Groundwater Supply

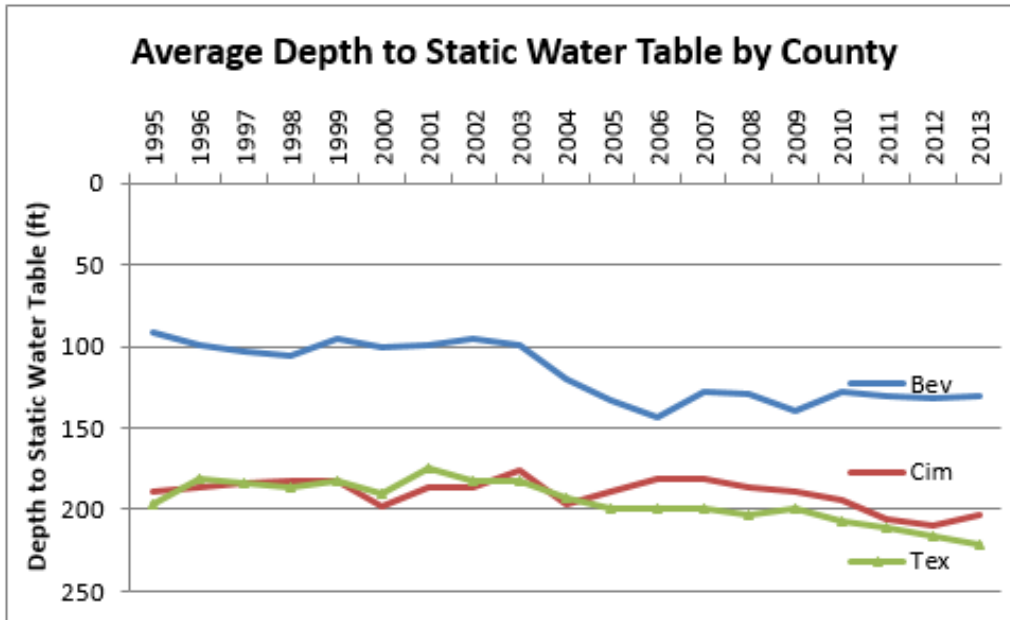
Karthik Ramaswamy

Graduate Student, Department of Agricultural Economics

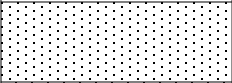
Oklahoma State University, USA

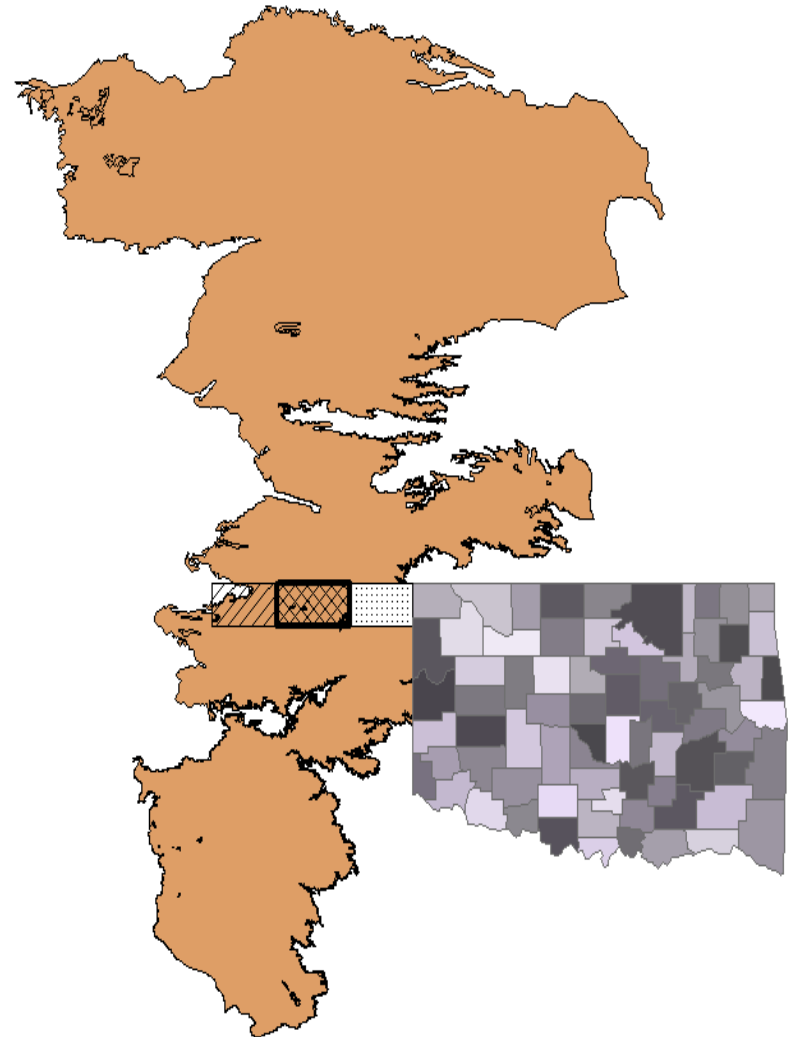
Research Advisor: Dr. Art Stoecker

Water Table Levels in Oklahoma Panhandle Overlying Ogallala Aquifer



Average Annual Decline

	County	(ft/year)
	Beaver	2.6
	Texas	1.9
	Cimmaron	0.9



Crop Production

Data collected for TEXAS COUNTY (*NASS & OPREC*)

Crop	Irrigated Land (acres)	Price (\$)	Yield (bu/acre)	Revenue (\$)
Corn	80,731	4.48	190 (w/22 inch)	851.2
Sorghum	13,259	4.18	145 (w/10 inch)	606.1
Wheat	45,036	6.34	45	285.3

- **Corn gives 9 bushels per acre-inch of water**
- **Sorghum gives 14.5 bushels per acre-inch of water**

NASS : National Agricultural Statistics Service (USDA)

OPREC : Oklahoma Panhandle Research Extension Center (OSU)

Objectives

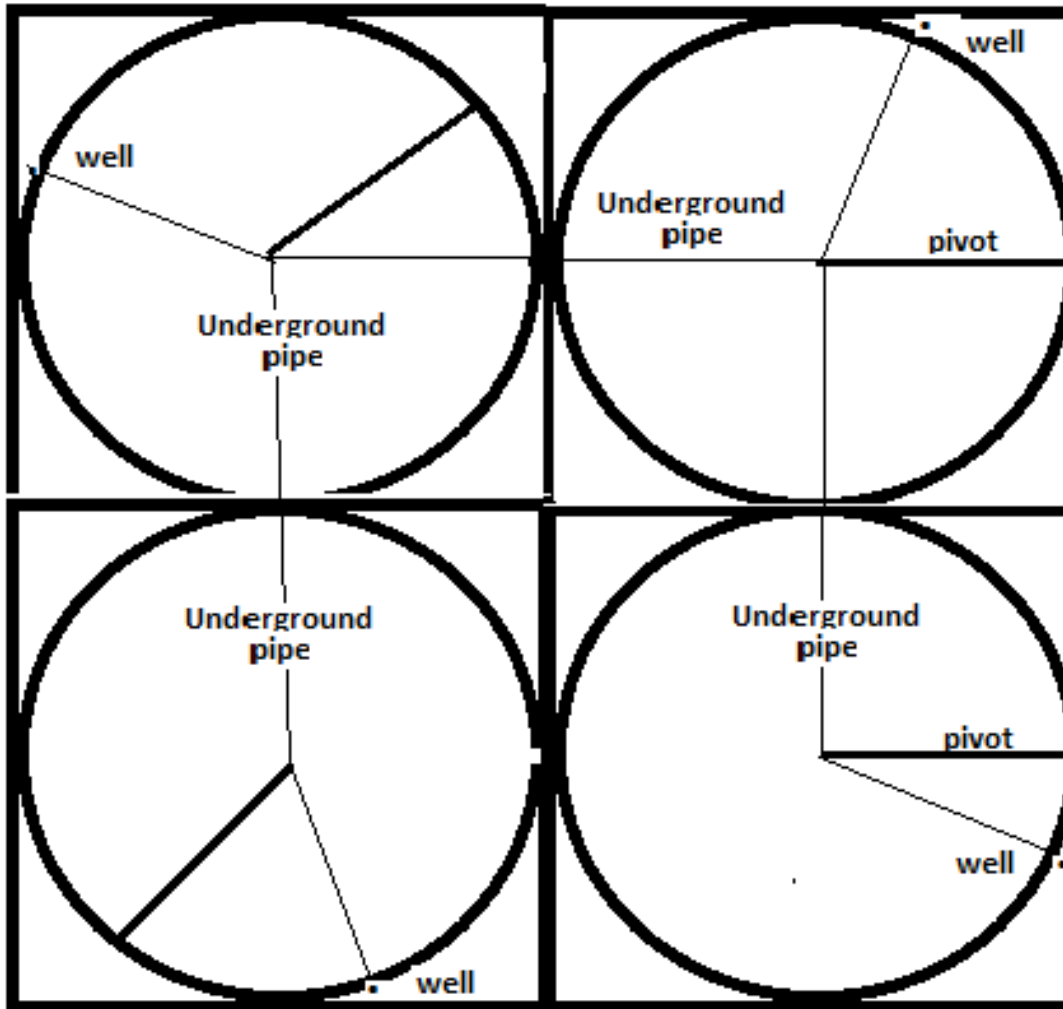
- **Maximize the net benefits from the remaining groundwater supply.**
- **Determine the optimal crop and size of the irrigation system over a 60-year period.**
- **Show the contrast of annual profit maximizer and long term optimal maximizer.**

Method

- **Develop a Mixed-Integer Programming Model to determine the maximum discounted benefit from a finite groundwater reserve.**
- **Simulate EPIC to obtain crop input and output parameters for alternate irrigation strategies.**
- **Prepare budgets to estimate the variable cost.**
- **Use Cooper-Jacob approximation to estimate well drawdowns and water supply that limits for each well capacity.**

**Federal Water Supply Interest Rates based on PL 99-662 are used in this study*

Representation Farm



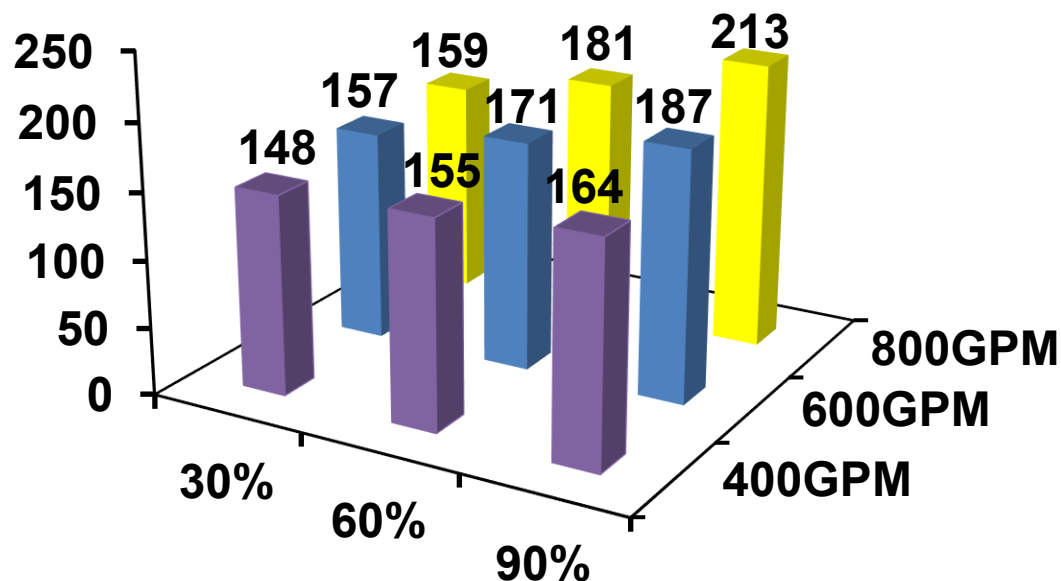
- 640-acre farm
- 4 existing wells tied
- 120-acre Pivot Circle

EPIC SIMULATION

Well Capacity (gpm)	Application Rate (mm)	Frequency (days)
800	36	4
700	36	5
600	36	6
500	36	7
400	36	8
300	36	11
200	36	16
100	36	32

GPM – gallons per minute

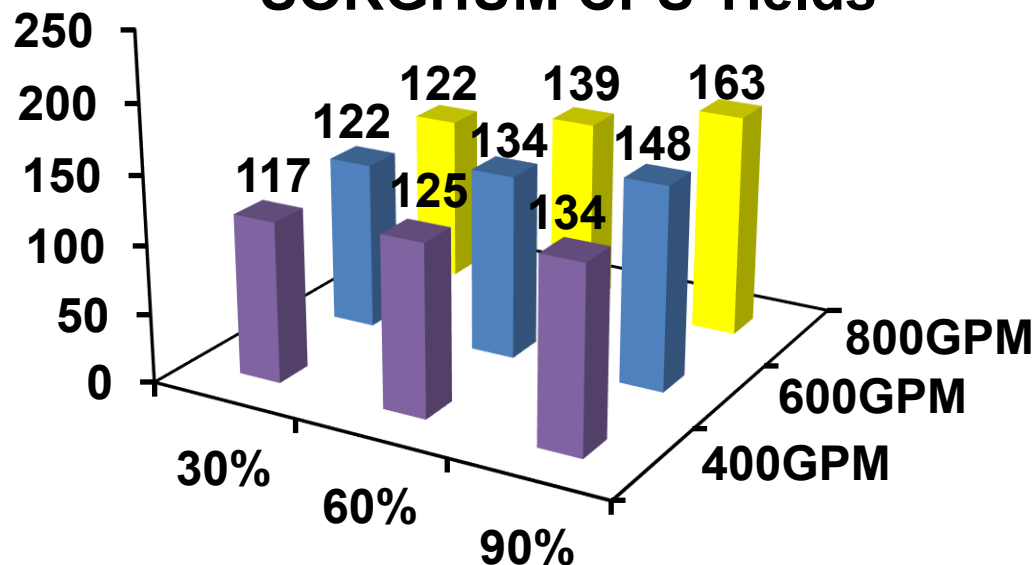
CORN CPS Yields



Corn Net Irrigation (inches)

STRESS/ GPM	30%	60%	90%
800	12.4	16.0	19.1
600	12.4	14.6	18.3
400	11.5	12.7	15.0

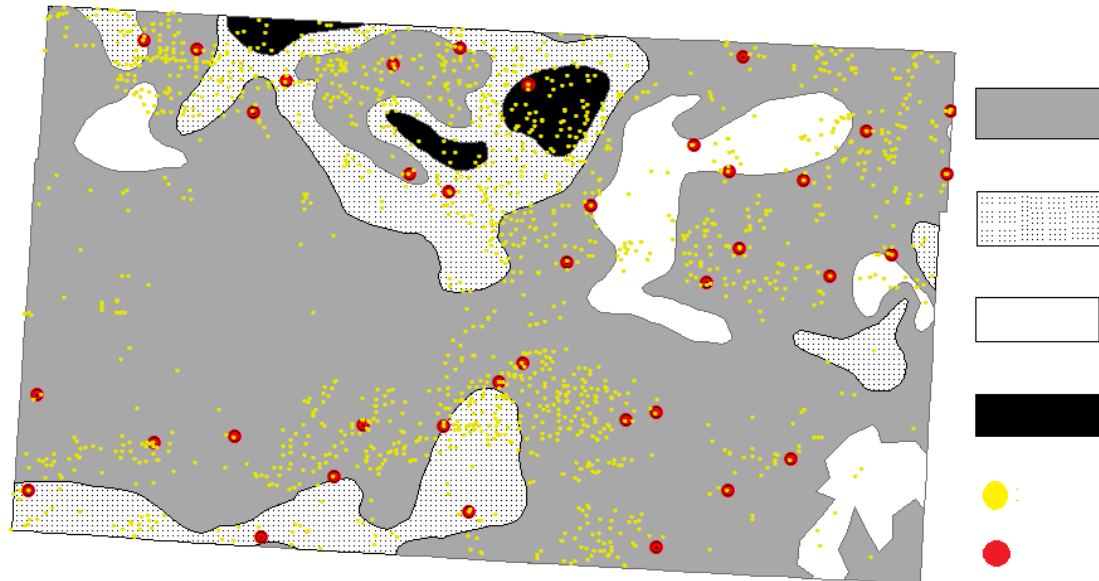
SORGHUM CPS Yields



Sorghum Net Irrigation (inches)

STRESS /GPM	30%	60%	90%
800	7.1	7.8	13.3
600	7.0	8.5	10.7
400	6.5	7.3	8.8

Hydraulic Conductivity Map



K = 25 - 50 ft²/day

K = 50 - 75 ft²/day

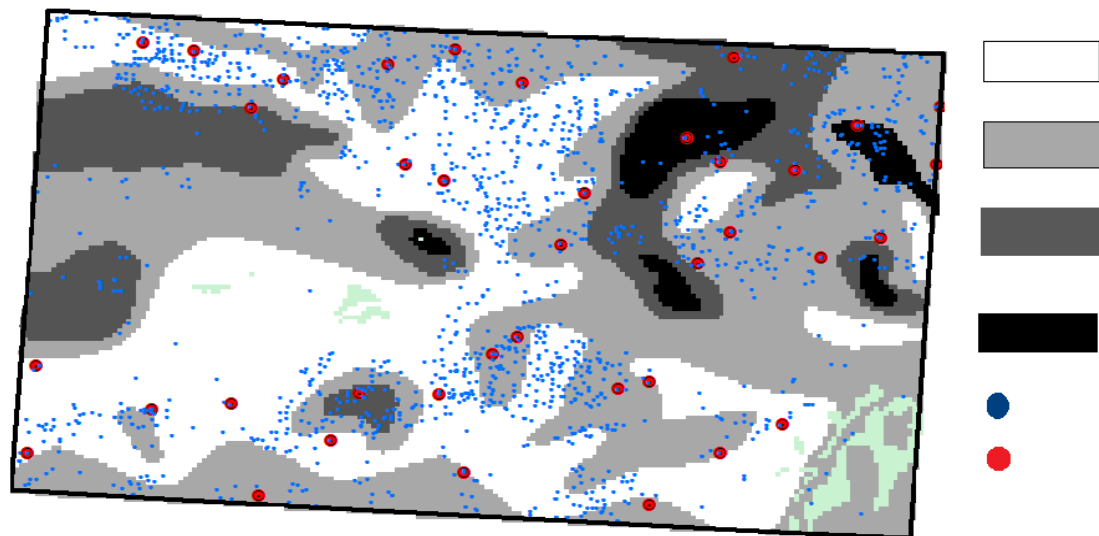
K = 75 - 100 ft²/day

K = 100 - 200 ft²/day

Irrigation Wells

Monitoring Wells

Specific Yield Map



K = 17.5% - 27%

K = 12.5% - 17.5%

K = 7.5% - 12.5%

K = 2.5% - 7.5%

Irrigation Wells

Monitoring Wells

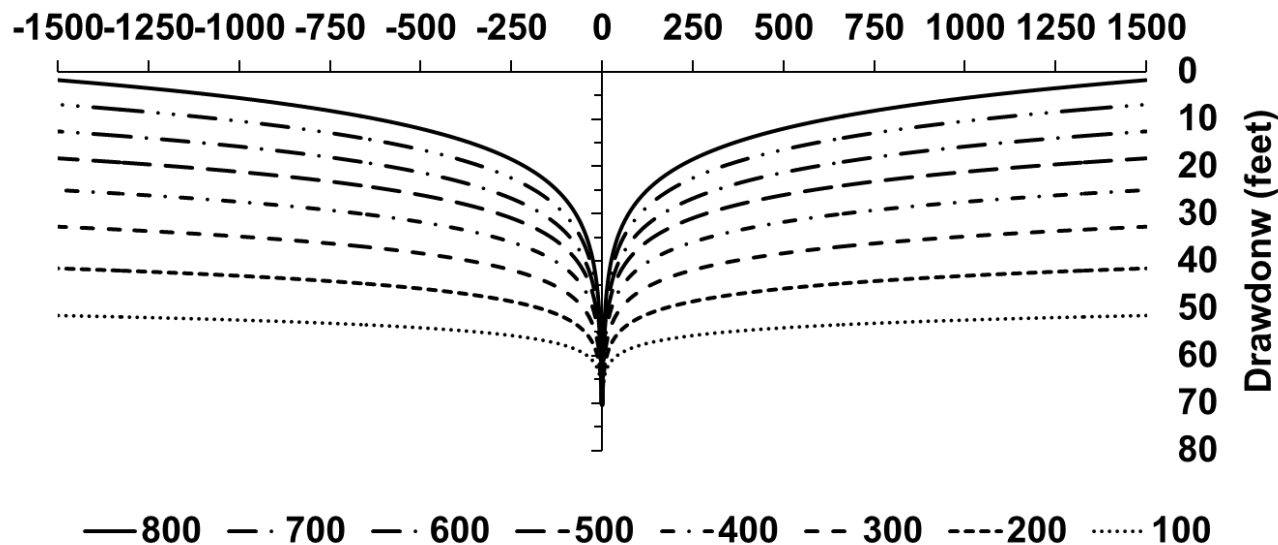
Water Supply Estimation

- What limits well capacity?
 - Total Well Depth
- Total Well Depth is
 - Static Water Level (SWL) + Saturated Thickness

Maximum Drawdown (DD) is useable saturated thickness

Drawdown Curves (Horizontal View)

Span from Well Radius (feet)



SWL	200
*safety zone 35 feet	
D.D for 90days pumping	
GPM	DD (feet)
800	70
700	64
600	58
500	52
400	45
300	37
200	28
100	17

Groundwater Well Interference

Multiple Well Case: 1-well surrounded by 4-wells at a distance of 800m

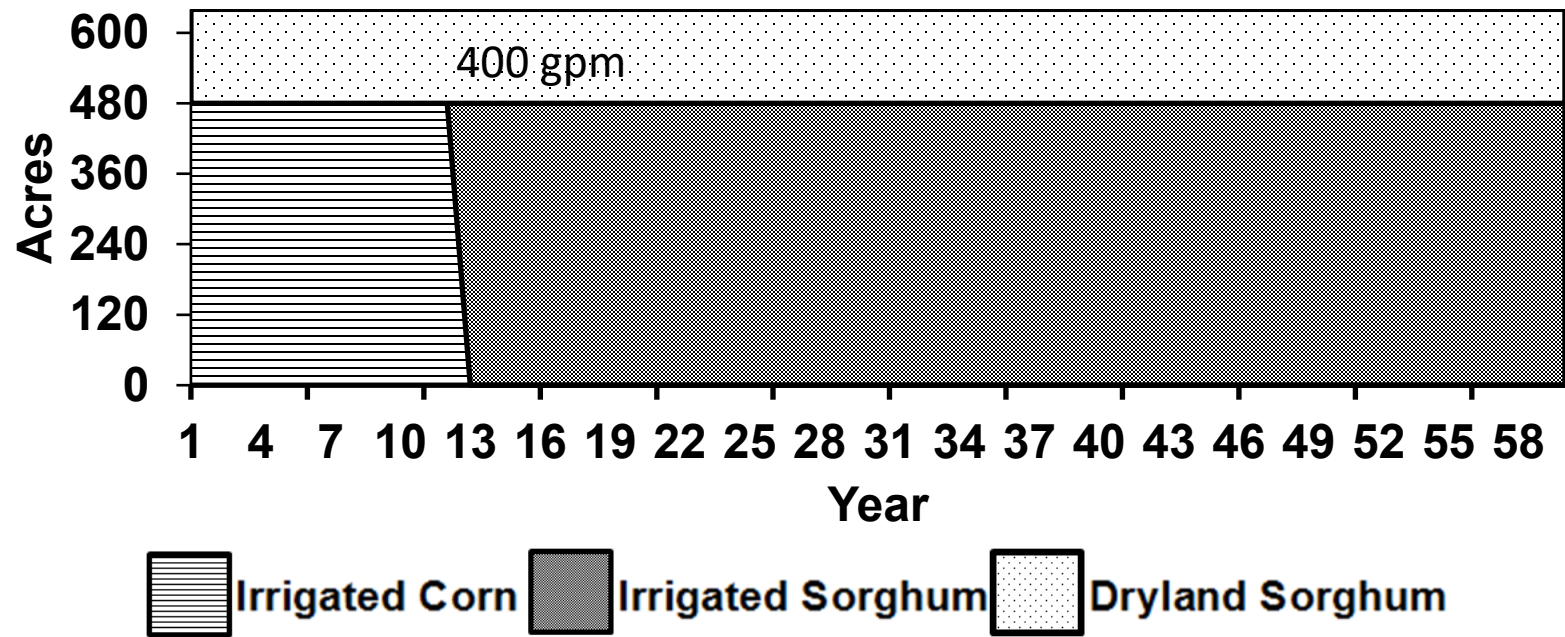
Well Capacity (GPM)	Single Well Drawdown (feet)	Multiple Well Drawdown (feet)
800	69.7	71.4
700	64.1	65.7
600	58.2	59.4
500	51.8	52.5
400	44.9	45.7
300	37.0	37.6
200	28.0	28.3
100	16.5	16.8

- As water table declines well interference problems are expected to reduce.

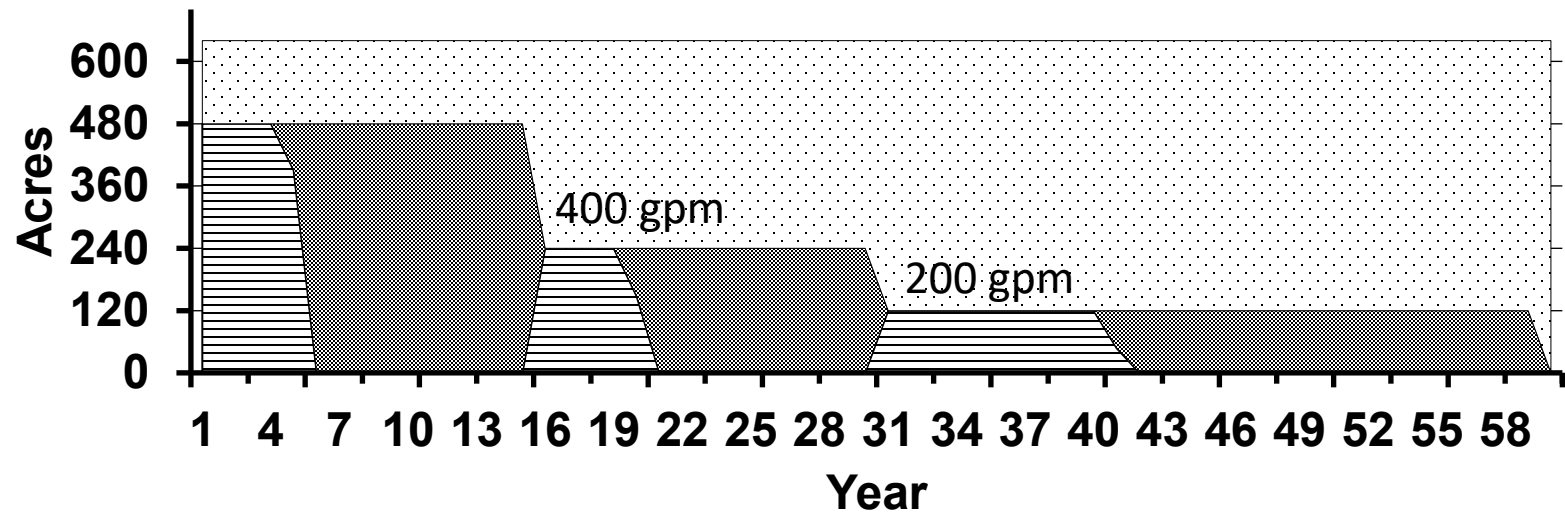
Well Assumptions

- It is assumed each average producer owns a 640-acre irrigated land which is 40% of total available irrigation land.
- For an average farm size with, HC = 25 feet²/day and SY = .18, water supply assumed to be a total of 23,800 acre-feet from 70 feet of saturated thickness.
- Estimated water supply, discounted net returns for each possible activity and irrigation purchase cost are incorporated into the programming model.

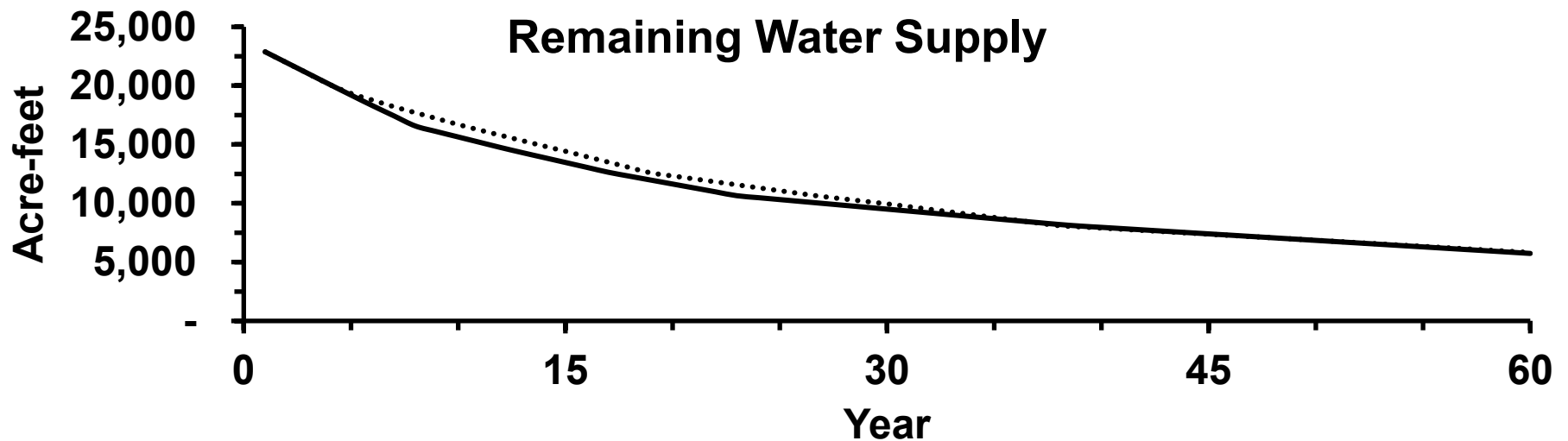
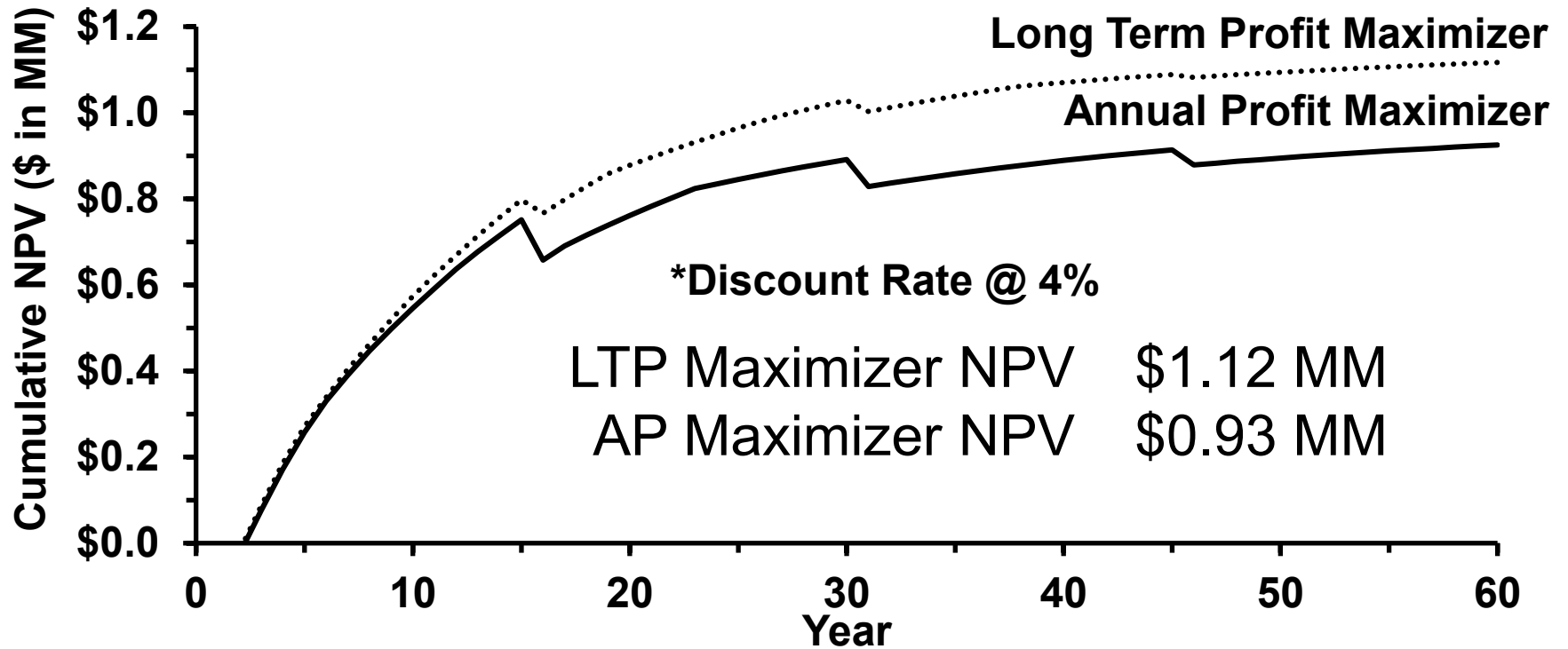
Annual Profit Maximizer Land Allocation



Optimal Long Term Maximizer Land Allocation



Net Present Value Comparision



Current Progress

- **Developing SDI programming model to allocate irrigated land at 50acre, 75acre, 100acre, 125acre and 155acre sizes.**
- **Seeking to observe the benefits and costs due to interaction in groundwater when distinct groups of producers compete for a common supply of groundwater.**
- **Use of Major and Minor Ranges of Hydraulic Conductivity and Specific Yield.**

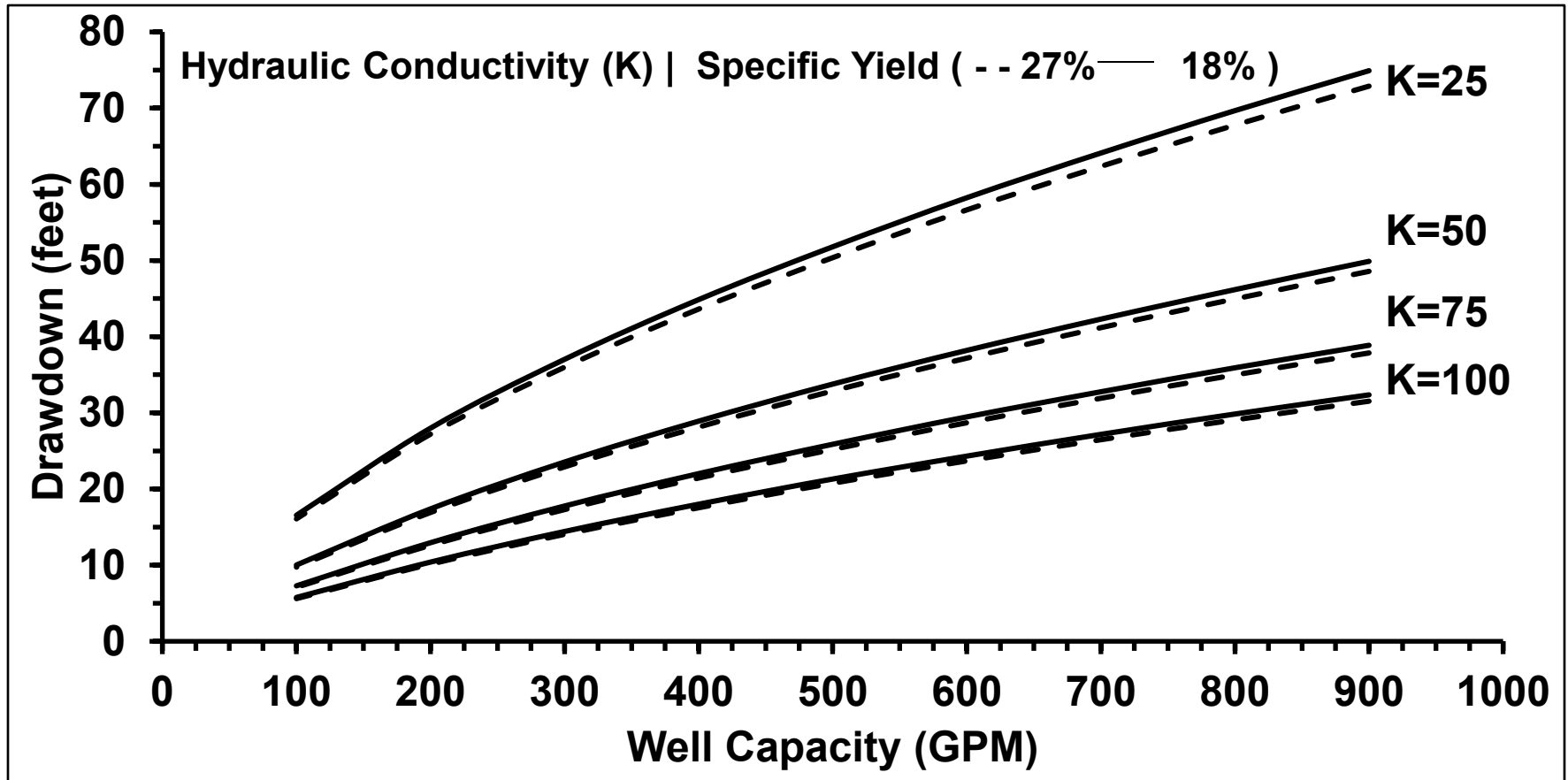
Net Returns of Subsurface Drip and Center Pivot

SDI @ 95% efficiency & CP @ 85% efficiency

	Irrigated Corn						Irrigated Sorghum					
	600 GPM		400 GPM		200 GPM		600 GPM		400 GPM		200 GPM	
	SDI	CP	SDI	CP	SDI	CP	SDI	CP	SDI	CP	SDI	CP
Yield (bu/ac)	202	182	179	159	144	119	161	146	147	131	97	92
Net Rev.	\$905	\$814	\$800	\$712	\$645	\$535	\$670	\$608	\$612	\$544	\$402	\$384
Tot. VC	\$678	\$649	\$622	\$598	\$546	\$509	\$18	\$444	\$18	\$410	\$14	\$324
Ann Sys Cost	\$65	\$45	\$65	\$45	\$65	\$45	\$65	\$45	\$65	\$45	\$65	\$45
Net Ret-Sys. Cost	\$162	\$120	\$113	\$69	\$34	-\$20	\$141	\$119	\$116	\$90	\$11	\$15
Ac. Inch/ac	20.4	20.1	14.9	14.9	9.9	8.6	11.4	10.6	9.0	8.7	2.9	3.4
Net Rev/Ac.in	\$8	\$6	\$8	\$5	\$3	-\$2	\$12	\$11	\$13	\$10	\$4	\$4

Annualized cost of \$90,700 SDI and \$60,100 CP at 4% over 15 years

Drawdown against Well Capacities for 90 days of pumping



- Total water storage increases as specific yield increases,

$$\text{Water Storage} = \text{Area} \times \text{Specific Yield} \times \text{Saturated Thickness}$$

Conclusion

- **Long term profit maximizer makes best use of remaining groundwater.**
- **SDI results are expected to give higher returns when irrigating grain sorghum lower than 600gpm.**
- **Spreading SDI acres is costly and exhausts the aquifer quickly.**
- **Groundwater interaction problems are lowered as water table declines.**

Thank You

Contact:

ramaswk@okstate.edu

505 Ag Hall, Stillwater, OK