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Economic and Environmental Impacts of Expanding Irrigation in the Southeast

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Economic and Environmental Impacts of Expanding Irrigation in the Southeast

Water for irrigation in the West and Midwest is now under stress due to changes in both supply and demand. There is also increasing concern that the concentration of grain production in the upper Midwest and nutrient loading in the Mississippi River may be impairing ecosystems of the Mississippi River Basin and contributing to hypoxia problems in the Gulf of Mexico. Furthermore, while the Intergovernmental Panel on Climate Change (IPCC, 2007) has indicated that predictions of regional climate change especially in precipitation are uncertain, there is a consensus that arid areas are likely to become drier and humid areas wetter. For the humid Southeast, IPCC models show on average slightly wetter conditions or no change. Thus climate change may add additional concerns about water in the West but may bode well for average precipitation in the Southeast. In fact, observational climatological analyses indicate that average annual rainfall has increased significantly in most of the Southeast the past 100 years (Ritschard and Cruise, 2002). It is also a hydrologic irony, that with the large water consuming natural vegetation in the Southeast, suburban and urban growth may actually reduce evapotranspiration so that population growth does not necessarily reduce water availability (Sun et al. 2006).

This paper is part of a larger study examining the economic and ecological consequences of expanding irrigation in the Southeast. Here we develop a methodology for estimating economically optimal irrigation water use at the field level under different climatic and economic scenarios. We then apply the methodology to the production irrigated corn in Alabama, a state that has recently passed legislation that provides tax incentives for irrigation adoption.

Regression analysis and principle component analysis are the most common tools used to estimate the derived demand for irrigation water. Use of these tools is hampered in this area because of a paucity of data due the low rates of irrigation adoption. There are very few observations of grower responses to economic and climatic variables. To circumvent this problem we utilize a crop growth simulation model, the Decision Support System for Agro-Technology (DSSAT), calibrated to the dominant soils in the study area as well as the cultivars planted.

DSSAT is used worldwide to model yield responses of a variety of crops to water applications, fertilizer applications, planting density, and a variety of other field-level conditions. The flexibility of this approach is extremely attractive, especially when projecting yield changes in future precipitation regimes. Here we can model the crop response to changes in rainfall patterns at a much finer time scale than the monthly or seasonal precipitation levels that are used in the econometric studies mentioned above. This part of the paper is especially well-suited for an oral presentation as it should initiate a much needed discussion about the relative merits of econometric models and crop growth simulation models.

Farm-level, microeconomic effects of irrigation adoption were estimated for 3 northern Alabama counties: Limestone, Lauderdale, and Madison. Data from four weather stations in each county (a total of twelve sites) spanning the years 1950 through 1999 were used to simulate corn production with and without irrigation. The output from those simulations were used to examine how farm income and water use would change with the adoption of irrigation under a variety of economic and weather conditions.

The DSSAT simulations for each site included 11 irrigation treatments, distinguished by the soil moisture threshold that triggered an irrigation application, and three soils. The 11 irrigation treatment thresholds ranged from 10% to 100% in increments of 10%, plus the rainfed treatment. When soil moisture dropped below the threshold, discrete irrigation applications of 25mm of water were applied until simulated soil moisture met or exceeded the threshold. The DSSAT output concerning yield and number of irrigation applications for each year and treatment and site and soil served as inputs to the microeconomic model.

Using a constant relative risk aversion (CRRA) utility function, the microeconomic model identified the irrigation treatment that maximized the expected utility of net returns to corn production, hereafter referred to as the optimal irrigation strategy. An optimal irrigation strategy was identified for each site and soil type and each economic scenario. The CRRA was further parameterized to explore how risk aversion affected the optimal strategy, varying the risk aversion coefficient from 0.5 (low risk aversion) to 1.1 (modest risk aversion) to 2.5 (strong risk aversion) to 6 (extremely risk averse).

The economic scenarios varied by input costs (irrigation cost/ha/application and fertilizer cost/ha) and output price (\$/bu). Eight scenarios of fertilizer and corn prices were examined: 2013 prices; 5-year average prices (2009-2013); 10-year average prices (2004-2013); 20-year average prices (1994-2013); the highest prices over the last 20 years; the lowest prices over the last 20 years; the highest fertilizer price and the lowest corn price over the last 20 years; and the lowest fertilizer price and highest corn price over the last 20 years. Two irrigation costs were also examined: the cost reported by the Alabama Extension Service in their irrigated corn enterprise budget; and an irrigation cost based on the average well depth at each site and the electricity costs needed to pump 25 mm of water from that depth, using 2013 electricity prices. This leads to 64 scenarios (4 risk aversion coefficients x 8 fertilizer-corn prices x 2 irrigation costs) for each of 3 soils at all 12 sites.

Lastly, we varied the weather distribution. Each site had 50 years of historical data. Using these data we first identified, for each site and soil and economic scenario and risk aversion level, the optimal scenario based on all 50 years. The optimal strategy here is the best one could do if provided historical weather information but no information about the weather for the coming season. If, however, the coming season was forecasted to be a dry one, the optimal strategy likely would change. To examine the effect of dry years on the optimal strategy, expected net revenues, and expected water use, we partitioned the weather data into three additional groups: the driest 10 years, the driest 5 years, and the driest 2 years. As a result, we have developed 64 scenarios across 3 soil types at 12 locations under 4 weather distributions.

Results show that there is no single optimal strategy across all economic and weather scenarios. The primary drivers in the selection of the optimal strategy are output price and the cost of an irrigation application. There are many scenarios in which the optimal strategy is rainfed production or no production at all, a result consistent with the low rates of irrigation adoption in the area. Under the right conditions, however, net returns to irrigation can reach \$430/acre. Expected water use per acre is also calculated under each economic and weather scenario.

The policy implications of the results are discussed at length in the paper. These include watershed effects resulting from expanding irrigation and the macro-economic effects of changes in expected farm incomes. Expected changes in tax revenues are also calculated and used to assess how long it would take for Alabama's tax incentives to become revenue neutral.