Reducing Tillage to Conserve Energy and Increase Profits

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Tillage objectives

Soils are tilled to prepare a seedbed for plants, to control weeds and prepare land for irrigation. In the past, primary tillage of most cropland was done with moldboard plows. Plowing buries weeds and crop residues, eliminates soil compaction within the plow depth, and conditions soil for better aeration and water intake. In some areas, plowing has given way to subsoiling or chiseling.

But, plowing or disking at the same depth over a period of years creates a plow sole or hardpan in many soils. This hardpan tends to reduce root development and must be broken up by deep plowing or subsoiling to a depth of 20" to 24" every few years.

Secondary tillage reduces clod size, produces an even surface for planting and assists in controlling weeds. It is done with a wide variety of implements, including floats, land planes, disk harrows, spike tooth harrows, spring tooth harrows, rotary cultivators, sweep cultivators and power mulchers.

"Minimum tillage" does not refer to a particular set of practices but rather to minimum practices consistent with the crop, the soil and climate. The minimum might be "no-till" where a crop is planted in the residue of the old crop without seedbed preparation, or it might be a tillage system that would still retain plowing as a primary tillage method. The term "reduced tillage" will be used in this discussion rather than "minimum tillage".

Tillage tests in Arizona

Reduced tillage tests were conducted at the Cotton Research Center in Phoenix, Safford Experimental Station and Marana Experimental Farm from 1965 to 1973. Tests compared several reduced tillage systems with a conventional six operation pre-plant tillage system consisting of disking, plowing, disking, disking, floating, and listing. The reduced tillage systems included (1) listing only, (2) chiseling to 14" and listing, (3) chiseling to 16" - 18" and listing, and (4) chiseling to 18" - 20" and listing. In some tests, cotton was planted in the same row each year, while in others, cotton rows were moved one-half row width each year.

The following conclusions were reached:

Yields did not decrease when chiseling was substituted for plowing.
Chiseling below 14" was not necessary.
Significant energy savings were made with reduced tillage.
Trash in the drill row interfered with planting. (The half-row move was best for trash coverage.)
Pre-plant herbicides applied on beds and incorporated with a rolling cultivator gave good results.

Five reduced tillage tests were made on grower operated farms in Pima, Pinal, Maricopa and Yuma Counties in 1974. In each case, chiseling to a 15" depth was substituted for plowing. On one farm a land planing operation preceded listing to reduce clod size. On another farm, there were two disking operations before listing. The other three tests involved only chiseling and listing pre-planting operations. Two growers reported substantial water savings. Only one grower thought the field with reduced tillage might have shown a yield loss. Another grower said the fuel saving for reduced tillage was over $5 per acre; however, accurate records of costs, yields and water use were not kept.

Reasons to consider reduced tillage

Reduced energy, machinery and labor costs are the major reason for reducing tillage operations.
Lower reported irrigation water use with reduced tillage could be important as water becomes more expensive. (These savings, however, may be related to irrigation practice improvement.)
Less tillage will conserve soil. Fewer operations and rougher fields will reduce blowing dust.
Soil compaction will be reduced because fewer trips will be made over fields. A higher water infiltration rate will be maintained for most soils.
Timeliness of farm operations may be improved. Double cropping may be more practical in areas where the time between harvesting one crop and planting another can be shortened.
Capital investment for farm machinery may be reduced.

Potential reduced tillage problems

Because weed control may be more difficult, herbicide use will probably need to be increased. Care must be taken to avoid residual herbicide problems.

Crop residue on soil surface may be a problem in planting, cultivating or irrigating. Better destruction of old plant fibers will be needed to minimize the problem. To achieve better break-up of

trash, some growers use flail type stalk choppers.

Insect carry-over may be more severe when crop residue is left on the surface.

Close monitoring of crop and soil by the farm manager will be required. More careful attention will need to be given to timing and the quality of performance of machine operations.

Tillage decisions

Farm operations vary from year to year, managers have different ideas about them, and some operations will vary with weather, soil and pests. If it rains just before planting, unplanned mulching may be required. If plowing or chiseling results in large clods on the surface, they may have to be broken up. And, if weeds are being particularly well controlled by herbicides, one or two cultivations may be eliminated. In each case, the farm manager must weigh the need for operations against costs. This means he needs a fairly accurate estimate of the cost of his machine operations. Since so many variables are involved, each manager should make his own estimates. The three tables will help make estimates with a minimum of calculations.

Table 1 shows field capacities of machines of varying widths operating at 85 percent of field efficiency at various speeds. Machine capacities for other field efficiencies can also be obtained from the table by multiplying the table value by the ratio of the desired efficiency to 85. As an example, a machine with an effective width of 10 feet travelling 4 miles per hour shows an effective field capacity of 4.12 acres per hour in the table. The field capacity at 75 percent field efficiency would be 75/85 x 4.12, or 3.64 acres per hour.

Table 2 shows fixed and repair costs for tillage implements per $1000 of list price, assuming a 2500 hour life. Fixed costs include taxes, housing, insurance, interest and depreciation. The first four items have been considered as 14 percent of average value. Depreciation is based on the price of a new machine and its value when sold or traded. Values for machines after usage were determined from equations suggested in the Yearbook of the American Society of Agricultural Engineers. Repair costs were also based on repair equations from the Yearbook.

Example:

A plow costing $3000 will be used an estimated 280 hours per year before being traded at the end of eight years. What annual fixed and repair cost can be expected?

The table shows an annual cost of $325 per $1000 list price at 300 hours use and $295 at 250 hours use. An interpolation for 280 hours follows:

$$\text{Annual cost} = \text{cost at 250 hours plus } \frac{30}{50} \text{ of cost difference}$$

$$\text{Cost difference} = \$30$$

$$\text{Annual cost per \$1000 list price} = \$259 + \frac{3}{5} \times \$30 = \$313$$

$$\text{Annual cost for plow} = \frac{\$3000}{1000} \text{ or } 3 \times \$313 = \$939$$

Table 3 shows diesel tractor costs per PTO HP hour. This includes fixed, repair, fuel and lubricant, but not the cost for a tractor operator. Wearout life for tractors is assumed to be 12,000 hours. Costs are based on equations from the same Yearbook. Fixed costs are based on a value of $200 per PTO horsepower for a new tractor. Depreciation is based on the value of a tractor after it has been used for a number of years, calculated by a formula developed to approximate used tractor values. Taxes, housing, insurance and interest have been considered as 14 percent of the average value. A tractor loading of 60% was used in the calculations for determining the amount of fuel used. Fuel use is assumed to be 13 HP hours per gallon of diesel and fuel cost assumed to be 80¢ per gallon.

Table 1. Field machine capacities in acres per hour at 85% field efficiency.

Effective Implement Width in ft	Machine Speed in MPH							
	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
4	1.03	1.24	1.44	1.65	1.85	2.06	2.27	2.47
4-1/3	1.12	1.34	1.56	1.76	2.01	2.23	2.45	2.68
4-2/3	1.20	1.44	1.68	1.92	2.17	2.41	2.65	2.89
5	1.29	1.55	1.80	2.06	2.32	2.58	2.83	3.09
5-1/3	1.37	1.65	1.92	2.20	2.47	2.75	3.02	3.29
5-2/3	1.46	1.75	2.04	2.34	2.63	2.92	3.21	3.51
6	1.55	1.85	2.16	2.47	2.78	3.09	3.40	3.71
6-1/3	1.63	1.96	2.28	2.61	2.93	3.26	3.59	3.91
6-2/3	1.72	2.06	2.40	2.75	3.09	3.44	3.78	4.12
7	1.80	2.16	2.52	2.88	3.25	3.61	3.97	4.32
7-1/3	1.88	2.27	2.64	3.02	3.40	3.78	4.15	4.53
7-2/3	1.97	2.37	2.76	3.16	3.56	3.95	4.35	4.74
8	2.06	2.47	2.88	3.30	3.71	4.12	4.53	4.95
8-1/3	2.15	2.57	3.00	3.43	3.86	4.29	4.72	5.15
8-2/3	2.23	2.68	3.13	3.57	4.02	4.47	4.91	5.36
9	2.32	2.78	3.25	3.71	4.17	4.64	5.10	5.56
9-1/3	2.40	2.88	3.36	3.85	4.33	4.81	5.29	5.77
9-2/3	2.49	2.99	3.49	3.96	4.48	4.98	5.48	5.98
10	2.58	3.09	3.61	4.12	4.63	5.15	5.67	6.18
10-1/3	2.66	3.19	3.73	4.26	4.79	5.32	5.85	6.39
10-2/3	2.75	3.30	3.85	4.40	4.95	5.50	6.05	6.60
11	2.83	3.40	3.97	4.53	5.10	5.67	6.23	6.80
11-1/3	2.92	3.50	4.09	4.67	5.25	5.84	6.42	7.00
11-2/3	3.00	3.61	4.21	4.81	5.41	6.01	6.61	7.21
12	3.09	3.71	4.33	4.95	5.56	6.18	6.80	7.42
12-1/3	3.18	3.81	4.45	5.08	5.72	6.35	6.99	7.62
12-2/3	3.26	3.92	4.57	5.22	5.87	6.52	7.18	7.83
13	3.35	4.02	4.69	5.36	6.03	6.70	7.37	8.04
13-1/3	3.43	4.12	4.81	5.49	6.18	6.87	7.55	8.24
13-2/3	3.52	4.23	4.93	5.63	6.34	7.04	7.75	8.45
14	3.60	4.33	5.05	7.77	6.49	7.21	7.93	8.65
15	3.86	4.64	5.41	6.18	6.95	7.73	8.50	9.27
16	4.12	4.95	5.77	6.59	7.42	8.24	9.07	9.89
17	4.38	5.25	6.13	7.01	7.88	8.76	9.63	10.51
18	4.64	5.56	6.49	7.42	8.35	9.27	10.20	11.13
19	4.89	5.87	6.85	7.83	8.81	9.79	10.77	11.75
20	5.15	6.18	7.21	8.24	9.27	10.30	11.33	12.36
22	5.67	6.80	7.93	9.07	10.20	11.33	12.47	13.60
24	6.18	7.42	8.65	9.89	11.13	12.36	13.60	14.84
26	6.70	8.04	9.38	10.72	12.05	13.39	14.73	16.07

Table 2. Annual fixed and repair costs for tillage implements per $1000 of list price. (Wearout life assumed 2500 hours)

Years Ownership	ANNUAL HOURS OF IMPLEMENT USE										
	50	100	150	200	250	300	400	500	600	700	800
3	$304	319	337	356	377	400	448	499	554	612	673
4	265	281	301	322	345	369	421	478	538		
5	240	257	278	300	325	351	407	467			
6	222	240	262	285	312	339	398				
7	208	227	250	275	302	331					
8	196	216	240	266	295	325					
9	187	208	233	260	289						
10	179	201	226	254	285						

Table 3. Diesel tractor costs per PTO HP hour.

Years Owned	Hours Use Per Year											
	400	500	600	700	800	900	1000	1200	1400	1600	1800	2000
3	$.181	.155	.138	.126	.117	.111	.105	.097	.092	.088	.085	.083
4	.166	.144	.129	.119	.111	.105	.101	.094	.089	.086	.084	.082
5	.157	.136	.123	.114	.107	.102	.098	.092	.088	.085	.083	.082
6	.150	.131	.119	.111	.104	.100	.096	.091	.087	.085	.083	.082
7	.145	.127	.116	.108	.102	.098	.095	.090	.087	.085		
8	.141	.124	.114	.106	.101	.097	.094	.090	.087			
9	.137	.122	.112	.105	.100	.096	.093	.090				
10	.135	.120	.110	.104	.099	.096	.093	.089				

Multiply the value found in the table according to tractor hours used each year, and years the tractor will be owned, by the PTO horsepower rating of the tractor to be used.

Example: A 100 PTO horsepower tractor will be kept for 8 years before trading and will average 1000 hours use per year. What is the cost of operation?

The table indicates a cost of $0.094 per PTO HP hour. Then 100 PTO HP x 0.094 = $9.40, not including operator cost.

The following example shows how the tables can be used to estimate machine performance and operation costs.

Tillage costs for conventional tillage and reduced tillage will be compared for a farm of 400 acres:

Conventional tillage	Reduced tillage
Plowing	Chiseling
Disking (twice)	Listing
Floating	Harrowing
Listing	
Harrowing	

Calculations to determine the annual hours of use for implements are shown in the summary below. Machine capacities are from Table 1.

Tillage Operation	Effective Implement width (ft.)	Speed M.P.H.	Machine Capacity Ac/Hr	Annual Hrs Use
Plowing (3 - 16")	4	4	1.65	242
Disking (Twice)	12	4½	5.56	144
Floating	12	4	4.95	81
Listing	13-1/3 (4 row)	3½	4.81	83
Harrowing	13-1/3 (4 row)	5	6.87	58
			Total for Conventional Tillage	608
Chiseling	6-2/3 (2 row)	4	2.75	145
Listing	13-1/3 (4 row)	3½	4.81	83
Harrowing	13-1/3 (4 row)	5	6.87	58
			Total for Reduced Tillage	286

Fixed and repair costs for tillage implements can now be estimated from Table 2 using the annual hours of use for implements just calculated It is assumed that equipment will be owned for 10 years unless 2500 hours of use is reached before that time.

Implement	Hrs Annual Use	Years Ownership	Annual Fixed and Repair Cost per $1000	Implement List Price	Implement Fixed and Repair Cost	
					Annual	per Hour
Plow (3 - 16)	242	10	$280	$3000	$ 840	$3.47
Disk (12')	144	10	223	5000	1115	7.74
Float (12')	81	10	193	2500	483	5.96
Lister (4 row)	83	10	194	2000	388	4.67
Harrow (3 section)	58	10	183	500	92	1.58
Chisel (5 shank)	145	10	224	1500	336	2.32

Tractor hour requirements were shown as 608 for conventional tillage and 286 for reduced tillage. For this problem it will be assumed a tractor will be used 700 hours more for other work on the farm. The tractor used with the conventional tillage program would then be used approximately 1300 hours per year and only 1000 hours per year with reduced tillage. It is assumed that both tractors would be traded after 8000 hours of use. The tractor used 1300 hours per year will be traded after six years use and the one used 1000 hours per year will be kept for eight years.

A 70 PTO horsepower tractor is to be used for estimating costs with both conventional and reduced tillage systems. Table 3 shows that a tractor kept six years before trading and used 1300 hours per year would cost $0.0885 per PTO horsepower hour to operate. A tractor owned for eight years and operated 1000 hours per year would cost $0.094 per PTO horsepower hour to operate. Tractor costs for the two systems would then be as shown below:

Tractor (conventional tillage) 70 PTO HP x 0.0885 = $6.20 per hour

Tractor (reduced tillage) 70 PTO HP x 0.094 = $6.58 per hour

A cost summary of conventional tillage practices compared to the reduced tillage program is shown below. Labor is included at a cost of $3.50 per hour.

TILLAGE COST SUMMARY
FOR 400 ACRES

Operation	Hrs. Annual Use	Cost Per Hour				Total Operation Cost	
		Fixed & Repair	Tractor	Labor	Total	Annual	Per Acre
			(CONVENTIONAL TILLAGE)				
Plowing	242	3.47	6.20	3.50	13.17	$3187	$ 7.97
Disking	72	7.74	6.20	3.50	17.44	1256	3.14
Disking	72	7.74	6.20	3.50	17.44	1256	3.14
Floating	81	5.96	6.20	3.50	15.66	1268	3.17
Listing	83	4.67	6.20	3.50	14.37	1192	2.98
Harrowing	58	1.58	6.20	3.50	11.28	654	1.64
TOTAL	608					$8813	$22.04
			(REDUCED TILLAGE)				
Chiseling	145	2.32	6.58	3.50	12.40	$1798	$ 4.50
Listing	83	4.67	6.58	3.50	14.75	1224	3.06
Harrowing	58	1.58	6.58	3.50	11.66	676	1.69
TOTAL	286					$3698	$ 9.25

Conventional tillage cost is shown as $8,813, compared to $3,698 for reduced tillage. Six machine operations are included in the conventional system and only three for reduced tillage. While the number of operations in a reduced tillage program can be extremely variable and may vary substantially from the ones listed, the tables and the estimating procedure given can simplify the costing of operations.