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Deficit Irrigation Management for Irrigated Corn in Nebraska: Economically Viable?

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According to the United States Department of Agriculture Economic Research Service (USDA-ERS, 2018), 80% of the water consumed in the United States is used to irrigate agricultural crops. The techniques used to irrigate have shifted from gravity systems to pressure-sprinklers, notably in the form of center-pivot irrigation systems (Colaizzi et al., 2009). Center-pivot systems use irrigation water more efficiently than earlier irrigation methods, and these systems have allowed output to increase even though the amount of water applied has not grown significantly (USDA-ERS, 2018). However, Spencer and Altman (2010) argue that current water use, particularly in the arid Western states, is not sustainable because of climate change and growing water demand. According to a report by the U.S. Geological Survey (2003), groundwater depletion is widespread across the United States leading to lower water tables, and increased pumping costs, land subsidence, reduced amounts of water in streams and rivers, and adverse effects on water quality. Effective irrigation management is critical for future food supplies, and sustainable farming systems.

The efficient use of scarce water resources is critical for agriculture, particularly for the prosperity of producers in the arid parts of the United States. New technology plays an important role in improving water use efficiencies. Simultaneously, research must be updated using both technological and methodological advancements to understand resulting economic outcomes.

Deficit irrigation represents an important concept in managing water use through irrigation (Hargreaves and Samani 1984; Martin, Brocklin and Wilmes 1989; English 1990). Research on deficit irrigation has spanned across a wide range of applications (Galindo et al. 2018; Expósito and Berbel 2020), has focused corn production (Payero et al. 2006; Klocke et al. 2011), and for recent work that focuses on corn production with an economic component, has continued to advance the deficit irrigation concept (Trout and Manning 2019). To understand the potential value of deficit irrigation, one must understand the yield response to water and the economic impact of yield reductions (English, 1990).

Goal and Objectives

In this study we determine the economic value of deficit irrigation management using both technological and methodological advancements. The use of soil moisture probes represents the technological improvement. We provide improvements in the methodology as follows. Regarding data, we employ a field-size study, instead of plots, where the irrigation decision is determined by the moisture level in the soil measured through a soil moisture probe. Regarding the understanding of the yield response to water, although we examine the commonly used quadratic function, we improve upon this specification by also examining an alternative response function, the linear response stochastic plateau. Our objectives are to identify the financial impact on producers of reducing water use by increasing irrigation costs, reducing irrigation amounts, the role of changes in corn prices, and extreme weather events on the profitability of irrigating corn under a deficit irrigation strategy.

Approach

We model the irrigation production system through the producer lens with a unique dataset collected through an experiment conducted by Irmak (2015a, b) between 2005 and 2010 from field plots with varying levels of irrigation (full irrigation, deficit irrigation, and rainfed), producing corn in central Nebraska. These data are used to estimate equations describing the yield response to irri-

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gation, and the relation between irrigation and evapotranspiration. These relations are then incorporated into constrained optimization models that calculate the profit-maximizing level of irrigation under differing weather and market conditions.

The amount of irrigation water applied not only constitutes a cost in the profit function but also leads to variations in revenue through its effects on yield. To account for the effect of irrigation on yield, yield-response functions are estimated, and the estimated parameters are included in the profit function. Because the irrigation applied to the crop depends on rainfall as measured by soil water content, we cannot distinguish between the contribution of rainfall and irrigation water.

What did we find?

Results suggest that the optimal economic strategy within our constrained optimization model is to fully irrigate, with the economic impact highly dependent on commodity prices, restriction level, and irrigation costs. The greatest economic losses caused by irrigation restrictions come from decreases in yield. Some simulations resulted in negative profits, indicating that a switch to alternative crops requiring less irrigation may be warranted.

Our results show that yield, and consequently profit, is heavily impacted by total water applied, similar to findings in past economic studies. Reducing irrigation causes a decrease in expected yield, resulting in decreased expected profits that switch from being positive to negative with large decreases in irrigation. Producers who make decisions based on market prices will adjust irrigation use to prices. For these producers, low corn price reduces irrigation use more than high irrigation costs and irrigation restrictions. Producers who ignore prices in their decision making would only change irrigation behavior through a constraint in irrigation, a result indicating policies that slightly increase irrigation costs will not impact water use. Some simulations resulted in negative profits, indicating a potential for a switch to alternative crops that require less water use. Crop insurance could provide indemnity payments, possibly making profits positive.

Our constrained optimization model indicates that full irrigation is the profit-maximizing strategy in all scenarios, even when there is a severe drought and high variable irrigation costs. Water is currently a small cost to producers and without government intervention, a large reduction in water available from natural resources, or a large increase in costs surrounding irrigation (labor, electricity, ownership of center pivot, etc.), producers would apply full irrigation to achieve the highest profit. Only substantial changes in irrigation costs would cause the producer to deviate from the optimal strategy of full irrigation. However, producers may experience large profit losses if deficit irrigation is implemented. If reducing irrigation is considered optimal for society, compensation for producers will need to be considered.

For additional information

For a copy of the full article titled "Economics of Deficit Irrigation in the Western Corn Belt", forthcoming in Agricultural and Resource Economics Review, please contact Lia Nogueira at lia.nogueira@unl.edu

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