RESIDUE MANAGEMENT, TILLAGE, AND NITROGEN RATE RESPONSE IN CONTINUOUS CORN
2016 (Final) Report on Project 802 NREC 2014-02376, February 2017

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This research has been underway since 2006 at the Crop Sciences Research & Education Centers at DeKalb, Monmouth, Urbana, and Perry. The objective is to evaluate long-term (10-years) effects of residue removal and tillage, and to see how these affect response to N rate in corn grown continuously. While the future market for corn residue as a biofuel feedstock remains a question, we have been able, through this project, to evaluate effects on yields, and are also examining the effects on soil properties.

Results

The field trial portion of this project ended with the 2015 season, expect at Urbana, where we conducted it in 2016 in order to provide a place for Dr. Pittelkow to analyze greenhouse gas emissions in selected treatments after 10 years of having these treatments in place. Data from the 2016 trial at Urbana showed N responses in line with previous trends, although the general shape of the response – lower yields at low N rates and a greater response to N under no-till compared to tilled – was not pronounced in 2016 (Figure 1). As a result, optimum N rates were between 162 and 166 lb. N/acre for all treatments except no-till with residue removed, which had an optimum N rate of only 142 lb. N/acre. As we have typically found in this trial, yields with tillage were higher than with no-till, and residue removal raised no-till yields but had little effect on yield of tilled treatments. At the optimum N rate, yields under no-till were 173 and 192 without and with residue removal, respectively, while removing residue in tilled plots raised yield only from 207 to 209 bu./acre.

While the interest in harvesting corn residue for energy production has waned in recent years, we have with this project generated an outstanding set of data showing how residue removal, tillage, and N interact to affect yield in continuous corn. As part of this final report, usable data collected over the life of the project are averaged and presented for each of the four Illinois locations and across locations. The shape of the responses are shown in figures, with optimum N rates (based on an N price of $0.375/lb. and a corn price of $3.75 per bushel) and yields at the optimum N rate shown for each residue treatment-tillage combination. Optimum N rates and yields are provided as numbers in Table 1, which also includes a return to N at the optimum N rate, calculated as the yield times the price per bushel minus the N rate times the price per lb. of N.

At DeKalb, for reasons that remain unclear, yields were low and there was little or no response to N from 2012 through 2014; responses were normal in 2015. We elected to use the data from 7 years, excluding 2012-2014 (Figure 2). Responses at this site tended to be to higher N rates, at moderate yield levels, compared to responses at other sites. Of the six residue-tillage combinations, three had optimum N rates that exceeded the highest N rate used (240 lb. N/acre); the no-removal, no-till treatment yielded only162 bu/acre at 240 lb. N, while removing part of the residue raised yields of no-till by 23 bushels, and the return to N by $86 per acre. Removing all of the residue and tilling changed the optimum N rate very little, but raised the yield by 15 bushels per acre. At this site, probably due to residue and tillage effects on soil temperature, removing residue and tilling tended to increase yield, but did little to lower N rates. An exception to this pattern was full removal with no-till, which yielded less than full removal with tillage, but

also needed less N. It's possible that soils dried out more with this treatment than with the others, and that this limited yields more than soil temperature.

At Monmouth, data from 2006 were not used due to an error in N rates that year. This was the highest-yielding location, and also the location that required the least N relative to yield (Figure 3). As was common at most sites, no-till with all of the residue present produced the lowest yields at the low N rate, and also had the highest optimum N rate among the treatments. Having all of the residue present and tilling produced the highest yield at this site, but also required one of the highest N rates; only no-till with all residue present required more N (Table 1). Removing residue dropped the optimum N rates by 40 to 50 lb. N per acre, but had little effect on yields. For reasons that aren't obvious, removing some of the residue lowered both yields and N rates some, and tillage within each of these two residue treatments had little effect on yield or optimum N rate. The return to N was $50 or more per acre less for the no-removal, no-till treatments compared to all of the other treatments, but the range in returns among the other five residue-tillage treatments was small (Table 1).

At Urbana, yields were low from 2010 through 2012; these are included in the data shown on Figure 4 but not in the numbers on Table 1. Responses were similar to those found at Monmouth, but the three no-till treatments all yielded about the same and responded similarly to N, while the three tilled treatments did the same, but at a yield level about 20 bushels higher (Figure 4). There was virtually no effect of residue treatments on responses to N at this site, and optimum N rates shown on Figure 4 were within the range of 170 to 200 lb. N/acre, with the exception of the no-removal tilled treatments, which yielded the most and also had the highest optimum N rate. It's possible that tillage had more effect on soil water availability than did the presence of residue at this site. Excluding the three low-yielding years increased yields and decreased optimum N rates, but did not change the pattern of no-till yielding less than tilled, with little difference due to the amount of residue present (Table 1). As a result, the average return to N was $68 per acre higher for tilled treatments than for no-till.

At Perry, yields averaged less than 35 bushels per acre in the drought year of 2012, so data from that year were excluded from the analysis. At this site, which has somewhat lighter soils than the other sites, no-till with all or some of the residue present yielded less at low N and responded to higher N rates than did the other treatments (Figure 5). The highest N rate did not maximize yield of the no-till treatment with all reside present, and the optimum N rate was 216 lb. N with no-till and partial residue removal; N responses and optimum N rates were similar among the other four treatments, including no-till following full removal of residue. At only 9 bushels, the range of yields was smaller at this site than at other sites (Table 1).

Across 32 site-years over 10 years at four Illinois sites, we found that residue removal has little effect on N response and yield levels under conventional tillage; while under no-till, yields are reduced at low N rates, and removing residue helps yields recover at higher N rates (Figure 6). Yields under no-till did not fully recover to those of tilled treatments even at the highest rate of N used, even though the optimum rate for this treatment (no removal, no-till) was reached. With no-till, removing some and all of the residue decreased the optimum N rate by 32 and 68 lb. N, respectively, while with tillage, these decreases were only 19 and 22 lb. N (Table 1). The no removal, no-till treatment yielded 180 bushels per acre at the optimum N rate, while yields of the other five residue-tillage treatments ranged only form 188 to 194 bushels per acre. The return to N was $66 higher for tilled than for no-till with no residue removal, but this difference was only $17 and $21 for partial and full removal, respectively.

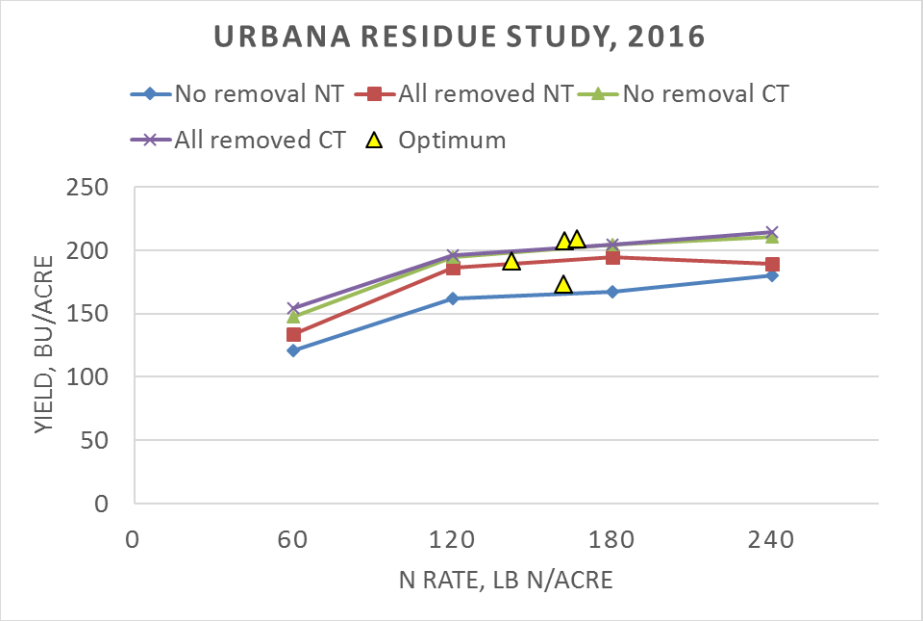

Figure 1. N rate responses of continuous corn (continuous since 2005) following residue removal (all or none) and tillage treatments (CT = tilled; NT = no-till) at Urbana in 2016.

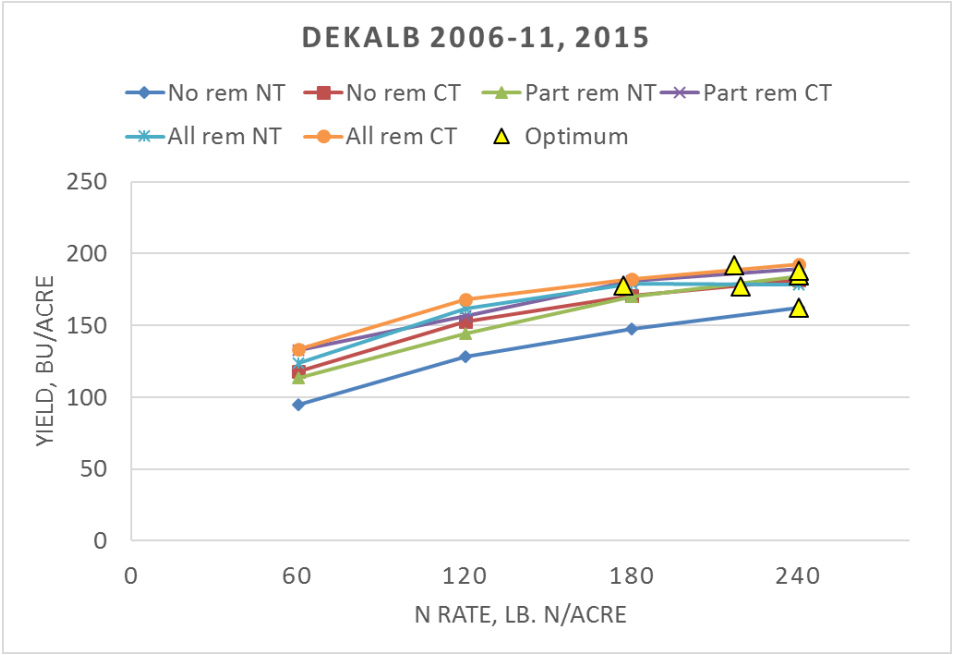

Figure 2. Response of continuous corn (continuous since 2005) to residue removal (none, part, or all), tillage (CT = tilled; NT = no-till), and N rate over 7 years (2006-2011 and 2015) at DeKalb, Illinois.

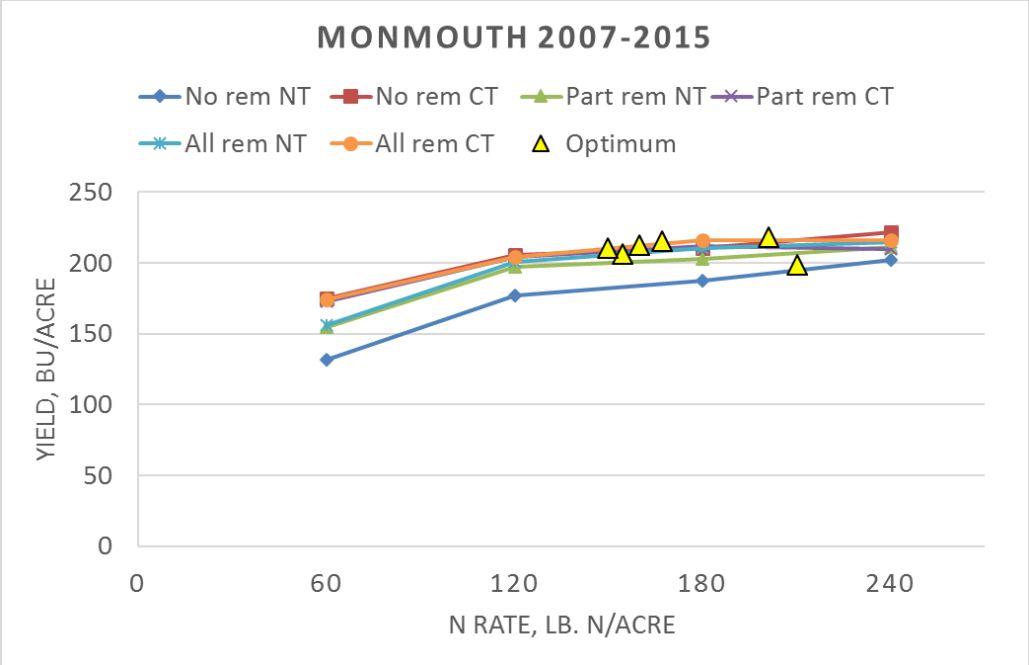

Figure 3. Response of continuous corn (continuous since 2005) to residue removal (none, part, or all), tillage (CT = tilled; NT = no-till), and N rate over 9 years (2007-2015) at Monmouth, IL.

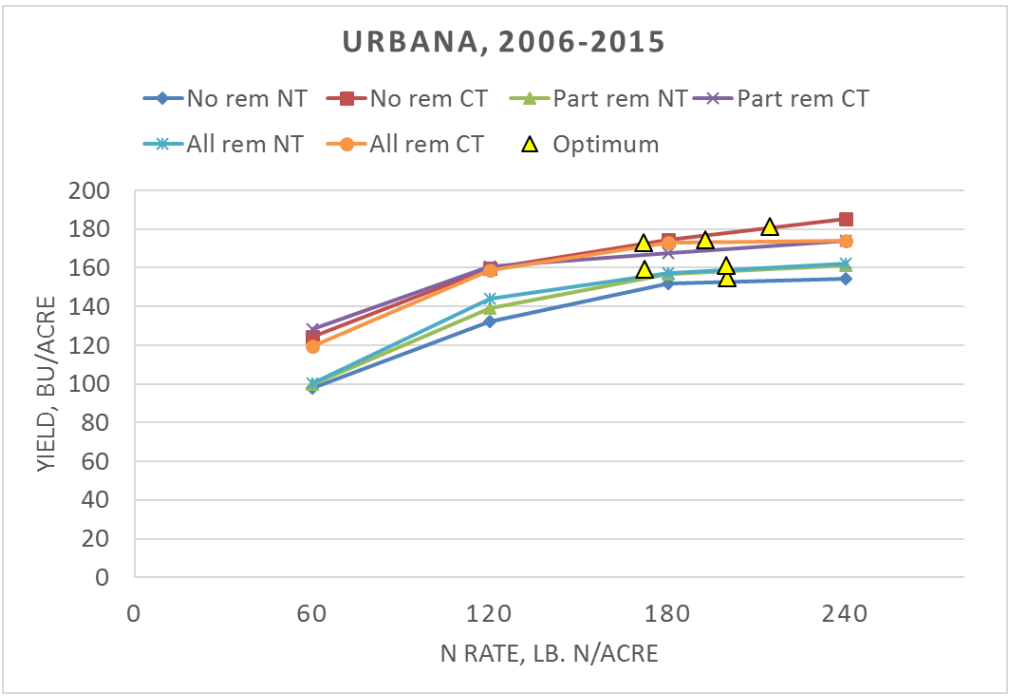

Figure 4. Response of continuous corn (continuous since 2005) to residue removal (none, part, or all), tillage (CT = tilled; NT = no-till), and N rate over 10 years (2006-2015) at Urbana, IL.

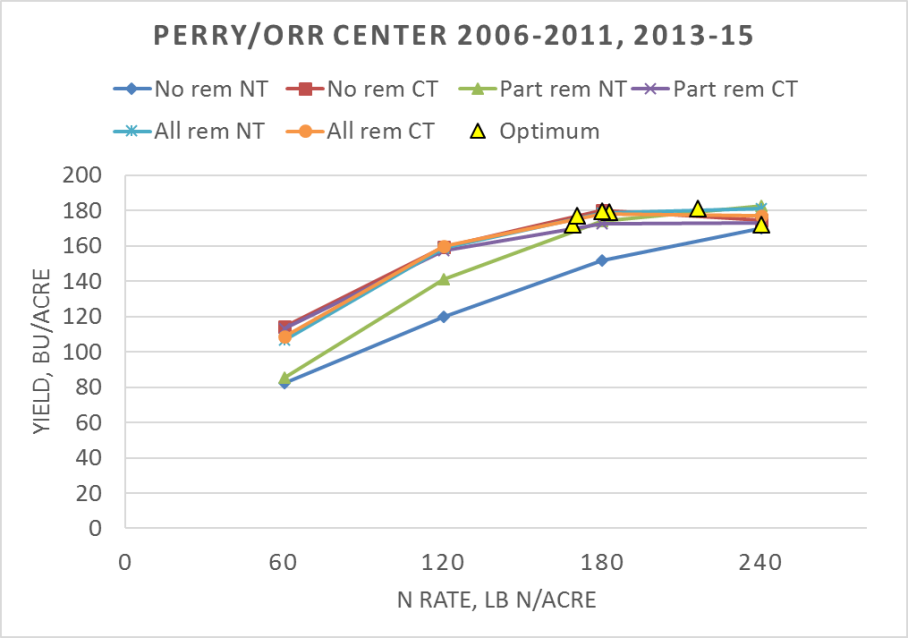

Figure 5. Response of continuous corn (continuous since 2005) to residue removal (none, part, or all), tillage (CT = tilled; NT = no-till), and N rate over 9 years (2006-2011, 2013-2015) at Perry (Orr Center), IL.

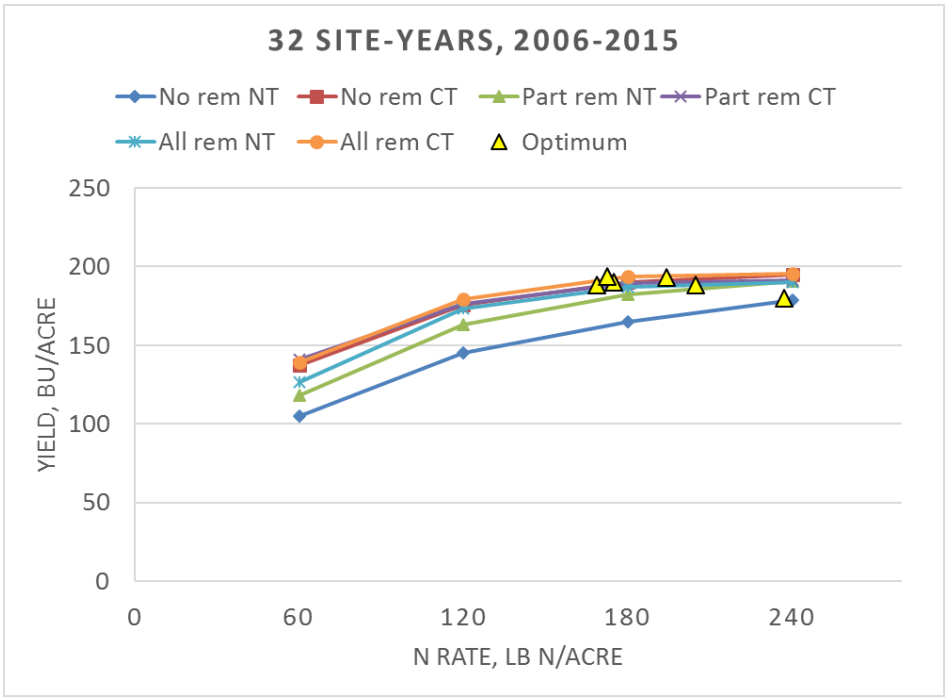

Figure 6. Response of continuous corn (continuous since 2005) to residue removal (none, part, or all), tillage (CT = tilled; NT = no-till), and N rate over 32 site-years at four locations in Illinois, 2006-2015.

Table 1. Optimum N rate, yield at optimum N rate, and return to N at the optimum rate averaged across years at each location and across 32 Illinois site-years, 2006-2015.

Residue treatment and tillage	DeKalb 7 years Optimum N rate	Yield at opt. N	Return to N	Monmouth 9 years Optimum N rate	Yield at opt. N	Return to N
	lb N/acre	bu/acre	$/acre	lb N/acre	bu/acre	$/acre
No removal, no-till	240	162	$518	210	198	$666
No removal, tilled	219	177	$582	201	218	$744
Partial removal, no-till	240	185	$604	154	206	$716
Partial removal, tilled	240	188	$615	150	210	$732
All removed, no-till	177	178	$601	160	212	$736
All removed, tilled	217	192	$638	167	215	$744
	Urbana 7 years			Perry 9 years		
No removal, no-till	200	176	$583	240	172	$555
No removal, tilled	194	199	$673	183	179	$603
Partial removal, no-till	165	179	$609	216	181	$599
Partial removal, tilled	153	192	$662	169	172	$581
All removed, no-till	158	179	$611	180	180	$606
All removed, tilled	163	196	$673	170	177	$600
	All 32 site-years					
No removal, no-till	237	180	$585			
No removal, tilled	194	193	$651			
Partial removal, no-till	205	189	$630			
Partial removal, tilled	175	190	$647			
All removed, no-till	169	188	$642			
All removed, tilled	172	194	$663			

Budget: Funds for this project have spent, as shown by the record of expenditures (through February 20, 2017) below. The ending balance will be adjusted to zero by Feb. 28, 2017.

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Line Description	Budget	Expenditures	Encumbrances	Balance
Total Salaries and Wages	**69,545.00**	**64,178.81**	**888.17**	**4,478.02**
Total Fringe Benefits	**29,420.00**	**21,160.89**	**378.63**	**7,880.48**
Total Travel	**4,500.00**	**950.09**	**0**	**3,549.91**
Materials and Supplies	1,505.00	1,164.46	0	340.54
Services	20,000.00	36,457.96	0	-16,457.96
Total Other Direct Costs	**21,533.22**	**37,622.42**	**0**	**-16,089.20**
Total Indirect Costs	**13,874.00**	**13,754.85**	**140.62**	**-21.47**
Total Budget, Expenditures, Encumbrances, and Balance:	**138,872.22**	**137,667.06**	**1,407.42**	**-202.26**

Outreach

Data from this trial have proven to be valuable, though interest in harvesting corn stover, at least for ethanol production, has waned since the start of the project in 2006. This project became part of the DOE regional biomass project, and a manuscript was published from that project (Karlen et al., 2014) that included yield data from this project through 2013. Another paper from this project with results of soil analyses was published in 2015 (citation below.) The data continue to be used in Extension programs, though as noted above, interest in this work among producers is not as high as it was 10 years ago. Scientific interest is high, however.

Villamil, María B., Joseph Little, and Emerson D. Nafziger. 2015. Corn residue, tillage, and nitrogen rate effects on soil properties. Soil Till. Res. 151: 61–66. doi:10.1016/j.still.2015.03.005

Work remaining (no additional funds from NREC are being sought)

All plots at all of the sites in this trial were sampled in the fall of 2015, following 10 years with treatments in place. A range of soil analyses is underway on these samples, and will eventually include extractable N, P, K, pH, total N, and total C. Data will be used to prepare and submit at least two additional manuscripts, including one on soil effects and one on yield effects.

We will also keep the trial in place at the Urbana site in 2017 to enable nitrous oxide measurements by Dr. Cameron Pittelkow for one more year (the third of 3 years in his NREC-funded nitrous oxide project.)