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Balancing tillage, soil loss, and profitability

H. Mark Hanna
Iowa State University, hmhanna@iastate.edu

Matt Helmers
Iowa State University, mhelmers@iastate.edu

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H. Mark Hanna, Extension ag engineer, Agricultural and Biosystems Engineering, Iowa State University; Matt Helmers, associate professor and Extension ag engineer, Agricultural and Biosystems Engineering, Iowa State University.

Profitability and environmental sustainability are major objectives in crop production. Decisions on whether to till and what operation to use have direct impact on these objectives. Because of potential adverse affects on soil erosion, structure, aggregate stability, and general soil health, potential for benefits should be carefully considered prior to field operations. Tillage objectives include soil loosening, incorporation of fertilizer or pesticide, weed control, and surface leveling after prior tillage to accommodate planting. Reducing surface residue cover may allow topsoil to warm faster in spring, promote soil drying, and alter the environment for some disease pathogens. Conversely, soil on sloping areas is exposed to longer term degradation by erosion and moisture loss in dry conditions is counterproductive.

Yield comparisons

Yield results have been collected since 2003 from long-term tillage comparisons at Iowa State University Research and Demonstration Farms across the state. Results are aggregated in tables 1 – 3 from north-central locations on glacial till soils (Ames and Kanawha), western Iowa loess (Calumet, Castana, and Lewis), and eastern Iowa loess (Chariton, Crawfordsville, and Nashua).

Corn yields have been generally higher across years and sites with a full-width tillage system, however soybean yields were unaffected as no-till yields were as likely to have the highest yield as other tillage systems in individual comparisons. Research farm staff are good crop producers, but it's worth noting that they often have 20 to 50 or more experiments to establish annually with almost as many research investigators to please in a timely fashion on each experiment. Given the desire to keep management similar across systems (e.g., fertility, pest control) and other work demands, management in reduced tillage (no-till, strip-till) and perhaps other systems may not always be as timely as farmer management of a homogeneous system, i.e. use of a single tillage type across most of the farm.

Table 1. Corn yields in corn-soybean rotation at ISU Research and Demonstration Farms

	Western Iowa loess	Eastern Iowa loess	Till	State average
Moldboard plow	172.7	185.0	193.0	183.7
Subsoil	172.5	185.2	188.2	182.5
Chisel plow	172.0	187.7	192.2	184.6
Strip-till	164.7	178.7	174.7	174.0
No-till	162.6	170.8	169.6	168.3

41 site-years including 11, 20, and 10 site-years in western Iowa loess, eastern Iowa loess, and till soils, respectively. Al-Kaisi and Hanna.

Table 2. Second year corn yields in corn-corn-soybean rotation at ISU Research and Demonstration Farms

	Western Iowa loess	Eastern Iowa loess	Till	State average
Moldboard plow	188.9	176.5	178.0	180.2
Subsoil	186.7	168.9	167.6	173.6
Chisel plow	184.6	169.9	171.0	174.2
Strip-till	170.7	167.2	156.0	166.0
No-till	168	153.6	148.2	156.6

25 site-years including 7, 13, and 5 site-years in western Iowa loess, eastern Iowa loess, and till soils, respectively. Al-Kaisi and Hanna.

Table 3. Soybean yields in corn-soybean rotation at ISU Research and Demonstration Farms

	Western Iowa loess	Eastern Iowa loess	Till	State average
Moldboard plow	51.9	57.5	50.9	54.4
Subsoil	52.6	55.8	50.2	53.6
Chisel plow	52.3	55.3	49.3	53.0
Strip-till	52.6	55.5	49.3	53.2
No-till	54.0	55.8	49.4	53.8

41 site-years including 11, 20, and 10 site-years in western Iowa loess, eastern Iowa loess, and till soils, respectively. Al-Kaisi and Hanna.

Economics

Input costs for land, seed, fertilizer, and pesticides are significant and recur regularly. Although machinery expenses may not be the first item considered when attempting to lower costs and increase profits, it may be more feasible to reduce machine costs if land, seed, and chemical prices aren't readily negotiable. Management differs as tillage is reduced, necessitating some degree of familiarity and comfort with a different system.

Seed and chemical costs frequently do not change with tillage system. Assuming these do not vary, a partial budgeting approach can be used to compare systems, vis`- a-vis`, are the cost of additional tillage trips returned by additional crop produced? Current costs for selected tillage operations are shown in table 4.

Table 4. Cost of field operations per acre

Operation	New	Used	Custom
Disc-subsoiler	$19.04	$17.65	$20.75
Subsoiler	16.95	14.70	18.45
Chisel plow	15.38	13.75	14.90
Field cultivate	13.08	9.96	12.30

Costs were calculated using new equipment or 5 to 10 year-old used equipment. Custom rates are from the Iowa Farm Custom Rate Survey, FM 1698.

Actual costs vary, particularly with age of equipment. Subsoiling ranges from $15 - $20 per acre with costs of $18 to $20 per acre for popular combination disc-subsoiler or newer equipment. Shallower chisel plowing costs are about $15 per acre. At least one secondary tillage pass before planting is usually required to level soil, costing about $12 per acre. Adding one secondary tillage pass, subsoiling adds about $30 per acre and chisel plowing about $27 per acre compared to using no tillage before planting. At current relatively high corn prices, tillage seems economically justified at least in the short term if longer term soil erosion and soil health are not considered. During a period of

$4 – 6/bu corn prices, an extra 5 to 7 bu/acre yield increase would be required for more aggressive tillage systems just to recoup machinery expenses without considering additional soil degradation or loss.

Energy considerations

Fuel costs and energy use are directly related to tillage depth. American Society of Agricultural and Biological Engineers data indicate that drawbar pull of most tillage implements is directly related to operating depth. In-field measurements with subsoiler equipment have shown fuel use nearly doubling as operating depth went from 9 to 18 inches.

Some component of energy is required simply to move the tractor and implement in the field, still chisel plowing at 6 to 8-in. depth typically requires about 1 gal/acre fuel use whereas subsoiling at 12-in. depth requires about 1.5 gal/acre. Long-term corn yield averages on ISU research farms typically differ by a fraction of a bushel per acre with yield averages from a chisel plow system often slightly ahead. Yield comparisons from all sites and years between subsoil and chisel plow systems are shown in figure 1. Results suggest that although deep tillage uses more diesel fuel, it doesn't cover extra costs unless a distinct problem is being corrected.

Soil loss

An important factor to consider in choosing a tillage system is the impact on soil erosion and overall soil loss. To investigate the impact that a chisel plow, strip till, or no-till system has on soil loss, the WEPP model was used at eight sites throughout Iowa (Zhou et al., 2009). WEPP is a process-based, distributed parameter prediction model for soil erosion and sediment delivery from hillslopes and small watersheds (Flanagan and Nearing, 1995). Processes implemented in WEPP include rill and interrill erosion, infiltration, percolation, sediment transport and deposition, surface runoff, evapotranspiration, snow accumulation and melt, irrigation, channel erosion, residue and canopy effects, and tillage effects. It is useful to simulate the impact of land use and/or field management practices on soil loss and sediment transport on hillslopes and in small watersheds. For the results presented within, a 50-yr weather record for each location was used in the modeling. As shown in Table 5, the no-till and strip tillage systems greatly reduced soil loss from all the sites modeled with, as expected, the most dramatic reductions at the sites with greater slope. This highlights the need for the greatest soil protection on those most sensitive lands. Despite dramatic reductions in soil loss with no-till at sites with slopes greater than 7%, the soil loss was still greater than 1 ton/acre/yr with the no-till. This highlights the potential need for implementation of other in-field or edge-of-field practices. An example of an in-field practice that could reduce soil erosion is a cover crop. It is important to note that while edge-of-field practices such as buffers reduce soil loss from the field they do not reduce in-field erosion. As such, a combination of practices should be used to reduce in-field erosion and soil loss from the field. Another important note relative to these results is that WEPP models the rill and interrill erosion but not ephemeral gully erosion which could be a major contributor to overall soil loss from the field. As such, practices such as grassed waterways that protect those areas susceptible to ephemeral gully erosion may be needed.

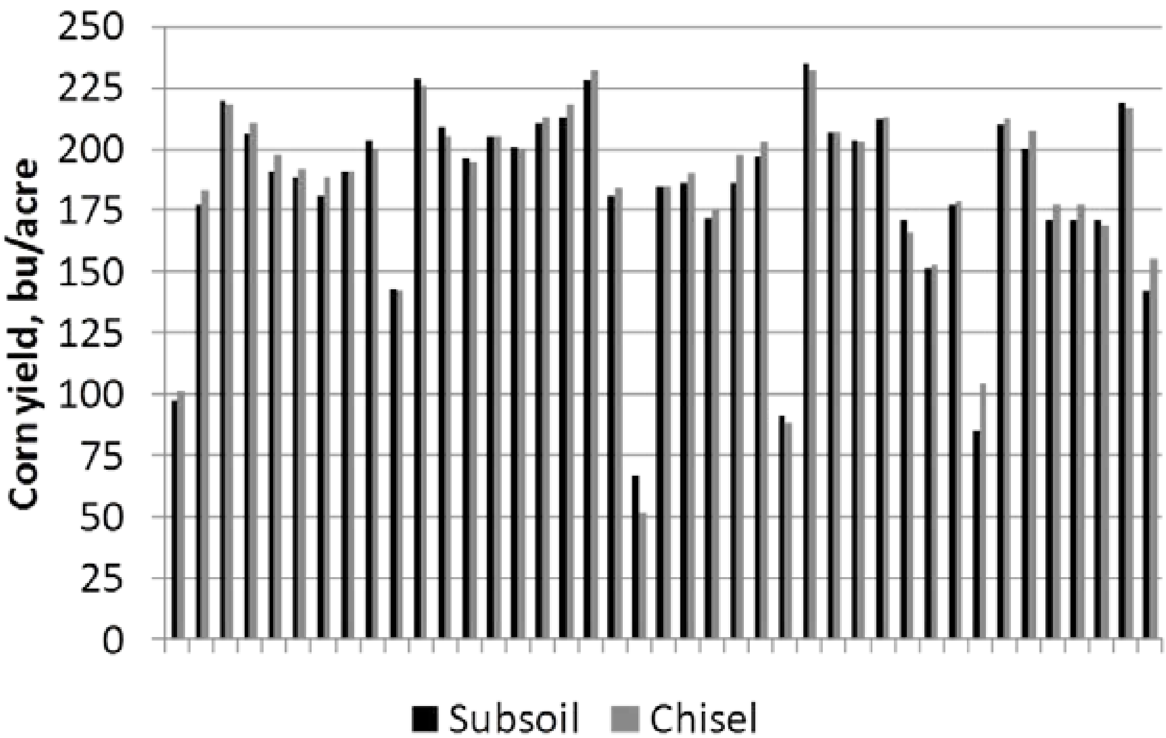

Figure 1. First year corn yields from subsoil and chisel plow tillage systems at ISU Research and Demonstration Farms (41 site-years).

Summary

Profitability and environmental sustainability impact tillage decisions. Multi-year tillage comparisons suggest no-till soybeans yield as well as other tillage systems across the state. Conversely corn yields frequently respond to some type of tillage, although when comparing full-width tillage systems shallower chisel plowing yields are equal to deeper subsoiling or ripping yields over time at different sites. From a soil- and energy-saving perspective, growers are encouraged to avoid tillage before planting soybeans and to carefully consider tillage requirements before planting corn. Longer-term environmental sustainability provides further reasons for cautious tillage use.

Table 5. Estimated annual soil loss from the WEPP model at various locations in Iowa

Site	Primary Soil	Area (acres)	Mean Slope (%)	Soil loss (ton/acre/yr)		
				Chisel Plow	Strip Till	No-Till
Northwest Iowa	Galva silty clay loam	111	2.1	2.3	0.5	0.3
Loess Hills	Ida silt loam	98	10.8	18.9	3.9	2.1
Des Moines Lobe	Nicollet loam	113	1.0	0.6	0.4	0.2
Western Deep Loess and Drift	Sharpsburg silty clay loam	89	7.1	13.4	2.6	1.4
Eastern Deep Loess and Drift	Nira silty clay loam	191	0.9	0.3	0.2	0.2
Eastern Till Prairie	Kenyon loam	197	3.2	1.6	0.5	0.3
Northeast Iowa	Fayette silt loam	302	9.5	12.5	2.1	1.1
Southern Thin Loess and Till Plain	Grundy silt loam	56	7.5	17.7	3.3	2.2

References

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