Potential of high residue conservation tillage to enhance water conservation and water use efficiency in corn production in the Southeast

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INTRODUCTION

After three years of development, Georgia adopted its first Comprehensive State-wide Water Management Plan in early February 2008 (Georgia Department of Natural Resources, 2008). The state will be divided into ten water planning regions, each run by a 25-member Water Planning Council. These councils are charged with drafting Water Development and Conservation Plans by region, which, matched to available resources, would include appropriate management practices for economically and environmentally sustainable use of the state’s water resources. Plans are expected to be finalized and adopted by mid 2011.

One of the economic sectors that will receive close scrutiny in this process is agriculture. Georgia has approximately 3,250,000 acres of harvested cropland, about 1,550,000 acres of which is irrigated (Georgia Statistics System, 2006), with corn, cotton and peanut accounting for about 1,150,000 acres of the irrigated land (NESPAL, 2006). Eleven of the 159 counties have 50,000 to 90,000 acres of irrigated land each, while 55 counties have >10,000 acres of irrigated land each. Average irrigation water use is estimated at about 1.1 billion gallon per day (BGD) compared to 6.5 BGD withdrawal for all sectors. Harrison and Hook (2005) estimate annual irrigation water use to fluctuate between 100 and 300 billion gallons.

Conservation tillage technology stands out among farming innovations developed in the last three to four decades with demonstrated benefits for enhancing sustainable farmland use (Soil and Water Conservation Society, 2006). Conservation tillage is an umbrella term that encompasses four interlinked cropping management practices: minimum or no soil disturbance, permanent residue cover on 30% or more of the surface, direct sowing, and sound crop rotation. No-till is one such practice where zero-tillage is adopted. During the previous two decades no-till has expanded to approximately 148 million acres of land worldwide (Pieri et al., 2002). In 2004 in the USA 40.7% (112.6 million acres) of all cropland was planted in conservation tillage with no-till comprising 22.6% of total cropland (CTIC, 2005). In the South the equivalent numbers were 26.8 and 19.8%, respectively, while in Georgia, they were 33.7 and 29.3%, respectively (CTIC, 2005).

Research across states and regions indicates that conservation tillage can lead to significant savings in water use and/or loss in crop production because of increased infiltration and reduced runoff as a result of improved soil quality through increased organic matter (Langdale et al., 1992; Reeves, 1997; Endale et al., 2000 and 2002; Reeves et al., 2005; Truman et al., 2005; Terra et al., 2005; Soil and Water Conservation Society, 2006; Sullivan et al., 2007). Surveys across the USA and globally show that producers rate labor savings (cost, time) as a primary reason for their decision to use conservation tillage, followed by availability of glyphosate resistant technology, reduced erosion, machinery savings (cost, time), conserving soil moisture, other cost savings, improved soil quality, crop protection from wind/sand, government incentives or cost-share, and higher yields, generally in that order (Uri, 1999; Pier et al., 2002; Shurley, 2006).

It is clear from these assessments that the value of conservation tillage in directly conserving water resources at farm, local, regional or national level has not yet been fully grasped or appreciated. As Georgia embarks on its
next phase of region-based water management planning and conservation, it is hoped that stakeholders involved in the process would consider conservation tillage farming as one of the many viable tools available toward achieving the stated goals. This should be supported by enhanced research to develop conservation tillage management practices tailored to specific crops and production systems across the regions. The objective of this paper is to highlight the potential of high residue conservation tillage to enhance water conservation and water use efficiency in corn production.

CORN PRODUCTION IN GEORGIA

In Georgia, producers annually planted approximately 1.6 million acres of corn in the 1970s. However, corn production declined in the southeastern USA in recent decades due to climate- and soil-related limitations coupled with low corn prices. Corn acreage in Georgia declined to < 300,000 by mid-1990s and stayed at that level through 2006 (CAES, 2007). However, as a result of recent increased demand and price for corn, Georgia growers planted 510,000 acres of corn in 2007 but harvested 450,000 acres, of which 290,000 was irrigated (NASS, 2008). Corn acreage is expected to stay at elevated levels for sometime due to increasing demand for ethanol. Most corn in Georgia is grown in the Coastal Plain of southwest Georgia. In 2007, Mitchell County produced the greatest amount of corn (3,149,000 bushels from 18,500 harvested acres) followed by seven other counties with > 2,000,000 bushels each (Irwin, Miller, Decatur, Early, Seminole, Terrell, and Burke; 12,000 to 19,000 harvested acres each). In 2004 only about 35.5% of corn was planted in conservation tillage (CTIC, 2005). There is thus great potential for increased adoption of conservation tillage and water conservation in corn production in Georgia.

Corn requires about 25 in. of net water from rainfall and irrigation combined for high yield (~250 bu acre⁻¹; CAES, 2007). Using the 2000 to 2008 rainfall data from Camilla, GA in Mitchell County, the amount of supplemental irrigation needed for high yield corn is presented in Table 1.

It would have taken a net average annual irrigation of approximately 78 billion gallons for maximized corn yield (25 in. net from rain plus irrigation) this decade on the basis of the assumptions indicated in Table 1. Note the potential variability by year, including 2005 when rainfall would have covered the crop water need, assuming adequate distribution by corn growth stage. At less than full irrigation, yield would have been reduced (see below). One major consideration that would hinder growers from applying full irrigation is cost of diesel fuel for pumps. Lower costs for electric power to drive the irrigation machinery coupled with the current relatively high corn price would increase the incentive toward applying full irrigation to maximize yield.

Assuming an extra 20% infiltration from the rain and irrigation each under a totally conservation tillage adoption scenario, total annual irrigation saving would amount to approximately 2.6 in., equivalent to approximately 20.5 billion gallons (1 in. on 290,000 acres @27154 gallons per acre-in. is 7.87 billion gallons). Under this scenario only 12 in. of the mean annual effective rainfall would infiltrate leaving a net water need of 13 in. and a gross need of 15.6 in. from irrigation in conventional tillage. Assuming a per capita water consumption of 160 gallons d⁻¹ (comparable to a national average of 153), 20.5 billion gallons is equivalent to the annual water need of 350,000 people. Endale et al. (2002), Reeves et al. (2005), and Truman et al. (2005) note that infiltration could be up to 50% higher in conservation tillage crops compared to conventionally tilled ones based on their own and other studies across southeastern U.S.

In a 2006 study (Endale et al., 2008) triggering irrigation for either conventional or conservation tillage whenever soil water potential got > 30 centibar (full irrigation) in an Orangeburg loamy sand (Camilla, GA) saved one inch of irrigation in the conservation tillage with little difference in yield between tillage systems. Total gross water input varied from 22.6 to 25.6 in. and yield from 216 to 238 bu acre⁻¹. In 2007 under the same amount of full irrigation on conventional and conservation tillage treatments, conservation tillage produced 11 and 4% greater yield on a Tifton loamy sand and Orangeburg loamy sand, respectively. Similarly in 2008, conservation tillage produced 20% greater yield on the Orangeburg loamy sand. Results were variable for other combinations of treatments with conservation tillage either matching conventional tillage yield or producing slightly lower yield. In the study, corn followed peanut, which created some soil disturbance during peanut harvesting. Analysis of the 2006 to 2008 data pooled across tillage systems (conventional vs. conservation, soil (Tifton loamy sand vs Orange burg loamy sand) and irrigation (dry, full and 2 in. deficit) treatments indicated that 89% of yield variability could be explained by total water input to black layer (Fig. 1).

According to a lognormal model, yield increment per unit of additional water input above 21 in. appears very limited, and water use efficiency declines.
Table 1. Rainfall in Camilla, GA, for March to mid-July from 2000-2008 and full (to make up 25 in. of effective rainfall plus irrigation), 2/3 and 1/3 full supplemental irrigation that would have been needed on 290,000 acres of corn fields.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall †</th>
<th>Effective rainfall ‡</th>
<th>Supplemental irrigation §</th>
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<tr>
<td></td>
<td>Mar to mid-Jul</td>
<td>in.</td>
<td>Full</td>
</tr>
<tr>
<td>2000</td>
<td>14.50</td>
<td>12.33</td>
<td>99,812,367,154</td>
</tr>
<tr>
<td>2001</td>
<td>23.42</td>
<td>19.91</td>
<td>40,106,065,950</td>
</tr>
<tr>
<td>2002</td>
<td>18.80</td>
<td>15.98</td>
<td>71,030,181,596</td>
</tr>
<tr>
<td>2004</td>
<td>12.60</td>
<td>10.71</td>
<td>112,530,077,052</td>
</tr>
<tr>
<td>2005</td>
<td>30.51</td>
<td>25.93</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>10.72</td>
<td>9.11</td>
<td>125,113,916,319</td>
</tr>
<tr>
<td>2007</td>
<td>9.89</td>
<td>8.41</td>
<td>130,669,547,485</td>
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<tr>
<td>Mean</td>
<td>17.84</td>
<td>15.17</td>
<td>78,257,883,186</td>
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† Assuming March 1st planting and black layer in mid-July
‡ Assuming 15% losses to interception and evaporation, etc.
§ Assuming 290,000 irrigated acres - as that of 2007. Full is 25 in. less effective rainfall expressed in gallons. Add an extra 10 to 20% for losses and inefficiencies. Also assume that effective rainfall is effectively distributed across growth stages.

This suggests that the effect of conservation tillage in saving water might be more under somewhat limited (<21 in.) than full irrigation. Under full irrigation, it might be the soil holding capacity that is limiting. The timing and amount of rainfall would be of influence too.

CONCLUSIONS

These limited field production data from Georgia and the literature across the country indicate that conservation tillage should be given serious consideration as one of the viable tools to help Georgia achieve its goals articulated in its first Comprehensive State-wide Water Management Plan. The Plan charges ten regionally-based Water Councils to draft Water Development and Conservation Plans by region for adoption by 2011. It is imperative that site-specific research be given full support to further develop scientifically-based conservation tillage management tools tailored to each region with respect to crops and production systems. The idea is applicable to the other states of the Southeast facing similar soil and weather related challenges as Georgia for crop production.

Figure 1. Corn yield and water use efficiency versus water input for 2006 to 2008 with data pooled across tillage, soil and irrigation treatments (Endale et al., 2008).
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