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Abstract
Tillage has been a common event in farming for centuries. New information and management practices are demonstrating better ways of managing the soil to reduce erosion and improve productivity and profitability. Tillage destroys the soil structure, actually increasing the weeds and reducing the water holding capacity of the soil. Highly erodible areas of a field can lose more than 5 tons of soil per year with conventional tillage. Converting to no-till management can reduce production costs more than $30 per acre per year, saving topsoil and reducing management time in the field.

Keywords
conventional tillage; conservation tillage; crop production

Cover Page Footnote
We are grateful to Tom Buman for providing the Agren SoilCalculator results. This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

The Cost of Tillage

G.F. Sassenrath

Summary
Tillage has been a common event in farming for centuries. New information and management practices are demonstrating better ways of managing the soil to reduce erosion and improve productivity and profitability. Tillage destroys the soil structure, actually increasing the weeds and reducing the water holding capacity of the soil. Highly erodible areas of a field can lose more than 5 tons of soil per year with conventional tillage. Converting to no-till management can reduce production costs more than $30 per acre per year, saving topsoil and reducing management time in the field.

Introduction
Tillage has been used for centuries. The common thought is that it is required to loosen the soil to prepare a good seed bed and can be used to control weeds. However, tillage damages the soil structure and increases erosion. In addition, over the long term, tillage increases compaction of the soil because of poor soil structure.

This research explores the real cost of tillage from a broader standpoint. Impacts of tillage on soil erosion, crop productivity, equipment and fuel costs, nutrients, water, and time requirements are presented. Long-term productivity and profitability are determined for a silt-loam soil in southeast Kansas.

Experimental Procedures
Three crop production fields in southeast Kansas were used to estimate costs of tillage. The soil types in the fields included Verdigris silt loam and Kenoma silt loam. One field was in long-term conventional tillage. One field had been in conventional tillage and was converted to no-till 5 years prior. The third field had been in no-till for more than 20 years.

Conventional tilled and no-till production systems were compared for a corn/soybean rotation system using the SoilCalculator from Agren, Inc. For the simulation, field size was set to 80 acres with a silt-loam soil in Labette County, KS. Specific management practices for the conventional tillage included chisel and cultivate prior to corn and soybean planting. No-till management had no tillage operations. Fertilizer, herbicide, fungicide, planting, and harvesting operations were the same for both conventional and no-till production. Grain yield for corn was estimated to be 170 bu/a with 3136 lb/a crop residue, and 40 bu/a for soybeans with 866 lb/a crop residue.

Cost-Return Budgets for southeast Kansas from the Kansas State University Department of Agricultural Economics were used to estimate production costs. Economic and productivity impacts for 1, 2, 5, 10, and 20 years were calculated with the Agren SoilCalculator based on the cost-return budgets for southeast Kansas. Crop water use was modeled using a modified evapotranspiration model based on the Penman-Monteith.

Soil samples were collected to a depth of 6 in. in each of the three fields in late June 2018. The soil was weighed, dried, and reweighed to determine total water content.

Results and Discussion

Conventional tillage increased the per-acre cost of production by $28.19 (Table 1). The one-year average soil loss across the entire field was calculated to be much greater in the tilled field than in the no-till field (2.9 tons for the tilled field vs. 0.5 tons for the no-till field; Table 2). Not all areas within a field will have the same rate of soil loss. For the areas of the fields with highest rates of erosion, the soil loss estimates were calculated as 5.7 tons from the tilled field versus 0.9 tons for the no-till field. Over a 10-year time period, this would result in a 0.19 in. of soil loss in a tilled field versus only a 0.03 in. soil loss in no-till. Similarly, the most erodible portion of the field would lose an estimated 0.39 in. of soil under tillage, with only a 0.06 in. of soil loss with no-till.

Soil loss decreases the productive capacity of the soil, reducing the crop yield. Nutrients are lost with the soil particles during erosion. Moreover, loss of soil reduces the water and nutrient holding capacity of the soil. These losses are additive. The Agren SoilCalculator estimated the average yield loss arising because of the calculated soil loss (Table 3 and 4). Soil erosion would result in $0.23 loss per acre in crop yield under conventional tillage in comparison to $0.04 lost with no-till. Similarly, nutrient loss was estimated at $15.07 per acre under conventional tillage compared to $2.69 per acre under no-till. Over the entire 80-acre field, this yearly lost productivity and nutrient loss would result in a cumulative erosion cost of $2,074.98 for the conventional tillage. Soil erosion still occurs under no-till production. However, the total cumulative cost of erosion is much less for no-till production, estimated at $370.52 per acre. These losses accumulate for each year the field is in production.

Soil is an important component of the water cycle. Healthy soil is able to hold more water and make that water available to the growing crop. It has been estimated (Bryant, 2015) that for every 1% increase in organic matter, soil available water increases by more than 20,000 gallons per acre. During the hottest time of the growing season, corn uses nearly 0.5 inch of water every day (Figure 1). The water in the soil was nearly double for the long-term no-till field than for the conventionally tilled field (Figure 2). This would provide much greater water available for the growing crop in the no-tilled field.

Tillage has often been reported to improve soil tilth. Some evidence suggests that tillage improves yields. However, new evidence is showing that the yield-drag from no-till is much smaller than originally thought and may even be non-existent. Tillage is expensive to implement. The cost of equipment and fuel averages about $14 per tillage pass per acre. That value is not per tillage event, it is per tillage pass. If multiple passes are made across a field, for example for field cultivation, each pass is costing about $14. Additionally, approximately 0.12 hours (7 minutes) are being spent on each acre of ground tilled. Moreover, nutrient and production losses cost about $15.23/acre. Tillage also reduces the water-holding capacity of the field, reducing water available to the growing crop. Most significantly, the loss of soil from a tilled field is not replaced. The loss of soil is nearly permanent, as it takes about 500 years to make an inch of soil. The lost soil is a permanent reduction in the productive capacity of the field.

No-till crop production is a viable alternative for southeast Kansas. While there is concern that no-till fields remain too wet in the spring, the fact is that the no-till fields have better soil structure. This improved soil structure allows access to no-till fields earlier than for tilled fields. No-till requires careful management to control weed populations. However, the increase in herbicide-resistant weeds makes weed control important in any production system. Moreover, it has been shown that tillage can actually increase the weed population (Chism et al. 2019). While the weed population was reduced immediately after a tillage event, the weeds were not controlled and additional measures were required to reduce weed pressure. The productivity and profitability of crop production can be improved by implementing no-till production methods.

Acknowledgments

We are grateful to Tom Buman for providing the Agren SoilCalculator results. This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

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Table 1. Production costs – conventional and no-tillage corn/soybean rotation

Tillage operation	Conventional tillage	No-tillage
	-------------------------------- $/acre --------------------------------	
Fall – chisel	$15.91	
Spring – cultivator	$12.28	
Total yearly costs	$28.19	$0.00

Costs estimated from the Kansas State University Cost-Return Budgets for southeast Kansas.

Table 2. Soil loss estimation – conventional and no-tillage corn/soybean rotation

Tillage operation	Conventional tillage	No-tillage
1-year soil loss (tons/acre)		
Field average	2.9 tons	0.5 tons
Top 20% most erodible average	5.7 tons	0.9 tons
10-year soil loss (inches)		
Field average	0.19 inches	0.03 inches
Top 20% most erodible average	0.39 inches	0.06 inches

Calculations modeled with the Agren SoilCalculator.

Table 3. Yield and nutrient loss estimation – conventional tillage

Year	Cumulative yield loss/acre	Cumulative nutrient loss/acre	Total yield and nutrient loss/acre	Total cumulative erosion cost
1	$0.23	$15.07	$15.30	$2,074.98
3	$1.37	$45.22	$46.59	$6,318.05
5	$3.43	$75.36	$78.79	$10,685.25
10	$12.59	$150.72	$163.31	$22,146.33
20	$48.06	$301.45	$349.50	$47,396.02

Calculations modeled with the Agren SoilCalculator.

Table 4. Yield and nutrient loss estimation – no-tillage

Year	Cumulative yield loss/acre	Cumulative nutrient loss/acre	Total yield and nutrient loss/acre	Total cumulative erosion cost
1	$0.04	$2.69	$2.73	$370.52
3	$0.25	$8.07	$8.32	$1,128.20
5	$0.61	$13.46	$14.07	$1,908.04
10	$2.25	$26.91	$29.16	$3,954.61
20	$8.58	$53.83	$62.41	$8,463.38

Calculations modeled with the Agren SoilCalculator.

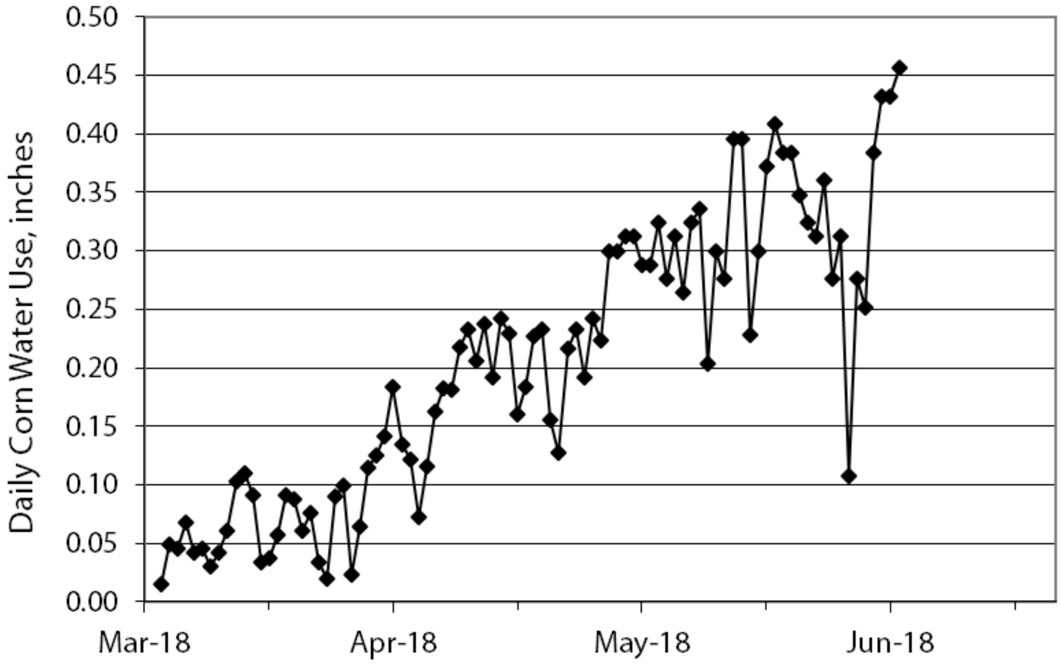

Figure 1. Corn water use for a Kenoma silt loam soil in Labette, KS. Daily water use was calculated using a modified Penman-Monteith equation for the corn growing season of 2018.

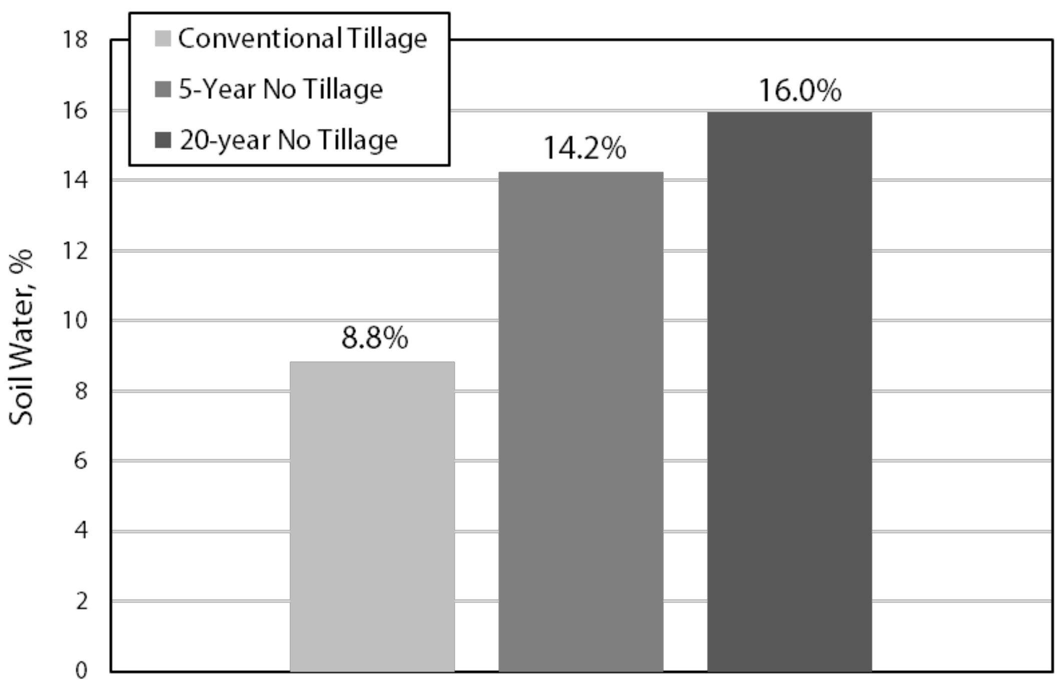

Figure 2. Soil water content of top 6 inches of soil from a conventional-tilled field, and fields that have been in no-till production for 5 years, and more than 20 years.