

IRRIGATED CROP CHOICES USING CENTER PIVOT: A LONG-TERM PROFIT MAXIMIZATION



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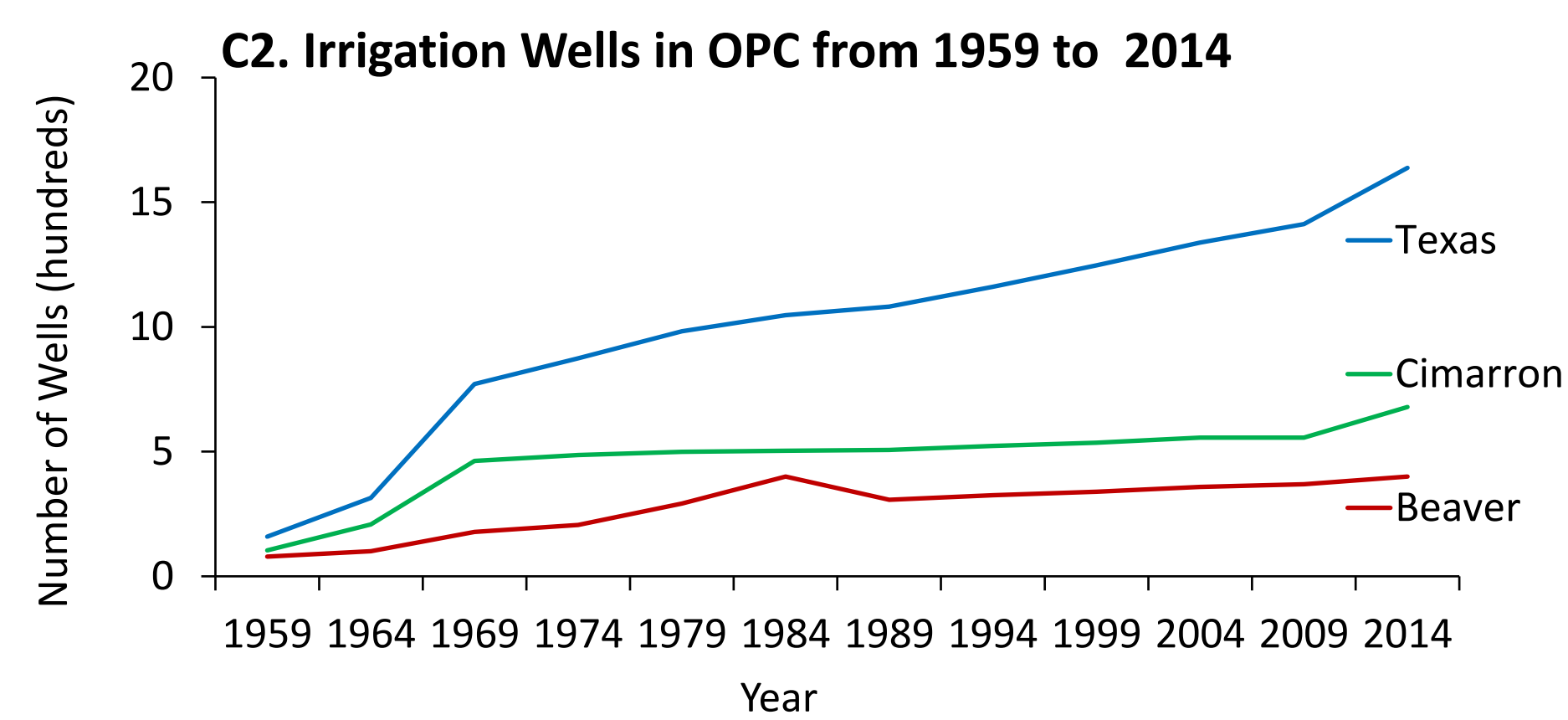
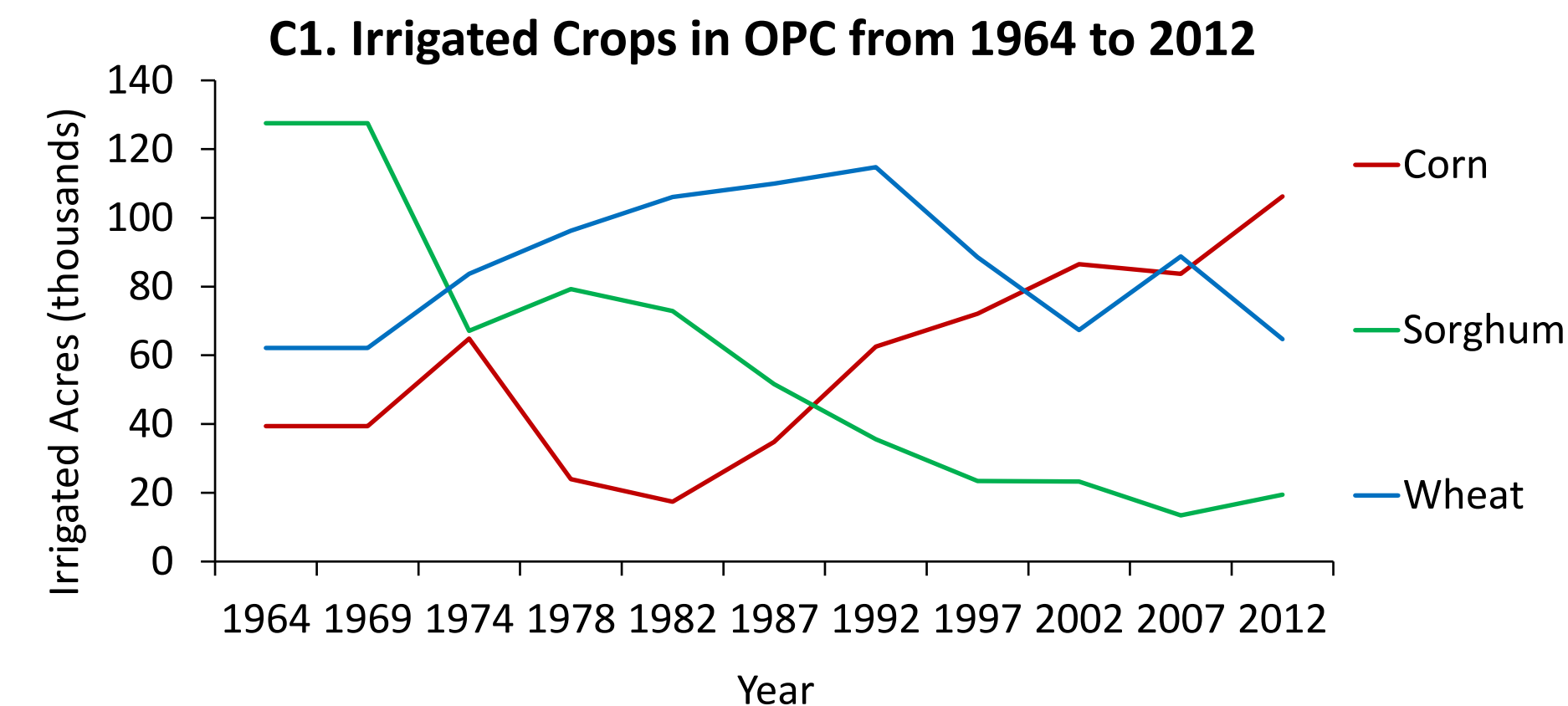


Introduction

Background

The project seeks to maximize the net benefits through extraction of remaining groundwater from Ogallala aquifer in the Oklahoma Panhandle. In recent decades, water-level in the Oklahoma Panhandle Counties (OPC) is declining at a rate of 1 to 3 feet, and estimated recharge is 0.25 feet per year. The continuous water table decline results in reduced well capacities, reduced yields and increased pumping cost.

In OPC, irrigation accounts for 86 percent of total groundwater use from Ogallala formation (OWRB). Irrigated acres increased along with irrigation wells since late 1970s as shown in Figure C1 and C2. The major irrigated crops are corn, sorghum and wheat. Corn generates higher returns per acre when land is more limiting, however, as the water table declines, water becomes scare and sorghum tends to give higher returns per unit of water.



Research and experimental trials conducted in OPC have shown 150 bushels of grain sorghum can be produced with 9.4 inches of irrigation, while 22 inches are required to produce 190 bushels of corn.

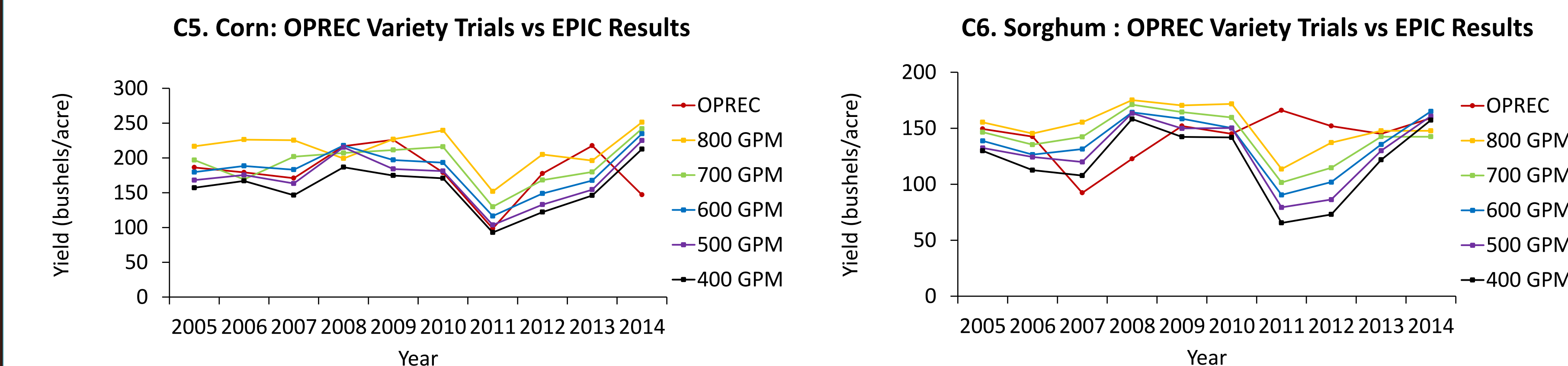
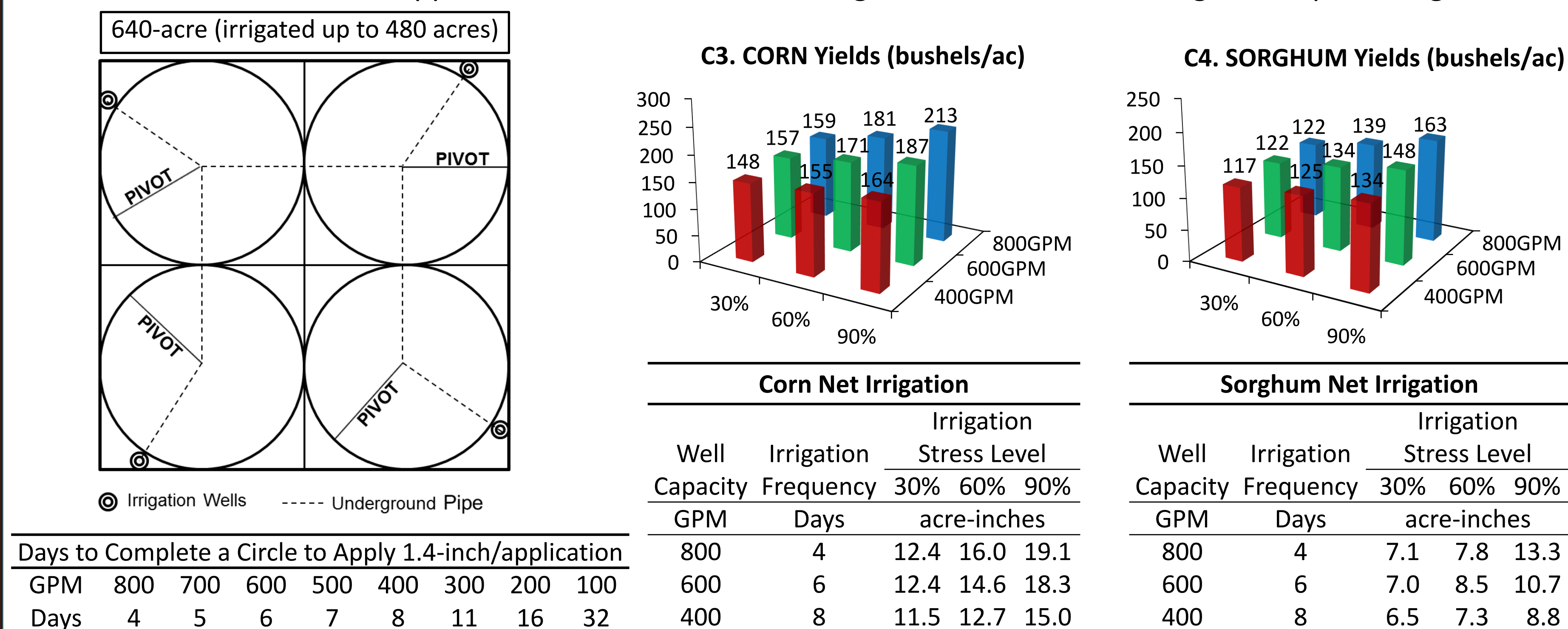
Objectives

1. Extend crop research on irrigated corn and sorghum yields and water use to be more representative of long term weather conditions in Oklahoma Panhandle.
2. Estimate impacts of recent USGS published Ogallala parameters on pumping cost considering pumping drawdown on various levels as the water table declines.
3. Determine optimal irrigation level and choice between irrigated corn and grain sorghum that maximizes the net benefits from the remaining groundwater supply.
4. Determine the most profitable sequence of pivot investment over the remaining life of the aquifer.

Methods and Procedures

Representative Section and Simulation Design

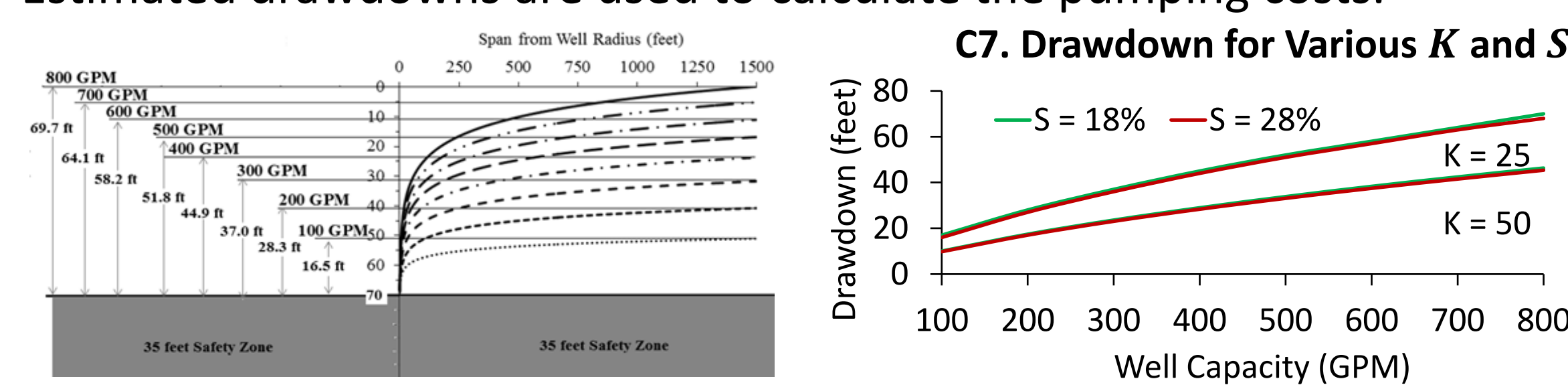
To accomplish the objectives a representative irrigated section of land in Texas County is visualized as shown below. EPIC simulation model was calibrated to extend the plot research by estimating the yields under additional stress levels and application rates for corn and sorghum on a 120-acre using center pivot irrigation.



Drawdown and Pumping Estimates

The amount of water pumped from the water table depends on the depth of the saturated thickness, duration of pumping, and hydraulic conductivity (K (feet per day)) and specific yield (S (percent)). When extracting groundwater from an unconfined aquifer, a cone of depression is formed, the depth of the cone of depression from Static Water Level (SWL) is called as the drawdown. The well-known and most widely used modified radial flow equation developed by Cooper and Jacob (1946) is used to estimate the drawdowns for single well at various discharge rates as shown below. Estimated drawdowns are used to calculate the pumping costs.

The drawdown for 18 and 28 percent of S did not show any major difference. However, the difference in K did show major effect on drawdown. The effect is shown in the Figure C7.



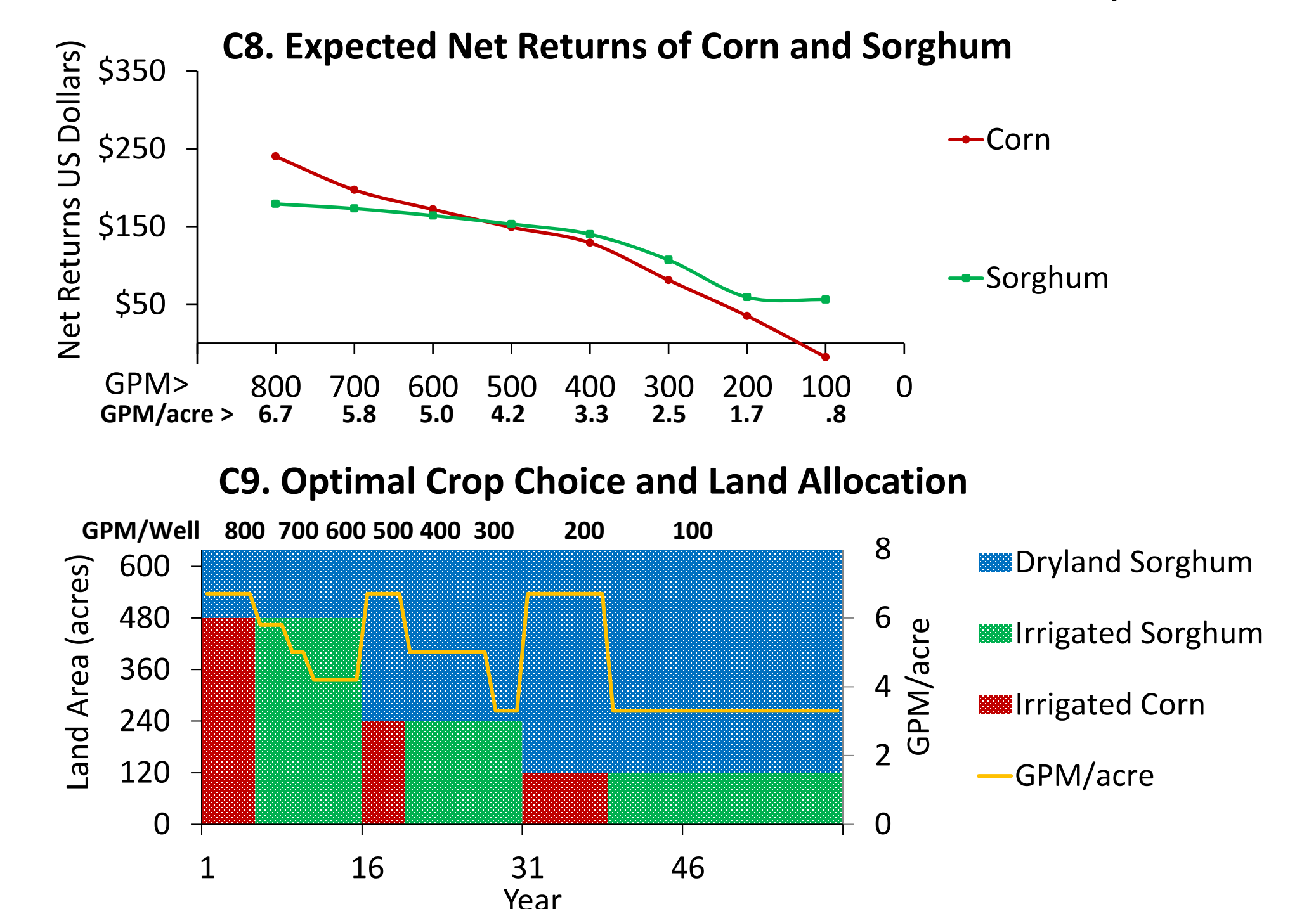
Mixed-Integer Programming

The Mixed-Integer Programming (MIP) model maximizes the Net Present Values (NPV) of the expected returns, and choice variables are crop area and irrigation levels. The pivot purchases every 15 years are treated as integer variables, which necessitate the use of an MIP model. The purchase of one, two, three, or four pivots allows the producer to irrigate up to 120, 240, 260, or 480 acres respectively for 15 years. The task of the programming model is to determine if the increases in net returns from irrigation are sufficient to warrant the cost of one or more pivots. Market price for corn is assumed as \$4.48 per bushel and grain sorghum is assumed as \$4.16 per bushel respectively. A single pivot will cost \$60,000 and allow up to 120 acres to be irrigated for 15 years.

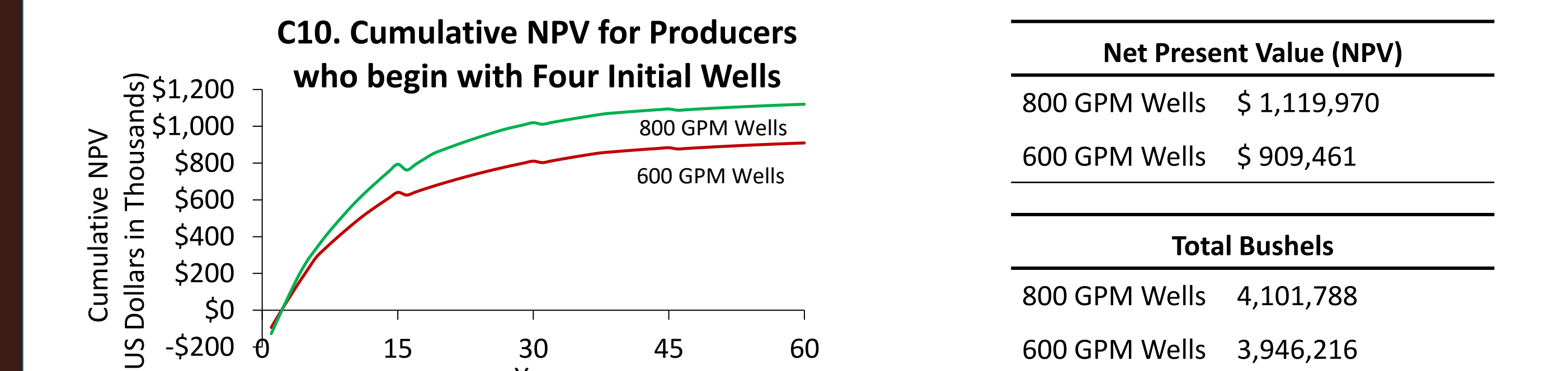
Results

Long-Term Profit Maximization

The choice between irrigated corn and grain sorghum is between income per acre of land, income per acre inch of ground water, and years of irrigation. Figure C8 shows that with irrigated corn higher return per acre than grain sorghum when well capacity is 6.7 GPM per irrigated acre or more but grain sorghum provides more income per irrigated acre when the GPM per acre declines below 5. As aging pivot systems are replaced, the producer can either replace all pivots or replace only some of the pivots and combine one or more wells and increase the GPM per acre.



Maximum discounted profits are obtained by first irrigating corn until the GPM/acre declines to 5.8/acre in the year 6, then sorghum is produced. At year 16, only two pivots are replaced with each pivot supplied by two wells. The GPM/acre increase to 6.7 GPM per acre and corn is produced. As the water level declines below 6.7 GPM/acre, sorghum is produced again. A similar process repeated in the year 31 when only one pivot supplied by four wells is produced. The GPM/acre increase to 6.7 and corn is produced again until the GPM/acre declines to 3.3 GPM/acre, and sorghum is produced again. The results sorghum is the crop selected as irrigation well capacity declines is shown in the Figure C9. Irrigation system investments decline with the water table. Reductions in the area irrigated present's short term opportunities for corn production pending further declines in the aquifer level. Figure C10 compares the cumulative discounted returns over a planning 60-year horizon when the producers begins with 800 GPM and with 600 GPM wells.



Net Present Value (NPV)	
800 GPM Wells	\$ 1,119,970
600 GPM Wells	\$ 909,461
Total Bushels	
800 GPM Wells	4,101,788
600 GPM Wells	3,946,216

References

- Ramaswamy, K. 2016. "Economics of Irrigated Crops Using Center Pivot System in Oklahoma Panhandle" MS thesis, Oklahoma State University.
- Stoecker, A., K. Ramaswamy, J. Warren, R. Jones, J. Campiche, A. Paul, and B. Lane. 2015. "Economic Modeling of Irrigated Corn vs. Grain Sorghum Using Center Pivot or Subsurface Drip Systems". USGS, OWRRI, Annual Technical Report FY 2014.
- Warren, J., A. Stoecker, J. Gatlin, K. Ramaswamy, R. Jones, J. Campiche, A. Paul, and B. Lane. 2016. "Optimizing the Economic Value Water from Ogallala Aquifer Used for Irrigation". USGS, OWRRI Annual Technical Report FY 2015.

Acknowledgment

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