An Economic Evaluation of Precision Deep Tillage Practices through the Analysis of Comparative Enterprise Budgets

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Abstract

Precision deep tillage allows for lower use of tillage though recognized variation with in a field. Comparative enterprise budgets, breakeven, and sensitivity analysis were preformed to prove that under long-term no-till conditions precision deep tillage can be a profitable form of tillage that will enter an optimal producer strategy.

Keywords

Precision Agriculture, Enterprise Budget, Sensitivity, Breakeven, Soil Cone Penetrometer, Variability, Deep Tillage, Precision Deep Tillage.

Introduction

Deep tillage research has been performed in many states across the country showing the value of deep tillage on fields that have history of traffic under wet conditions and heavy axial loads. This can be multiplied depending on the specific soil chemistry that make them more susceptible to developing hard pans or soil compaction that causes water permeation, and root penetration problems. One of the major oversights of such research is the fact that not all soils are subject to soil compaction at the same amount or in a uniform field area. Some fields have soils that require more tillage, less tillage, or no-tillage and they all may be present in the same field is as often the case for farmland in Kentucky. For this reason the expensive operation of deep tillage could be varied to lower the cost to the producer without compromising yield potential. With site-specific soil management a farmer could better maximize profitability if the cost of acquiring data and applying the tillage does not exceed the productive benefits of the tillage.

Every time an implement is used on the land for preparation of planting it incurs additional cost to the producer. Deep tillage is an expensive practice that requires an additional farm implement specifically for deep tillage, more fuel, and machinery fixed costs per acre than no-tillage or conventional tillage. In the process of developing enterprise budgets it is important to apply estimated costs to each method of tillage to find the most accurate valuation of the specific practice.

Background

In looking at deep tillage specific relationships have been found between soil structure and the profitability of deep tillage. In the piece titled "Economic and Agronomic Assessment of Deep Tillage in Soybean Production on Mississippi River

Valley Soils." (Pearce, Dillon, and Keisling) factors involving the profitability of deep tillage were discussed by the evaluation of economic data collected from the University of Arkansas dealing with deep tillage experimentation. The greatest impacts of deep tillage were found to be on the clayey soils located in the Mississippi river alluvium. The results of deep tillage on these soils were comparable to the productive increases of irrigation on other soils. These results were compared to conventional shallow tillage and deep chisel tillage. The best results were attained when the deep tillage was performed in the fall. Other observations recorded that leaving the deep tilled soil untouched and broken into large 30cm by 70cm clods till spring seed bed preparation showed greater results then immediate smooth finishing which was more aesthetically pleasing to farmers.

I Kentucky conventional method of tillage management would more than likely be no-till. In analyzing the enterprise budgets the methods of no-till, uniform deep tillage and precision deep tillage have been selected to represent common practice. Producers will default to no-till fields unless there is a visible problem in the majority of the field and prior to this point there is already yield being lost that is visibly undetectable (Murdock, 1995). Producers practicing deep tillage will perform the operation uniformly in a rotational program or as they see compaction. The margin of yield loss is often not detected until the problem has become severe to extreme in the degree of compaction which is more than likely varies within the field (Schwab, Murdock, and Wells). With this in mind the use of Precision Agriculture (PA) technologies could have potential to address this variability.

The main idea that is stressed in any of the PA literature is that the use of the technology more specifically meets the spatial needs of agricultural land in terms of input application and efficient usage of inputs applied. By recording spatial data through monitoring yields with spatial connection and applying site-specific crop management (SSCM) producers can more efficiently meet the needs of the crop. (SSCM) is defined as "matching resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field" (McBratney and Whelan).

In recent times it has been recognized that the variability in agricultural land is one of the most important reasons why PA has become a revived aspect in agricultural literature (Weiss). This revival of land variability has opened the door to different technologies within PA. Precision tillage is one of the emerging new technologies that can play a role in future soil conservation, carbon sequester issues, and improved yields for producers. The implications of precision tillage come from the fact that with today's emerging technologies farmers have larger machines that more efficiently cover the land and with their introduction frequently headland compaction has become a problem and also moisture related compaction. The use of this new technology can target tillage to certain areas of greatest need and leave others untouched, lowering costs, increasing productivity, and reducing erosion compared to field basis tillage (Wells, Shearer, and Murdock, 2002).

In searching for methods to examine the economics of Precision Deep Tillage defining the operations in the field and the cost relationships with these operations were the first issues to be addressed. Identifying the methods of tillage and production research came from the manuscript (Wells, Stombaugh, and Shearer, 2004) looking at what the base no-till, uniform deep till, and precision deep till operations might be. Sensitivity and break-even methods were examined in (Oriade, Dillon, and Keisling) to be explanatory and show defined differences in operational returns. Linking the differences in operations in relation to soil characteristics with respect different soil physics was well represented through looking at the budgeting, breakeven, and sensitivity from (Pearce, Dillon, Keisling, and Wilson).

Multiple zone breakeven analysis was displayed by looking at nutrient variability management through variable rate technology and uniform rate technology to define the advantages of managing spatial variability (English, Mahajanashetti, and Roberts). (Bullock, Lowenberg-DeBoer, and Swinton) gave a diverse prospective of comparisons of variable rate application and uniform rate application of inputs with respect to recorded variability in fields showing profitable usages of spacial data collection technology and variable input application. The data collection system of using a multiple-probe soil cone penetrometer was well explained by (Raper, Washington, and Jarrell) to be an accurate system to define compaction and variability within field zones. Defining the mechanical relationships in efficiency was examined in a machinery optimization and selection model produced by (Sogaard and Sorensen).

Objectives

The reasoning behind economic research on precision deep tillage is to assess the feasibility of producers taking on the additional cost of on farm research of soil structure to lower the input use and improve soil conservation:

1) Define the physical relationships between no-tillage, uniform deep tillage, and precision (variable rate) deep tillage involved in the usage of inputs as well as the relative returns to the different levels of tillage.

2) Compose enterprise budgets based on the physical requirements each of the tillage methods and format them in a comparative production plan.

3) Conduct sensitivity analysis to define the profit maximizing tillage strategy in relation to input use and yield differences to define an applicable producer tillage strategy.

Methods

The enterprise budgets were generated using the Mississippi State Budget Generator. The independent variables that are unchanged across the different methods of production are price of crop, fertilizer and lime rates, pre-emergence chemical application, seed and planting equipment with operator labor, post-emergence chemical application, and harvest machinery with operator labor. Dependent variables will include fuel cost, labor for tillage operation, amount of corn produced, hauling expense for the product, and fixed costs including additional mechanical resources and data collection costs.

The three enterprise budgets produced including no-tillage, uniform deep tillage, and variable rate deep tillage. Each budget will differ by input level and production returns. The crop that is used in these budgets is corn. The physical information for this enterprise budget analysis will come from the precision deep tillage data collected in field trials and soil compaction research from the University of Kentucky. From this information, economic relationships have assessed on the basis of net returns by degree of compaction for each tillage method, weighted average net return based on long term no-till soil conditions, and weighted average breakeven yield based on long term no-till soil conditions. Further a break even analysis is used to cite the additional returns needed to justify the adoption of precision tillage technology.

The sensitivity analysis of the three tillage method budgets is subject to fluctuations in yield reduction, and percentage of field with compaction. Comparative relationships of yield will be manipulated under each budget. Finally the variation of site specific tillage in the headlands or haul roads of fields on the basis of percentage of total field area compacted (10, 20, 50%) and degree of compaction little, slight, moderate, severe, and extreme.

Data and Results

The field practices used for the budgeting process are differed by tillage method and the cost of application as well as the yield of the crop. A standard production system was established for production under each tillage method. First the no-till production system which is seen in (Table 7.), follows a process of fertilizer and lime application custom (01/15/05), pre-emergence chemical application (3/20/05), planting (4/01/05), post-emergence chemical application (5/15/05), harvest (10/15/05), custom haul crop (10/15/05), and sell crop (10/15/05). The uniform deep tillage (Table 8.) method of production follows the same regiment of activities except the uniform deep tillage application is preformed in the fall (11/15/04) before fertilizer application (01/15/05) and the land is cultipacked (3/15/05) before pre-emergence chemical application (3/15/05). The precision deep tillage (Table 9.) method of production is the same as the deep tillage method with the exception of data collection operation in the fall (11/01/04) before deep tillage application (11/15/04). All deep tillage application costs were based on a depth of 40 centemeter as prescribed to be a general benefit by (Wells, Stombaugh, and Shearer).

The budgets for each operation were developed through the use of the Mississippi State Budget Generator (MSBG) using select input and output information that was corrected to meet last years product prices. Diesel fuel was valued at 1.6 per gallon, interest rate was 5%, and corn price was $2.34 per bushel. The machinery specifications included: 190 horsepower MFWD tractor, 4 shank lo-till implement, 16 row 30 inch folding planter, 20' cultipacker, 240 horsepower combine with 8 row thirty inch corn head, and 500 bushel grain cart. The 190 horsepower MFWD tractor will perform all draft type activities to lower the cost to the operator. All variable input prices are the same for the three budgets except for data collection, deep tillage cost on varying application, and the cost of variable cultipacker operations.

The cost of data collection was assessed on the basis of a joint project between the University of Kentucky and Miles Enterprises on a portable cone penetrometer which is still in the experimental stages. Projected cost of data collection portable soil cone penetrometer (PSCP) was assessed to be near the cost of hiring custom grid soil sampling of $7.00/acre semiannually. There are two major methods of soil compaction data collection with one being (PSCP) seen in (Figure 1.) and the other being a tractor mounted multiple-probe soil cone penetrometer (MSCP) (Figure 2.). The major difference is the versatility of the (PSCP) compared to the multiple readings taken by the (MSCP). For this research the custom hiring of (PSCP) data collection was selected. The additional cost of a precision deep implement was assessed based on the cost of modification of the base implement for uniform deep tillage. According to the unit used in (Wells, Stombaugh, and Shearer) Case IH ecolo-til (Figure 3.) the additional cost of the implement modification including software to drive the implement was $3,300.00. Assumptions made in the technological adoption is that the producer already has a GPS receiver on the combine that can be used on the tillage implement and a personal digital assistant or lap top with a farm management/GIS software package to calculate and correct the precision deep tillage application.

The breakeven yields based on selected total costs by tillage method were assessed in (Table 1.).

Table 1. Base Breakeven yield based on selected total cost by tillage method.

	Method of Tillage		
	No-till	Uniform DT	Prec. DT
Base Breakeven Yield in bu/ac	104.11	109.56	111.33

Clearly the additional cost of uniform deep tillage (UDT) and precision deep tillage (PDT) raise the breakeven yield above selected total cost.

In the interest of examining yield loss due to compaction information from (Table 2.) was used to derive the characteristics of soil compaction to place value on the variation within the field.

Table 2. Estimates of yield loss due to different amounts of soil compaction.

Degree of Compaction	**Estimated Yield Loss (%)**		
	Corn	**Tobacco**	**Soybeans**
Extreme	30 to 50	50 to 60	20 to 40
Severe	10 to 20	20 to 40	10 to 15
Moderate	5 to 10	10 to 20	5 to 10

Extreme--strongly compacted layer beginning 2 to 3 inches from surface extending to a depth of 10 to 12 inches.

Severe--strongly compacted layer beginning 6 to 8 inches below the surface extending to a depth of 12 to 14 inches.

Moderate--strongly compacted layer as described in severe, but not continuous and exists in about 50% of the field.

*Table from (Schwab, Murdock, and Wells)

To place a set yield loss percentage for corn by the various degrees of compaction the midpoint of the ranges were selected for each degree of compaction: extreme 40%, severe 15%, and moderate 7.5%. These were the yield losses applied to the no-till method in (Table 3.) at a price of $2.34 per bushel.

After placing a value on loss the net returns above selected cost by tillage method could be applied by changing the yields of the enterprise budgets to reflect the change in net returns based on tillage operation and degree of compaction in (Table 3.). In assigning values to the UDT and PDT it is assumed that all yield loss is avoided by applying the deep tillage application. Input use was also varied on PDT to test the sensitivity of applying deep tillage at reduced rates of 10%, 20%, and 50% of the field. The (Base) is no compaction.

Table 3. Net returns above selected cost by tillage method.

Tillage Method	**Degree of Compaction**			
	Base	Moderate	Severe	Extreme
No-Till	107.36	91.02	58.35	-23.32
Uniform Deep Till	94.61	94.61	94.61	94.61
Precision Deep Till 100%	90.49	90.49	90.49	90.49
Precision Deep Till 50%	97.18	97.18	97.18	97.18
Precision Deep Till 20%	101.16	101.16	101.16	101.16
Precision Deep Till 10%	102.5	102.5	102.5	102.5

It is apparent in (Table 3.) that the highest net return comes from no compaction and no-till. In whole field applications UDT has higher net returns than PDT method due to the additional cost of the PDT implement modification and data collection which is $4.12 on a whole field application. Another conclusion that can be draw from (Table 3.) is that as the percentage of the field deep tilled is decreased to 50% or less the net returns above selected cost shows the PDT method to be the greatest net return in all compaction scenarios.

In the pursuit of applying these budgets to an average soil compaction variability situation the following (Table 4.) was used to place a value on compaction variability across field tillage history and amount of compaction. This table was derived from compaction research on University of Kentucky, Princeton Research Station field data.

Table 4. Effect of tillage on soil compaction.

Tillage History	Field		Amount of Compaction			
			Little	Slight	Moderate	Severe
	No.	%	-------------------------	%	-----------------------	
No-Till	32	19	50	22	15	13
Disc	37	22	27	3	24	46
Conventional	94	56	45	25	17	13
Subsoil	6	4	67	0	16	17
Total	169	100				
* From (Murdock, Gray, and Higgins), 1995.						

Under our long-term no-till situation, no-till was the tillage history used to display common compaction by amount and percentage of the field. This was used to derive a weighted average net return per acre based on tillage strategy. These calculations decipher how targeting variability of compaction in whole field applications for each of the three selected methods of tillage. The comparison of WANR is shown in (Table 5).

Table 5. Net returns above selected cost by tillage method as a weighted average of soil compaction conditions of long term No-till from Table 1.

Tillage Method	Amount of Compaction				Weighted Average Net Return/Acre
	Little 50%	Slight 22%	Mod. 15%	Severe 13%	
No-Till	107.36	107.36	91.02	58.35	98.54
Uniform Deep Till	94.61	94.61	94.61	94.61	94.61
Precision Deep Till	103.83	103.83	101.82	102.09	103.30

In deriving the value of each tillage method no-till was set to have no yield loss at Little or Slight amounts of compaction. The loss on Moderate compaction was 7.5% and Severe 15% at $2.34 per bushel. The full productive value was assumed on all levels of compaction for UDT and PDT. The difference in net returns between no-till and PDT were the data collection cost of $3.53 per acre. Another depiction of this example is a breakeven yield analysis under the same conditions in (Table 6.).

Table 6. Breakeven yield based on tillage method and % of area compacted.

Tillage Method	Amount of Compaction				Weighted Avg. Breakeven Yield/Acre
	Little 50%	Slight 22%	Mod. 15%	Severe 13%	
No-Till	104.11	104.11	111.61	126.61	108.16
Uniform Deep Till	109.56	109.56	109.56	109.56	109.56
Precision Deep Till 100%	105.62	105.62	106.49	106.37	105.85

As shown above in (Table 6.) we have a clearly lower weighted average breakeven yield under the PDT method.

<u>Conclusions and Other Research</u>

Keep in mind that these calculations reflect the lowest compaction loss due to the long-term no-till tillage history numbers from (Table 4.) with a total of 28% of the field compacted. The use of compaction amounts from (Table 4.) based on tillage histories show percentage of field area compaction to be: disc 70%, conventional 33%, and subsoil 30%. This would all prove with even more difference in weighted average net returns and weighted average breakeven yield that precision deep tillage would be the optimal tillage method.

The ideology of using precision deep tillage is to target variability within a field. Research in Kentucky by (Schwab, Murdock, and Wells) and (Wells, Stombaugh, and Shearer) of soil compaction all show yield loss above the thresh hold tested. By using a soil cone penetrometer system producers can target potential yield loss in the field that they could not see otherwise except through compaction data collection. The same is true with other precision agriculture technologies such as yield mapping, grid soil sampling, and near infrared imaging. Site-specific crop management technology is limited most by the effective and economical collection of spatial data. For PDT to be an optimal or even feasible tillage solution the innovation of such data collection methods as the experimental portable soil cone penetrometer have to come to fruition.

Further research in the area of PDT application could be applied to other compaction data collection methods such as flyover near infrared images soon after precipitation to detect standing water and compare the areas to previous crop year yield maps. Within the area of economics PDT could be used as a risk management strategy under various soil types, crops, and production systems. As more data is collected the potential profitability and adoption of precision deep tillage application will become clearer.

Table 7. Estimated costs and returns per acre
No-till Corn
University of Kentucky, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Corn	bu	2.34	150.0000	351.00	_________
TOTAL INCOME				351.00	_________
DIRECT EXPENSES					
CUSTOM SPRAY					
Custom Apply	acre	7.00	2.0000	14.00	_________
FERTILIZERS					
DAP	cwt	12.66	1.5000	18.99	_________
Potash (60% K2O)	cwt	8.87	1.2000	10.64	_________
Urea, Solid (46% N)	cwt	12.77	3.3000	42.14	_________
HERBICIDES					
AAtrex 4L	pt	1.36	4.0000	5.44	_________
Glystar Plus	pt	3.36	4.0000	13.44	_________
INSECTICIDES					
Force 3G	lb	4.38	4.0000	17.52	_________
SEED/PLANTS					
Corn Seed BtRR	thous	1.69	28.0000	47.32	_________
CUSTOM FERT/LIME					
Custom Apply Fert	acre	4.00	1.0000	4.00	_________
Lime (Spread)	ton	12.00	0.7500	9.00	_________
CUSTOM HARVEST/HAUL					
Haul Corn	bu	0.16	150.0000	24.00	_________
OPERATOR LABOR					
Tractors	hour	8.00	0.1747	1.40	_________
Harvesters	hour	8.00	0.1277	1.02	_________
HAND LABOR					
Implements	hour	6.44	0.0470	0.30	_________
DIESEL FUEL					
Tractors	gal	1.60	1.7086	2.74	_________
Harvesters	gal	1.60	1.5772	2.52	_________
REPAIR & MAINTENANCE					
Implements	acre	2.51	1.0000	2.51	_________
Tractors	acre	0.60	1.0000	0.60	_________
Harvesters	acre	1.93	1.0000	1.93	_________
INTEREST ON OP. CAP.	acre	8.44	1.0000	8.44	_________
TOTAL DIRECT EXPENSES				227.95	_________
RETURNS ABOVE DIRECT EXPENSES				123.05	_________
FIXED EXPENSES					
Implements	acre	4.26	1.0000	4.26	_________
Tractors	acre	3.83	1.0000	3.83	_________
Harvesters	acre	7.60	1.0000	7.60	_________
TOTAL FIXED EXPENSES				15.69	_________
TOTAL SPECIFIED EXPENSES				243.64	_________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				107.36	_________

Note: Cost of production estimates are based on last year's input price

Table 8. Estimated costs and returns per acre
Deep Till Corn
University of Kentucky, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Corn	bu	2.34	150.0000	351.00	_________

TOTAL INCOME				351.00	_________
DIRECT EXPENSES					
CUSTOM SPRAY					
Custom Apply	acre	7.00	2.0000	14.00	_________
FERTILIZERS					
DAP	cwt	12.66	1.5000	18.99	_________
Potash (60% K2O)	cwt	8.87	1.2000	10.64	_________
Urea, Solid (46% N)	cwt	12.77	3.3000	42.14	_________
HERBICIDES					
AAtrex 4L	pt	1.36	4.0000	5.44	_________
Glystar Plus	pt	3.36	4.0000	13.44	_________
INSECTICIDES					
Force 3G	lb	4.38	4.0000	17.52	_________
SEED/PLANTS					
Corn Seed BtRR	thous	1.69	28.0000	47.32	_________
CUSTOM FERT/LIME					
Custom Apply Fert	acre	4.00	1.0000	4.00	_________
Lime (Spread)	ton	12.00	0.7500	9.00	_________
CUSTOM HARVEST/HAUL					
Haul Corn	bu	0.16	150.0000	24.00	_________
OPERATOR LABOR					
Tractors	hour	8.00	0.4030	3.23	_________
Harvesters	hour	8.00	0.1277	1.02	_________
HAND LABOR					
Implements	hour	6.44	0.0470	0.30	_________
DIESEL FUEL					
Tractors	gal	1.60	3.9412	6.31	_________
Harvesters	gal	1.60	1.5772	2.52	_________
REPAIR & MAINTENANCE					
Implements	acre	2.95	1.0000	2.95	_________
Tractors	acre	1.39	1.0000	1.39	_________
Harvesters	acre	1.93	1.0000	1.93	_________
INTEREST ON OP. CAP.	acre	8.57	1.0000	8.57	_________

TOTAL DIRECT EXPENSES				234.71	_________
RETURNS ABOVE DIRECT EXPENSES				116.29	_________
FIXED EXPENSES					
Implements	acre	5.24	1.0000	5.24	_________
Tractors	acre	8.84	1.0000	8.84	_________
Harvesters	acre	7.60	1.0000	7.60	_________

TOTAL FIXED EXPENSES				21.68	_________

TOTAL SPECIFIED EXPENSES				256.39	_________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				94.61	_________

Table 9. Estimated costs and returns per acre
Precision Deep Till Corn
University of Kentucky, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Corn	bu	2.34	150.0000	351.00	_________

TOTAL INCOME				351.00	_________
DIRECT EXPENSES					
CUSTOM SPRAY					
Custom Apply	acre	7.00	2.0000	14.00	_________
FERTILIZERS					
DAP	cwt	12.66	1.5000	18.99	_________
Potash (60% K2O)	cwt	8.87	1.2000	10.64	_________
Urea, Solid (46% N)	cwt	12.77	3.3000	42.14	_________
HERBICIDES					
AAtrex 4L	pt	1.36	4.0000	5.44	_________
Glystar Plus	pt	3.36	4.0000	13.44	_________
INSECTICIDES					
Force 3G	lb	4.38	4.0000	17.52	_________
SEED/PLANTS					
Corn Seed BtRR	thous	1.69	28.0000	47.32	_________
SERVICE FEE					
SCP Data Collection	acre	7.00	0.5000	3.50	_________
CUSTOM FERT/LIME					
Custom Apply Fert	acre	4.00	1.0000	4.00	_________
Lime (Spread)	ton	12.00	0.7500	9.00	_________
CUSTOM HARVEST/HAUL					
Haul Corn	bu	0.16	150.0000	24.00	_________
OPERATOR LABOR					
Tractors	hour	8.00	0.4030	3.23	_________
Harvesters	hour	8.00	0.1277	1.02	_________
HAND LABOR					
Implements	hour	6.44	0.0470	0.30	_________
DIESEL FUEL					
Tractors	gal	1.60	3.9412	6.31	_________
Harvesters	gal	1.60	1.5772	2.52	_________
REPAIR & MAINTENANCE					
Implements	acre	3.12	1.0000	3.12	_________
Tractors	acre	1.39	1.0000	1.39	_________
Harvesters	acre	1.93	1.0000	1.93	_________
INTEREST ON OP. CAP.	acre	8.60	1.0000	8.60	_________

TOTAL DIRECT EXPENSES				238.41	_________
RETURNS ABOVE DIRECT EXPENSES				112.59	_________
FIXED EXPENSES					
Implements	acre	5.66	1.0000	5.66	_________
Tractors	acre	8.84	1.0000	8.84	_________
Harvesters	acre	7.60	1.0000	7.60	_________

TOTAL FIXED EXPENSES				22.10	_________

TOTAL SPECIFIED EXPENSES				260.51	_________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				90.49	_________

Note: Cost of production estimates are based on last year's input price

Figure 1.

Figure 2.

Figure 3.

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