Continuous Corn and Corn–Soybean Profits over a 45-Year Tillage and Fertilizer Experiment

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ABSTRACT
Studies comparing profitability of tillage systems often examine narrow windows of time or exclude annual price fluctuations. This study uses a continuous corn (Zea mays L.) (CC; 1970–1990) and corn–soybean [Glycine max (L.) Merr.] (CS; 1991–2014) Tillage × Fertilizer study in somewhat poorly drained soils in southern Illinois to reconstruct partial annual budgets with historical prices for crops, fertilizers, lime, herbicides, fuel, labor, and machinery. Combinations of tillage (moldboard plow [MP], chisel tillage [ChT], alternate tillage [AT], and no-till [NT]) and fertilizer (Control, N-only, N+P fertilizer, N+P+NK fertilizer, and NK broadcast) treatments were evaluated. The CC profits were highest in NPK-applied treatments followed by N-only and Control. The MP treatments were similar to ChT and more profitable than NT, while AT fell between. In CS, NPK-applied treatments were similar regardless of tillage. Combined costs for herbicide, machinery, labor, and diesel were higher in MP and ChT systems than AT and lowest in NT, but were a small percentage of total costs (26.6, 26.0, 21.5, and 18.2%, respectively). Nitrogen fertilizer offered a return on investment of 396% in CC and 133% in CS while P & K returned 78% in CC and 109% in CS. Sensitivity analysis in CS showed that NT would be less profitable than MP if herbicide costs increased 850%. A 300% machinery cost increase would have made MP less profitable than NT. These findings suggest that since 1991 CS under NT carried the same potential for profit as other tillage systems under full fertility management.

Core Ideas
• Cumulative profit (1970–2014) in no-till was similar to other tillage types with NPK.
• Relative profits were more sensitive to changes in machinery than herbicide cost.
• Return on fertilizer ranged from 56 to 251% for P and K and 69 to 434% for N.

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Abbreviations: AT, alternate tillage; CC, continuous corn; ChT, chisel tillage; CS, corn–soybean; MP, moldboard plow; NT, no-till.
systems (Cook and Trlica, 2016; Karlen et al., 2013), while other studies demonstrated reductions in yield, especially on poorly drained sites or in sites under CC (Dick et al., 1991; Griffith et al., 1988).

Studies based on the results of yield trials have estimated the economic returns of different crop production systems in the Corn Belt. Al-Kaisi and Yin (2004) evaluated corn yield and economic return on several different soil types under long-term NT management in Iowa, with NT providing as much or more return as other tillage systems under CS rotation. An experiment on a sloping erodible site in southern Illinois showed increased yield and economic returns in NT vs. MP and ChT over several seasons (Phillips et al., 1997). Doster et al. (1983) estimated greater return for NT in sandy well-drained soils, but poorer performance than other tillage systems in poorly drained soils. In a survey of Iowa farmers, Liu and Duffy (1996) reported that most conservation tillage systems (no-till, reduced-till, ridge-till, or mulch-till) had higher profits than conventional tillage due to lower production costs, and also provided environmental benefits.

Adoption of conservation tillage may involve slow shifts in several important factors in the crop production system that affect yield and profitability, such as operator familiarity with the new equipment and practices, weed and disease prevalence, and long-term changes in soil properties (Kumar et al., 2012). Overlaid on changes related to tillage practice are fluctuations on both short-term (e.g., weather, input prices, and commodity values) and longer-term scales (climate change, improved plant genetics, introduction of new technologies) that can also affect both yield and profits. Any real-world farm in operation for more than a few seasons will necessarily integrate both these short- and longer-term influences in their overall profits. However, most economic analyses of relative profitability of different tillage systems have evaluated revenues and costs based on fixed prices and/or yield histories of 10 yr or less (e.g., McIsaac et al., 1990; Phillips et al., 1997; Al-Kaisi and Yin, 2004; Karlen et al., 2013). Annual and longer-term variations in prices and yield have to our knowledge not been accounted for in any detailed study of crop system economics in the Corn Belt. Moreover, there remains a general perception that NT is attractive as a production system primarily in erodible or well-drained soils (Triplett and Dick, 2008).

An experiment begun in 1970 in southern Illinois provides a unique 45-yr historical record of crop yields and inputs for several tillage and fertilizer treatments in a flat, somewhat poorly drained site under CC (1970–1990) and CS systems (1991–2014). The present study used these records to explore tillage and fertilizer management influences on historic economic returns. The objectives of this study were to: (i) Evaluate CC and CS annual profits and cumulative profits in different tillage and fertility treatments; (ii) Determine return on investment for fertilizer additions; (iii) Examine the sensitivity of historic profits to machinery and herbicide cost fluctuations in NT and MP tillage treatments; and (iv) Estimate the relative soil conservation benefits of NT and MP management. The annual partial budget approach, combined with reconstructed historic prices, allows the profitability of the different production systems to be evaluated within the actual economic environment in which crop production occurred.

### MATERIALS AND METHODS

Historic costs and revenues from corn and soybean production were estimated from operational details and yield data collected over 45 yr from a long-term Tillage × Fertilizer trial initiated in 1970 on a somewhat-poorly drained Bethalto silt loam (fine-silty, mixed, superactive, mesic Udollic Endoaqualf) at the Belleville Research Center near Belleville, IL (exact field-plot coordinates: 38.519179° N, 89.843248° W). Continuous corn was grown on the site from 1970 to 1990, and CS rotation was implemented from 1991 to 2014. The experimental design was a split-plot with tillage as the whole plot treatment and five fertilizer treatments randomized within tillage strips as the subplot. Tillage treatments for spring seedbed preparation consisted of: moldboard plow (MP); chisel tillage (ChT); alternate tillage (AT; with 2 yr no-till and 1 yr MP); and no-till (NT). Fertilizer treatments consisted of: (i) unfertilized check (Control); (ii) broadcast nitrogen only (N-only); (iii) broadcast nitrogen plus NPK starter (N+PKstarter); (iv) broadcast NPK plus NPK starter (NPK+NPKstarter); and (v) broadcast NPK only (NPK).

Additional details can be found in Table 1. Each tillage × fertilizer combination was replicated in four blocks. Details of the experimental treatments and analysis of yield and soil chemical properties can be found in Cook and Trlica (2016).

| Table 1. Fertilizer and tillage treatments 1970 to 2014. Note: No fertilizer was applied before soybean seasons (odd-numbered years after 1990) (from Cook and Trlica, 2016). |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Control                        | 0–0–0                           | 0–0–0                           | 0–0–0                           |
| N-only                         | 140–0–0                         | 196–0–0                         | 196–0–0                         |
| N+PK starter                  | 129–0–0 + 11–25–24 (starter)    | 179–0–0 + 17–39–112 (starter)   | 196–24–140                      |
| Tillage treatment             | Seedbed preparation steps       |                                 |                                 |
| Moldboard (MP)                | Moldboard plow, tandem disk, cultivator, culti-mulcher |
| Chisel (ChT)                  | Tandem disk, chisel plow, tandem disk, cultivator, culti-mulcher |
| Alternate (AT)                | Two years no-till, 1 yr MP treatment |
| No-till (NT)                  | None                            |                                 |

† In 1973 total K application rates were 112 kg ha⁻¹ in the N+PKstarter and 224 kg ha⁻¹ in the NPK and NPK+PKstarter fertilizer treatments.
This study used a partial budget approach which addressed factors that differed among treatments to permit comparison of relative profits of varying crop production technologies (Swinton and Lowenberg-DeBoer, 1998). Factors that were identical across all treatments (e.g., seed and pre-emergent herbicide costs across treatments) were excluded from this analysis. Recorded yield and cultivation practices for each plot were used to represent varying production systems on a typical hectare of farmland. Annual partial budgets for each Tillage × Fertilizer combination estimated trends in income, costs, and profits that varied among treatments over the 45-yr experiment. Treatment variables that were tracked in the partial budgets were yield, fertilizer, lime rate, post-emergent herbicide, machinery use, fuel, and labor.

Yearly revenue for each experimental plot for 1970 to 2014 was estimated using measured crop yield and the national average price of corn or soybean by marketing year (USDA NASS, 2016a). National average nominal prices paid per tonne of ammonium nitrate, urea, potash (potassium chloride, 60–62% K2O), triple superphosphate (TSP, 44–46% P2O5) (USDA ERS, 2016a) and agricultural lime (with application costs included) (USDA NASS, 2016b) were taken for marketing year 2009 to 2014, calendar year 2002 to 2008, and month of April 1970 to 2001. Costs for paraquat (1,1’-dimethyl-4,4’-bipyridinium ion) and glyphosate [N-(phosphonomethyl) glycine] used for post-emergence control of annual weeds in NT and AT plots from 1991 to 2014 were estimated based on records of herbicide application rates and the reported national average prices for each active ingredient (USDA NASS, 2016a, 2016b). Herbicide prices prior to 1991 were back-projected from the 1991 national average using the reported Agricultural Chemicals price index (1977 baseline) (USDA NASS, 2016b).

Machinery use was modeled according to operational history for the different treatments and costs related to machinery maintenance, depreciation, housing, insurance, and repairs. Costs for each category were estimated based on 2015 per-area machinery budgets that assumed the use of a 75 horsepower diesel tractor, using the middle of the potential range of cost per area for each tillage, planting, spraying, and fertilizer implement type (Farmdoc, 2015). The size of the machinery and implements used were factors in the cost estimate of these budgets, but this study focused on estimated profits using a single tractor size and the mid-range cost of each implement, and as such the sensitivity of profits to machinery sizes was not evaluated. Machinery use costs were projected for other crop years using the national agricultural Machinery Totals price (2011 baseline) (USDA NASS 2016a, 2016b). The machinery budgets also provided estimates of fuel consumption and labor time requirements for each machine activity, which were used to calculate per-activity costs for each. Diesel fuel costs per gallon were estimated based on the national average January price (USDA NASS, 2016b). National agricultural hourly wage labor rates reported by USDA NASS for “wages only” workers (1970–1973), “machine operators” (1974–1979), “all workers” (1980–1989), and “labor, hired” (1990–2014) were used to estimate labor costs for each production system (USDA NASS, 2016a; USDA ERS, 2016b).

All input costs and revenues in each year were adjusted to 2014 U.S. dollars prior to calculating annual profits using the Prices Paid Index for Commodities and Services, Interest, Taxes, and Farm Wage Rates (PPITW) prepared by USDA NASS. The 2011-baseline index was used for 1990 to 2014, and from 1975 to 1989 the 1990-baseline PPITW records from USDA NASS were recalculated to the 2011 benchmark (USDA NASS, 2016a). Values of PPITW (1967 baseline) reported in the Annual USDA NASS Agricultural Price Summaries for 1970 to 1974 were recalculated to the 2011 baseline using the 1990-baseline index as an intermediary (USDA NASS, 2016b). Annual net profit for each treatment was estimated by subtracting 2014-adjusted historic costs from revenue. A cumulative profit for each treatment subplot was also calculated using the running sum of the annual profits.

**Return on Investment**

Fertilizers, particularly N, P, and K, are a critical component of maintaining high yields and yield is a primary driver of profit in agronomic systems. A comparison of profits between Control and N-only treatments allowed for an assessment of the return on investment for N fertilizer. By a similar approach, the difference between N-only and NPK-applied treatments allowed for an assessment of the percent return on investment for P and K fertilizer. We used fertilizer treatment profits within each rep and tillage to calculate percent return on investment as the difference in profit (e.g., N-only minus Control) divided by the cost of fertilizer.

**Sensitivity Analysis**

A sensitivity analysis was performed using the NPK broadcast treatments in the CS rotation to assess the robustness of the profit results to changes in inputs costs. Elasticities were calculated to judge the relative importance of different input price fluctuations on profit in MP and NT as the “extreme” treatments. Elasticities are a measure of the percent change in a dependent variable (profit) divided by the percent change in an independent variable (costs) (Pannell, 1997).

Based on elasticity results, we selected machinery and herbicide costs as inputs to vary within MP and NT systems and recalculated mean profit each year for each treatment. To account for differing operational practices in corn and soybean years, the 24 yr of CS rotation mean profits were segmented into 12 consecutive CS “year-pairs” (e.g., 1991 soybean with 1992 corn, excluding the year-pair 2007/2008 due to weather-related loss of the 2008 corn crop prior to harvest). Each year-pair was considered an independent sample since there was no significant linear effect of time. Tillage treatments (NT vs. MP) were compared under different price scenarios using an independent sample t test.

**Soil Conservation Benefit Calculation**

We compared estimated soil loss from NT vs. MP using the universal soil loss equation with rainfall erosivity of $R = 220$, soil erodibility factor of $K = 0.37$, topographic factors of $LS = 0.1$, and crop and management factor values of $C = 0.32$ for MP and $C = 0.075$ for NT (Walker and Pope, 1983). We used an erosion prevention benefit estimate ($$ tonne^{-1}$) for the Corn Belt region (Hansen and Ribaudo, 2008) for the social and environmental benefit of soil conservation by using NT instead of MP treatments (e.g., reduced ditch clearance,
reduced water treatment burden, fishery productivity, reduced flood damage; see Table 1 in Hansen and Ribaudo, 2008). We excluded the value of any direct effects on soil productivity since changes in yields and profits are already addressed in this economic analysis.

Statistics

Profit was analyzed with a mixed linear model across each rotation (CC, CS) including fixed effects of: Tillage, Fertilizer, and Tillage × Fertilizer. Random effects were included for the class variables Year (to account for year-to-year variability), Replicate (Rep), Rep×Tillage, and Year×Rep×Tillage (to account for whole-plot error). The Kenward–Roger method was used to estimate the denominator degrees of freedom of the F statistics (Kenward and Roger, 1997). A repeated measure statement was included with a first order auto-regressive [AR(1)] covariance structure with Rep×Tillage×Fertilizer as the subject. Tukey’s HSD was applied for separation of means with α = 0.05. Cumulative Profit was analyzed with a mixed linear model based on the split-plot design at the end of each rotation (CC, CS) and after the entire combined experiment (CC and CS) with fixed effects of Tillage, Fertilizer, and Tillage × Fertilizer and random effects for the class variables Rep and Rep×Tillage. Return on Investment for N and for P+K was analyzed with a mixed linear model with Tillage as a fixed effect and Rep and Year as random effects for each rotation. PROC GLIMMIX in SAS 9.4 and JMP 12.2 were used to estimate the linear mixed models (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Mean Annual Profit

Mean annual profit for the CC rotation showed a significant influence for tillage (P = 0.0002) and fertilizer (P < 0.0001) but no interaction (P = 0.7324; Fig. 1). Control fertilizer showed the lowest relative profit, followed by N-only treatments, and all NPK-applied treatments were greatest and similar. The MP and ChT treatments were similar and had greater profit than NT, and AT fell in between. In contrast to these results, Karlen et al. (2013) found that in a CC rotation in Iowa that NT had slightly higher profitability than MP. Other studies have also found no differences in profitability due to tillage, particularly in well-drained soils (Al-Kaisi and Yin 2004; Doster et al., 1983). In more highly erodible soils in southern Illinois, NT had higher yield and profitability than ChT or MP (Phillips et al., 1997).

Cumulative Profits

Cumulative profit during the CC period (1970–1990, data not shown) showed a significant effect for fertilizer (P < 0.0001) and for tillage (P < 0.0001) but showed no significant effect for their interaction (P = 0.4094). As in all other situations, Control fertilizer treatments were all similar and lowest overall, followed by the N-only fertilizer treatment. It has been previously shown that CC in Wisconsin was not profitable between 1990 and 2004 with less than 112 kg N ha⁻¹ under an annually varying price of ammonium nitrate fertilizer (Stanger et al., 2008). All NPK-applied treatments were highest and similar. Among tillage treatments, MP, ChT, and AT showed higher cumulative profits than the NT treatment.

The CS period (1991–2014, data not shown) cumulative profit showed a significant effect for fertilizer (P < 0.0001), no significant effect for tillage (P < 0.3588), and a significant interaction (P < 0.0009). As in CC, all complete NPK-applied...
treatments had higher and similar profits than N-only and Control treatments. The NT/N-only and NT/Control were the lowest profit treatments.

Across the entire CC and CS rotations, cumulative profit from 1970 to 2014 showed a significant effect of fertilizer ($P < 0.0001$), tillage ($P = 0.0004$), and their interaction ($P = 0.0238$) (Fig. 3). Control fertilizer treatments gave the lowest cumulative profit overall, with NT/Control less than ChT/Control treatments. The NT/N-only treatments had lower cumulative profit than all other N-only tillage treatments. There were no significant differences among NPK-applied treatments, which were highest in cumulative profits. Overall, fertilizer was the dominant determinant of yield as well as profit. Tillage, when sufficient fertilizer was applied, had no discernable effect on cumulative profitability, despite any long-term cumulative changes or interactions with soils, climate, or plant genetics over time.

**Price and Income Histories in Different Production Systems**

Profits were affected by the different field operations, yield, crop prices, and quantity and historic prices of inputs. Crop revenues were higher in the CC rotation than in the CS rotation ($P < 0.0001$; data not shown) due to higher corn prices, particularly from 1974 to 1976, as corn yield was lower in CC than in CS (Cook and Trlica, 2016). Trends in revenue have been driven more by crop price fluctuations than by yield, as yield at this site has remained fairly constant over time within each rotation. When comparing rotations in the same years, CS rotations have been shown to be significantly more profitable than CC rotations by $269 \ \text{ha}^{-1}$ in Wisconsin (Stanger et al., 2008). In our experiment, we could not directly compare CC to CS profits since they occurred in different periods.

Seedbed preparation costs analyzed in this study included machinery, labor, diesel, and herbicide costs associated with field operations. Over the course of the experiment, machinery
costs have trended upward over time, diesel and labor costs have remained fairly constant and a small percentage of tillage costs, and herbicide costs in NT and AT treatments have declined, possibly due in part to the appearance of generic glyphosate after patent expiry in 2000 or to the expanded production and use of glyphosate once crops with engineered resistance were introduced in the mid-1990s (Fig. 4A). From 1970 to 2014, seedbed preparation costs were lowest \( (P < 0.0001) \) in the NT treatments \((70.1 \pm 0.68 \text{ U.S. dollars [USD] ha}^{-1}) \) followed by AT \((86.1 \pm 0.90 \text{ USD ha}^{-1}) \) due to the lower per-hectare cost of herbicide compared to costs associated with tillage in MP and ChT. Field operation costs were higher in ChT \((110.3 \pm 0.52 \text{ USD ha}^{-1}) \) and MP \((114.0 \pm 0.53 \text{ USD ha}^{-1}) \), which were similar. Following the per-unit cost of fertilizers (N, P, and K), the per-hectare cost of fertilizer treatment spiked in the mid-1970s followed by a general decline until the mid-2000’s, which then increased to levels similar to the early 1980s (Fig. 4B). Fertilizer costs in CS were half the cost in CC due to applications only occurring in corn years.

**Return on Investment for Fertilizers**

Percent return on investment for N was \(396\% \pm 18\) in CC and \(133\% \pm 13\) in CS. The effect of tillage on fertilizer return was significant for N in CC and for N and P+K in CS rotation (Table 2). In the CC rotation, the MP treatment had a higher return than NT or ChT while AT fell in between. However, in
the CS rotation MP, ChT, and AT were all significantly higher than NT. The lower rate of return on N in NT reflects the poor corn yield in the NT/N-only treatment relative to other N-only treatments (Cook and Trlica, 2016). This may be due to intensive tillage practices releasing plant-available P and K allowing greater response to N in MP, ChT, and AT treatments. Return on N was lower in CS because the rotated cropping system eliminates N applications in soybean years. Higher returns on investment for N fertilizer are expected when other nutrient limitations such as P and K are alleviated (Schlegel et al., 1996). Our return on investment for N fertilizer likely underestimates the potential return since our N-only treatments were likely limited by P and/or K, especially in NT treatments.

Return on P and K was 78% ± 12 in CC and 109% ± 12 in CS for all NPK-applied treatments across all tillage treatments. The lower return for CC reflects the smaller yield increase in corn between N-only and NPK-applied treatments, while the larger return for CS reflects the relatively large response of soybean yield and income to application of P and K. Many studies have shown positive responses of soybean to added P and K (e.g., Bharati et al., 1986). There was an indication of differences (P = 0.0716) due to tillage in the CC rotation. When each NPK-applied fertilizer treatment was analyzed separately, NT treatments tended to have the highest return for P and K fertilizer. In the NPK broadcast treatment, NT was higher than MP (P = 0.0230) and in the NPK+NPK starter treatment NT was higher than AT (P = 0.0305) with the other treatments falling in between. The N+NPK starter treatment showed all tillage treatments to have similar return for P and K (P = 0.4684; data not shown). In the CS rotation, all three NPK-applied treatments showed similar trends in return on P and K. The NT treatment had a significantly higher return than all other tillage treatments (Table 2), probably because the NT/N-only benchmark was lower in yield than other N-only tillage treatments (Cook and Trlica, 2016). These results show that overall even with large price swings through time, N, P, and K fertilizer remained an important investment to maintain profits. The particularly high rates of return for P and K fertilizer in the NT/NPK-applied treatments demonstrates the importance of managing P and K fertility for maintaining competitive profits under long-term NT at this site.

**Sensitivity Analysis**

Based on elasticities, fertilizer cost (N, P, and K combined) had the greatest impact on profit in both tillage treatments (Table 3), as would be expected given that fertilizer makes up a much greater percentage of total costs than other inputs. After fertilizer, for MP treatments machinery had the greatest impact on profit while herbicide had the greatest impact in the NT system. There is often a trade-off between machinery and herbicide costs in NT and more intensive tillage systems (Chase and Duffy, 1991), but the more recent relative decline in herbicide costs for NT did not appear to have meaningfully reduced the sensitivity of NT profits to these costs over the whole course of the experiment.

In the CS rotation, annual machinery and herbicide costs were modified from −100% to the approximate point where NT and MP profits became significantly different (Fig. 5). A 300% increase in machinery cost was required to significantly disadvantage MP from NT, but a complete elimination of machinery cost did not cause profits to be significantly different. In contrast, an 850% increase in herbicide cost was required to make NT significantly less profitable than MP. Because MP did not receive post-emergent herbicide, there was no change in profit regardless of herbicide price. The NT profit was changed very little with changes in machinery cost because the only machinery operation included the planter, sprayer, and fertilizer application.

The results from the sensitivity analysis showed that NT and MP tillage treatment profits were robust to changes in herbicide or machinery costs. Similarly, Meyer-Autrich et al. (2006) showed that a 50% increase in energy cost (which affected both fertilizer cost and tillage-related costs) only decreased profit in MP by 2 to 4% compared to ChT. Across the CS rotation, average machinery costs in the MP treatment were $98 ha⁻¹ and trending up while herbicide costs were $49 ha⁻¹ and trending down (Fig. 4). Based on these past trends we would expect that a continued rise in machinery costs is more likely in the future than increased herbicide costs, however neither a 300% rise in machinery cost nor an 850% increase in herbicide cost in the near future seems likely.

Table 3. Elasticity of profit across entire CS rotation, that is, the ratio of percent change in profit to percent change in cost of input (excluding 2007/2008 rotation due to missing corn yield data).

<table>
<thead>
<tr>
<th>Input</th>
<th>Profit elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer (NPK)</td>
<td>-0.174</td>
</tr>
<tr>
<td>Machinery</td>
<td>-0.075</td>
</tr>
<tr>
<td>Lime</td>
<td>-0.016</td>
</tr>
<tr>
<td>Labor</td>
<td>-0.015</td>
</tr>
<tr>
<td>Diesel</td>
<td>-0.007</td>
</tr>
<tr>
<td>Herbicide</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 2. Return on investment for N and P+K fertilizers (standard error of mean in parentheses). P values indicate significance of model effect of Tillage on percent return, letters indicate Tukey’s HSD groupings within each return category.

<table>
<thead>
<tr>
<th>Return</th>
<th>N Continuous corn</th>
<th>P+K Continuous corn</th>
<th>N Corn–soybean</th>
<th>P+K Corn–soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moldboard plow</td>
<td>434 (31)a</td>
<td>56 (23)a</td>
<td>156 (27)a</td>
<td>63 (15)b</td>
</tr>
<tr>
<td>Chisel till</td>
<td>363 (36)b</td>
<td>71 (28)a</td>
<td>136 (23)a</td>
<td>58 (15)b</td>
</tr>
<tr>
<td>Alternate till</td>
<td>415 (38)ab</td>
<td>62 (22)a</td>
<td>172 (26)a</td>
<td>64 (18)b</td>
</tr>
<tr>
<td>No-till</td>
<td>370 (35)b</td>
<td>123 (20)a</td>
<td>69 (22)b</td>
<td>251 (28)a</td>
</tr>
<tr>
<td>All tillage types</td>
<td>396 (18)</td>
<td>78 (12)</td>
<td>133 (13)</td>
<td>109 (12)</td>
</tr>
<tr>
<td>P value</td>
<td>0.0102</td>
<td>0.0716</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Tillage model standard error</td>
<td>65</td>
<td>38</td>
<td>42</td>
<td>34</td>
</tr>
</tbody>
</table>
Soil Conservation Benefit

Benefits of NT often include reduction in soil loss on highly erodible slopes. At this relatively flat site (<2% slope), we estimated that MP would have lost 0.58 Mg ha\(^{-1}\) yr\(^{-1}\) of topsoil compared to 0.13 Mg ha\(^{-1}\) yr\(^{-1}\) in NT (Walker and Pope, 1983). A reduction in soil loss from MP to NT would be equivalent to approximately $47.74 ha\(^{-1}\) yr\(^{-1}\) (under the same soil conservation benefit estimates) which is approximately half of the estimated seedbed preparation costs for MP in the present study. However, since external benefits do not accrue to the farmer, additional incentives may be necessary to encourage adoption of conservation tillage (Grandy et al., 2006).

CONCLUSIONS

Fertilizer use had dominant influence on profitability while tillage had a relatively minor influence overall. Under the current CS system, NT management has been as profitable on average as other, more intensive, tillage system in NPK-applied plots. Fertilizer had a positive return on investment even with large fluctuations in costs year to year. The NT only had a significant profit disadvantage compared to other tillage types under conditions of prolonged absence of P and K fertilization. Sensitivity analysis for herbicide and machinery costs indicated that the competitiveness of NT and MP were not likely to be reversed by small errors in estimated costs or large future changes in costs. While soil loss is likely minor at this site, the additional soil conservation measures (NT) did not reduce profitability. We conclude that with adequate application of NPK fertilizer, profits under NT can be comparable with other tillage systems in CS production in non-sloping, somewhat poorly drained soils of southern Illinois.

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REFERENCES


Fig. 5. Sensitivity of mean annual profit for no-till (NT) and moldboard plow (MP) in corn–soybean (CS) rotation to changes from baseline (A) herbicide or (B) machinery costs adjusted to 2014 dollars. Error bars represent standard error of the mean. *P* values show significance of independent sample t tests at selected levels of price change (~100%, 0, 100%, 300% for machinery, and 850% for herbicide).


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Graber, L. 1928.


