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The impact of field size and energy cost on the profitability of supplemental corn irrigation

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ABSTRACT

Supplemental irrigation in corn production is increasing for humid regions across the world. Little is known about the profitability of irrigating corn in the humid southeastern region of the United States. Our objective was to determine the breakeven price of corn where investment in center-pivot irrigation would be profitable in Tennessee. We considered the effects of field size, energy price, and energy source on the breakeven price of corn. We estimated yield response to nitrogen (N) for irrigated and non-irrigated corn, and allowed expected yield and economically optimal N fertilization to vary with the breakeven price. Field size and the cost of running electricity to the center-pivot were two important factors in choosing between diesel and electricity as the energy source. The breakeven price of corn ranged between \$249–\$283 Mg^{-1} for the small-sized field, \$168–\$190 Mg^{-1} for the medium-sized field, and \$149–\$171 Mg^{-1} for the large-sized field. As field size increased, electricity became more economically viable relative to diesel. At current corn prices, irrigating corn appears profitable on fields greater than 51 ha. However, historically, the probability for the breakeven corn price occurring is zero for the small-sized field, between 6–14% for the medium-sized field, and 12–27% for the large-sized field.

1. Introduction

Demand for food crops has been increasing in response to a number of factors including a growing global population, expanding economies in developing countries, and rising biofuels production among other factors (Trostle, 2008). To meet the growing demand for food, more than half of world cereal production is anticipated to be produced using irrigation by 2050 (Rosegrant et al., 2009). Globally, irrigation is expected to expand in humid regions that generally receive sufficient annual rainfall to grow crops without irrigation in most years (Mullen et al., 2009; Rosegrant et al., 2009; Schaible and Aillery, 2012). The primary purpose of irrigation in humid regions is to supplement rainfed crop production during periodic short-term droughts.

Research has shown that timely supplemental irrigation in humid regions can increase yields (Bruns et al., 2003; Smith and Riley, 1992), decrease crop disease (Smith and Riley, 1992; Vories et al., 2009), and stabilize yields (Apland et al., 1980; Dalton et al., 2004; Epperson et al., 1993; Evans and Sadler, 2008; Henning, 1989; Vories et al., 2009; Salazar et al., 2012). Another advantage of supplemental irrigation in humid regions is the availability of abundant water for irrigation, and that water is often inexpensive or free (Gonzalez-Alvarez et al., 2006; Mullen et al., 2009). For example, the doctrine of riparian water rights is followed by most states in the humid subtropical zone of the southeastern United States (Christy et al., 2005; Myszewski et al., 2005). The riparian doctrine states that water rights are not quantitatively fixed and water is not explicitly priced (Griffin, 2006). When water is inexpensive or free, farmers make irrigation decisions based on water needs and the energy cost of pumping water, not the price of water (Gonzalez-Alvarez et al., 2006; Mullen et al., 2009).

In the United States, supplemental irrigation of crops in humid regions such as the southeast has been growing rapidly (Dalton et al., 2004; Gonzalez-Alvarez et al., 2006; Schaible and Aillery, 2012). Schaible and Aillery (2012) reported that the largest increase in irrigated crop production in the United States since 1998 has been in the southeastern states of Georgia, Alabama, and Mississippi. The majority of the growth in irrigation for this region has been for corn production (Salazar et al., 2012; Vories

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et al., 2009). Vories et al. (2009) noted that 62% of all corn hectares in the Mid-South (Louisiana, Mississippi, Alabama, Arkansas, Tennessee, and Kentucky) were irrigated in 2003, and Lee (2013) stated that 72% of Georgia corn hectares were irrigated in 2011.

A plausible explanation for the increase in irrigated corn production in the southeastern United States may be the increased price for corn since 2006 (Mullen et al., 2009). Even though irrigation in the southeastern United States is increasing for corn production and the price of corn is historically high, little is known about the long-term profitability at the farm-level of irrigating corn in the humid southeastern United States. For example, center pivot irrigation systems are more expensive to install on the smaller and more irregularly shaped fields that are common in the eastern United States (Hatch et al., 1991), but may be profitable under higher corn prices.

Our research objective was to evaluate the breakeven corn price above which a center-pivot irrigation system becomes profitable in the southeastern United States. Annual rainfall is sufficient to produce corn but irrigation is used as a supplement. We considered the effects of different energy sources, energy prices, and field sizes on the breakeven corn price. Stochastic yield response to N fertilizer was estimated for irrigated and non-irrigated corn, and expected yields and profit-maximizing N fertilizer rates were allowed to vary with the breakeven corn price. Partial budgets were used to calculate net cash flows over time for irrigated and non-irrigated corn, and a financial analysis was performed over the life of the irrigation system to solve for the time-adjusted breakeven corn price.

The breakeven corn prices were compared to historical corn prices to determine the probability that a producer who invests in center-pivot irrigation would achieve a breakeven profit of zero. Our framework and results will help farmers evaluate the profitability of irrigation investment in other southeastern states as well other humid regions in the world. Furthermore, the results have implications for future agricultural water management in the southeastern United States and specifically Tennessee.

2. Literature review

Several studies analyzed the feasibility of investing in irrigation systems at the farm level (Caswell and Zilberman, 1986; Guerrero et al., 2010; Letey et al., 1990; O'Brien et al., 2001; Peterson and Ding, 2005; Seo et al., 2008). These studies, however, focus on arid regions where water is scarce and irrigation is vital for crop production. The aforementioned analyses are insightful for arid regions because they demonstrate methods to reduce irrigation costs. However, water is relatively cheap and abundant in the southeastern United States and other humid areas, and producers have little incentive to conserve water or increase water use efficiency (Sheriff, 2005; Vories et al., 2009). Therefore, these studies provide little insight into the profitability of irrigating crops in humid regions such as the southeastern United States.

Mullen et al. (2009) evaluated the factors driving irrigation water demand in the southeastern United States using a multi-crop production model. Since the riparian doctrine is widely recognized in this region, Mullen et al. (2009) followed Gonzalez-Alvarez et al. (2006) by using the energy cost of pumping water as a proxy for the price of water. They found that energy cost slightly influenced water demand, but crop prices have the greatest influence on irrigation water demand. Other economic research on irrigation in humid regions has primarily focused on production risk management. Boggess et al. (1983) determined optimal irrigation scheduling that maximized net returns, and Boggess et al. (1985) surveyed farmers in the southeastern United States to determine their perception of using irrigation to manage production risk. Dalton et al. (2004) compared using irrigation with enrolling in crop insurance to manage potato production risk in Maine in the northeastern United States under humid conditions. They found that crop insurance was inefficient to minimize producers' production risk in humid regions, and that supplemental irrigation was beneficial depending on the scale (i.e., field size) of the system with a larger scale providing more risk-management benefits.

More recently, DeJonge et al. (2007) simulated yields for irrigating corn in Iowa, and calculated the breakeven corn price for irrigation on a 52 ha field. They found a breakeven corn price for irrigation of \$182.18 Mg^{-1}. Irrigation was not profitable since the average price of corn used to calculate net returns was \$79 Mg^{-1} (\$2 bu^{-1}). Although DeJonge et al. (2007) provide useful insights; they used simulated rather than actual yield data to estimate breakeven prices. In addition, irrigating corn in humid regions may be profitable given the higher corn prices since 2006, the last year of their study. In our literature review, we have found no studies evaluating the profitability of irrigated corn production in humid regions using actual corn yield data rather than simulated yield data. The impact of field size, energy source, and energy price on the breakeven price for corn also has not been studied.

Another limitation of many corn irrigation studies is the exclusion of inputs other than water (e.g., DeJonge et al., 2007). Along with water, nitrogen (N) fertilizer is likely the most important input in corn production (Stone et al., 2010). Research has shown that N fertilizer provides the largest economic return per dollar spent relative to all other farm inputs (Pikul et al., 2005). A large number of studies have focused on estimating the profit-maximizing N fertilization rate for corn (e.g., Bullock and Bullock, 1994; Cerrato and Blackmer, 1990; Frank et al., 1990; Llewelyn and Featherstone, 1997). These studies show that as the price of corn and N change, the economically optimal N fertilization rate also changes. For a profit-maximizing corn producer, an increase (decrease) in the price of corn results in an increase (decrease) in the optimal N fertilization rate. Irrigation and N fertilizer are complements in row crop production, so irrigating corn will likely increase both yield and the optimal N fertilization rate (Dinnes et al., 2002; Stone et al., 2010; Vickner et al., 1998). Stone et al. (2010) estimated corn yield response functions to N in the southeastern United States, and found that optimal rates vary between irrigated and non-irrigated corn. Therefore, the corn price and the physical relationship between yield, irrigation, and N impacts corn producers' net returns. To avoid overstating or understating the profitability of irrigation, the physical relationship between yield, irrigation, and N should be considered along with corn and N prices.

3. Data

3.1. Yields and nitrogen rates

Corn yield data come from N fertilization experiments conducted at the University of Tennessee Milan Research and Education Center (35°56′N, 88°43′W) from 2006 to 2011. Non-irrigated corn was grown on a Grenada soil (fine-silty, mixed, active, thermic Oxyaquic Fraglossudalfs) and irrigated corn was produced on a Loring soil (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs), which were considered well suited for corn production in Tennessee (USDA-NRCS, 1999). The two experiments were located on fields that have been under no-till production for over a decade (Yin et al., 2011). Corn (cultivar Pioneer 33N58) was planted in 76-cm rows in April in rotation with soybeans. Each plot was 4.6 m wide and 9.1 m long.

The experimental design was a randomized complete block with five or six N fertilization treatments as strip-plots and four