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Crop Residue and Tillage Considerations in Energy Conservation

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Large quantities of agricultural crop residues are utilized in several ways in Michigan, and some are disposed of at a loss to the producer. With a national, as well as a local, shortage of economically priced energy, consideration is being given to collecting agricultural residues and converting them to alcohol or other substitutes for conventional fuel. Agronomists and conservationists, particularly, question the validity of such proposals.

Tillage operations to incorporate crop residues and prepare a proper seed and root bed require considerable energy. The amount used varies with the kind of implement and the number and kind of tillage operations. Reducing the number of tillage treatments and utilizing implements more efficiently can significantly reduce energy requirements for crop production.

Agricultural Residues

Disposition of agricultural residues produced in Michigan is shown in Table 1. An estimated 1,060,000 tons (T) are fed to livestock on the farm where they are produced. Some are collected and sold for purposes other than fuel (709,000 T). The forestry industry uses 68,000 T of its residues for fuel.

About half the agricultural residues are returned directly to the soil as crop residues or indirectly as livestock manure (3,308,000 T), and approximately one-sixth is wasted in that it is disposed of at an economic loss (1,696,000 T).

Agronomists have long recognized the value of soil organic matter, which originated as residue from plant and animal life, in maintaining soil productivity.

Table 2 — Approximate pounds per acre of organic matter produced as crop residues for the yield level shown.*

Crop	*Yield*	*Crop residue†*
	Bu/A	*Lbs/A*
Barley	80	3,500
Corn	150	9,000
Oat	100	4,000
Rye	40	3,000
Sorghum	80	6,600
Wheat	60	4,000
Soybean	40	3,200

**Average values calculated from several sources.*
†Dry weight.

Table 1 — Annual disposition in Michigan of available agricultural residues.*

Residue	*Sold*	*Fed*	*Fuel*	*Returned*	*Wasted*	*Total*
	Dry tons					
Field crop	298,546	1,060,456	0	3,021,973	19,045	4,400,020
Forestry	406,309	0	67,809	0	1,620,260	2,094,378
Manure	4,053	0	0	286,481	56,866	347,337
Total	708,908	1,060,456	67,809	3,308,391	1,696,171	6,841,735

**Stanford Research Institute, Menlo Park, Cal. 94025 (1976). An evaluation of the use of agricultural residues as an energy feed stock. Vol. II. N.S.F. and A.E.R.T. grants No. AER 74-18615 A03 and NSF/RANN/SE/GI/18615/FR/76/3.*

[1]*Appreciation is expressed to Dr. Carter M. Harrison for assistance in the preparation of this bulletin.*

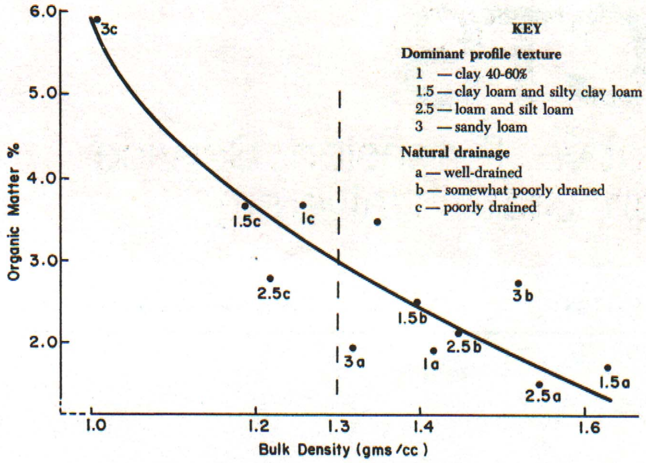

Figure 1—Average bulk density values of soil management groups as related to average soil organic matter levels.

Agronomic Functions of Crop Residues

Crop residues returned to the soil are a source of organic matter, which contributes to the formation of a stable soil structure, aids in the maintenance of high soil fertility levels and helps to protect soil against wind and water erosion.

Crop residues are a variable source of soil organic matter; Table 2 shows the amount of crop residue produced by different field crops. Such residues decompose and ultimately replace part of the soil humus lost each year in crop production. Humus and other organic compounds represent a natural storehouse for water and essential plant food elements.

Soil organic matter levels are closely related to the physical condition of the soil, which in turn affects power requirements for tillage, water infiltration rates, oxygen diffusion rates, etc.

The general relation of total organic matter and density of Michigan soils is shown in Figure 1. The points on the graph represent specific soil management

Table 3 — Approximate amount of nutrients contained in the residues of crops for the yield level shown.*

Crop	*Yield*	*N*	*P*	*K*	*Ca*	*Mg*	*S*	*Mn*
	Bu/A				*Lb/A*			
Barley	80	24	4	40	14	4	7	0.5
Corn	150	100	16	116	26	20	14	1.5
Oat	100	35	8	80	12	15	13	0.4
Rye	40	20	4	28	10	3	4	0.2
Sorghum	80	80	11	90	33	19	10	0.3
Wheat	60	30	5	35	9	4	6	0.2
Soybean	40	70	16	50	30	18	11	0.4

**Calculated from several sources. Values vary greatly with variety, kind of soil, level of management, and season.*

Table 4 — Potential soil losses from wind erosion in cornfields harvested for grain or silage in central Michigan.

Dominant profile texture	*Soil Mgt. Group*	*Potential yield Grain*	*Potential yield Silage*	*Field width*	*Potential soil loss (T/A/Yr)* Standing residue*	Chisel plow†	Mold-board plow†	Harvested for silage*
		bu/A	*T/A*	*Ft*				
Loam	2.5a	110	17	50	Tr‡	Tr	Tr	Tr
Loam	2.5a	110	17	100	Tr	Tr	Tr	Tr
Loam	2.5a	110	17	200	Tr	Tr	Tr	Tr
Loam	2.5a	110	17	400	Tr	Tr	0.6	Tr
Loam	2.5a	110	17	800	Tr	0.5	0.9	0.5
Sandy loam	3a	95	16	50	Tr	Tr	Tr	Tr
Sandy loam	3a	95	16	100	Tr	Tr	Tr	Tr
Sandy loam	3a	95	16	200	Tr	Tr	Tr	Tr
Sandy loam	3a	95	16	400	Tr	0.5	0.8	0.6
Sandy loam	3a	95	16	800	Tr	0.7	1.2	0.8
Loamy sand	4a	75	13	50	Tr	0.6	0.7	0.8
Loamy sand	4a	75	13	100	Tr	0.9	1.2	1.0
Loamy sand	4a	75	13	200	0.6	1.3	1.8	1.5
Loamy sand	4a	75	13	400	1.2	2.3	2.8	2.7
Loamy sand	4a	75	13	800	1.5	2.7	3.8	3.1

**Spring plowed.*
†Fall plowed.
‡Tr—less 0.5 T/A/Yr.

groups whose characteristics are defined by soil texture and the drainage conditions under which the soil was formed. For specifics, refer to the key on the graph. Density is expressed as the weight of a volume of soil material (gm/cc). The higher the organic matter level, the more porous the soil. Humus aids in maintaining stable soil structure. Generally, root growth rates are slow, and crop yields are less than optimum when bulk density values are above the 1.3 level. The data suggest that most of Michigan's agricultural soils are too compact for optimum yields and high power requirements are common.

Another agronomic value of crop residues is related to their chemical composition. Residues are a source of essential plant food elements (Table 3). Higher rates of commercial fertilizer and lime are required when residues are harvested and removed from the field. The values shown in Table 3 are for a specific yield. The greater the yield, the greater the nutrient loss when residues are removed.

Crop residues on the soil's surface reduce both wind and water erosion. The information in Table 4 reflects potential soil losses from **wind** erosion as related to use of crop residues. The data suggest that wind erosion need not be a serious problem in Michigan, providing crop residues remain on the field's surface. Furthermore, standing crop residues, such as the stubble left following harvest of grain and then spring-plowed or when no-till methods are used, are very effective in reducing soil losses. The data show that even stubble from corn harvested for silage reduces soil losses from wind erosion.

In contrast, where fields are fall plowed, some residues, if not all, are buried. The soil is then exposed to winter and spring winds. Chisel plowing in the fall covers less residue than moldboard plowing, thus leaving the fields somewhat rough and therefore more resistant to erosion.

The information in Table 4 does not consider a major effect of wind erosion—that of sand blasting and destruction of small seedlings shortly after emerg-

Table 6 — Draft and draw bar horsepower (DBHP) requirements per foot of width for selected farm implements related to effective tillage.*

Operation	*Speed*	*Draft*	*DBHP*	*DBHP*
	mph	*Lb/Ft*	*Per Ft*	*Hrs/Acre*
Shred stalks	5.0	200	2.7	5.7
Moldboard plow				
Coarse texture soil	4.5	450	5.4	12.5
Medium texture soil	4.5	750	9.0	21.0
Fine texture soil	4.5	1050	12.6	29.3
Tiller behind plow	4.5	260	3.1	7.3
Chisel plow	4.5	720	8.6	20.0
Tandem disc				
1st pass, plowed	4.0	340	3.6	9.5
2nd pass, plowed	4.5	280	3.4	7.4
Corn stalks	4.5	250	3.0	6.6
Heavy duty disc	4.5	620	7.5	17.5
Spring tooth harrow	5.0	720	3.6	8.0
Field cultivator	5.5	240	3.5	6.7
Roller-packer	6.0	140	2.4	4.0
Mulcher packer	5.0	280	3.7	7.8
Row crop planting				
Conventional	4.5	385†	4.6†	6.3†
No-till	4.0	540†	5.8†	8.6†
Grain drill	4.0	115	1.3	3.6
Rotary hoe	7.0	110	2.3	3.0
Cultivate	3.5	150	1.4	4.4
Spray	7.5	40	0.8	1.6

**Data from R. G. White, M.S.U. Agr. Eng. Facts No. 39 (1975) and No. 41 (1975).*

†Per 30-inch row—not per foot of width.

Table 5 — Potential soil losses from water erosion in cornfields harvested for grain or silage in central Michigan (6% slope).*

Dominant profile texture	*Soil mgt. group*	*Potential yield Grain*	*Potential yield Silage*	*Slope length*	*Potential soil loss (T/A/Yr): Standing residue†*	*Chisel plow‡*	*Moldboard plow‡*	*Harvest for silage†*	*Tolerable loss*
		Bu/A	*T/A*	*Ft*					*T/A/Yr*
Clay loam	1.5a	105	17	100	4	5	11	7	3
Clay loam	1.5a	105	17	200	6	7	15	10	3
Clay loam	1.5a	105	17	300	8	9	19	13	3
Clay loam	1.5a	105	17	400	9	10	22	15	3
Loam	2.5a	110	17	100	6	7	15	10	3-4
Loam	2.5a	110	17	200	9	10	22	15	3-4
Loam	2.5a	110	17	300	11	13	27	18	3-4
Loam	2.5a	110	17	400	13	15	32	21	3-4
Sandy loam	3a	95	16	100	5	6	13	9	4
Sandy loam	3a	95	16	200	8	9	19	13	4
Sandy loam	3a	95	16	300	10	11	23	15	4
Sandy loam	3a	95	16	400	11	12	27	18	4

**Assume: R Rainfall value = 95, continuous corn, minimum tillage. Chisel plow use results in 50% cover. Moldboard plow leaves soil bare for up to six months.*

†Spring plow.

‡Fall plow.

ence. At times, sand movement is enough to cut off small plants completely, even where potential soil loss may be less than one ton per acre.

The value of crop residues in reducing **water** erosion (Table 5) is many times greater than in the case of wind erosion (Table 4). The potential soil losses may seem high, but they are in general agreement with those values obtained from two research watersheds at East Lansing and those from the old erosion demonstration plots of the Soil Conservation Districts.

The effect of tillage implements, time of plowing, and use of crop residues is similar to that described for wind erosion in that the longer the time and the greater the amount of residue left on the soil surface, the more effective these factors are in keeping the soil in place.

Tillage and Crop Residue Management

Tillage may be necessary for a number of reasons including the utilization of crop residues. The best decision on tillage implements and crop production methods can be made only after an evaluation of the nature and amount of residue, the compactness of the soil and the conservation needs of the field.

Complete incorporation of residue into the soil is a good method of controlling insects or diseases. The moldboard plow is better than any other tillage implement for this purpose, but unfortunately the plow has a higher energy requirement per area worked than any other primary tillage tool.

Under other circumstances, where soil erosion is a likely problem or where the soil is deeply compacted, the chisel plow may be a good choice. It is superior to the moldboard under these conditions because it leaves approximately half the crop residue on the soil surface while loosening the soil to approximately the same depth as a moldboard plow. This condition reduces soil erosion losses and aids in reducing water evaporation losses.

Where soil erosion is a potential problem and with soil types that drain rapidly and have a relatively stable structure, no-till methods are best. With all crop residues on the soil surface, both wind and water erosion is reduced to a minimum.

Implement Energy Requirements

Energy requirements (draft and drawbar horsepower) for various tillage implements are given in Table 6. The values represent average conditions and vary, depending upon implement adjustment, speed at which the implement is used, tillage depth and soil conditions.

No attempt is made here to evaluate draft requirements for deep tillage, such as subsoiling, because requirements are variable, depending primarily upon soil moisture levels, kinds of soil and tillage depth.

Table 7 — Tractor PTO horsepower requirements per chisel plow shank for different soil texture.*

		Surface soil texture		
Depth	*Speed*	*Sandy loam*	*Loam*	*Clay*
inch	*mph*	*PTO horsepower*		
6	4	2.5	5.0	8.0
	5	3.0	6.0	10.0
8	4	3.5	6.0	11.0
	5	4.5	8.0	14.0
10	4	4.5	8.0	14.0
	5	5.5	10.0	17.0
12	4	5.5	9.5	16.5
	5	6.5	12.0	20.5

From: "Tips on Performance," Ford Tractor Co.

Table 8 — Fuel requirements for farm tractors.*

Horsepower class Max. observed PTO H.P.	*Fuel consumption† Gasoline*	*Diesel*
	Gal/hr	
20-39	2.7	2.0
40-59	4.2	2.9
60-79	5.8	4.0
80-99	7.6	5.3
100-124	—	6.6
125-149	—	7.9
150-174	—	9.2
175-200	—	10.5

**White, R. G. (1974). Fuel requirements for selected farming operations. Michigan State Univ. Ext. Bul. E-780.*
†Operating at 75 percent maximum load.

Table 9 — Estimated fuel requirements for selected field operations related to tillage.*

	Diesel fuel (gal./A†)		
Operation	*Low*	*Average*	*High*
Stalk shredder	0.42	0.63	0.95
Moldboard plow	0.91	1.82	3.64
Chisel plow	0.56	1.12	2.24
Rotary plow	1.22	2.10	3.44
Heavy tandem disc	0.39	0.77	1.54
Standard tandem disc			
Plowed soil—first time	0.32	0.63	1.26
Plowed soil—second time	0.25	0.49	0.98
Cornstalks	0.28	0.56	1.12
Spring tooth harrow	0.21	0.42	0.84
Spike tooth harrow	0.14	0.28	0.56
Field cultivator	0.35	0.70	1.40
Planting 40-inch rows	0.32	0.49	0.74
Planting 30-inch rows	0.42	0.63	0.95
Grain drill	0.25	0.35	0.53
Potato planter	0.63	0.95	1.40
Vegetable planter	0.63	0.95	1.40
Transplanter	0.84	1.26	1.89
Cultivation—first	0.28	0.42	0.63
Cultivation—second	0.25	0.35	0.53
Rotary hoe	0.11	0.18	0.28
Sprayer	0.07	0.11	0.17

**Calculated from data from R. G. White, Michigan State Univ. Ext. Bul. E-780.*
†For gasoline, multiply by 1.4; for L.P. gas, by 1.7.

For single shaft subsoilers, values as low as 500 and as high as 1,200 pounds have been observed on Michigan soils.

Speed and Depth

Obviously, the size of a tillage implement should be matched to the power of a tractor. Not so obvious is that power requirements are dependent upon kind of soil and tractor speed. The chisel plow is used to illustrate this. The information in Table 7 shows that tractor power takeoff horsepower (PTO H.P.) requirements increase with tillage depth and the amount of clay in the soil. The values shown represent requirements for one shank of a chisel plow equipped with 2-inch reversible shovels. Power requirements vary from those shown when using twisted shovels or sweeps.

Fuel Requirements for Tillage

Fuel requirements can be evaluated in several ways. Less diesel fuel is used per hour than gasoline. Obviously, the greater the PTO, the greater the fuel consumption for any given time period (Table 8).

Root and seedbed preparation make heavy demands upon fuel. Only a few years ago, the standard recipe in Michigan was to moldboard plow in the spring, double disk twice, drag harrow twice, and then plant.

There is no standard recipe in Michigan today. A recent survey of 100 navy bean farmers showed that 34 plowed in the spring and 61 plowed in the fall. Five did not plow. Sixty-two used field cultivators one or more times, and one used it six times. The disc was used on 56 farms. These tillage treatments were made before herbicides were applied. Many farmers made two tillage treatments to incorporate chemicals into the soil. Thus, there was great variation in methods and, therefore, in fuel consumed.

Ranges of fuel requirements for several tillage tools are reported in Table 9. The fuel used on a given farm varies not only with kind of tillage tool but with the age, kind and condition of the tractor, tire condition, kind of soil, condition of soil, depth of operation, and adjustment of the equipment. The data are relative to the fuel used for different implements; i.e., more fuel is consumed when moldboard plowing than when chisel plowing, assuming similar tillage depth.

Tillage Systems Compared

The fuel requirements for planting corn with nine tillage systems are shown in Table 10. In analyzing the systems outlined, it may seem that several of the systems are extreme. The systems are all realistic under the proper circumstances. All were designed to illustrate that an extra treatment or two consumes extra fuel and if a reason for the extra operation is not obvious, it probably should not be done.

The data suggest where reducing or combining operations may be logical. Some Michigan crop producers have successfully substituted the chisel plow for the moldboard, but two chiseling operations require more fuel than one moldboard plowing. In addition, stalk shredding or dicing is usually necessary before using a chisel plow.

An increasing number of farmers now successfully use no-till methods which represent the most fuel-conserving system. For details on successful no-till

Table 10 — Estimated diesel fuel requirements for planting corn under 9 tillage systems.

Tillage operation	*Tillage system* 1	2	3	4	5	6	7	8	9
	Conventional tillage		*Reduced tillage*	*Plow and plant*	*Plow-plant*	*Chisel plow*	*Tandem disc*	*Rotary plow*	*No-till*
	Gal/A								
Moldboard plow	1.82			1.82					
Plow with trailing tool			2.10						
Chisel plow		1.12							
Chisel plow		1.12				1.12			
Disc harrow	0.63	0.63					0.77		
Disc harrow	0.49	0.49					0.49		
Drag harrow	0.42	0.42				0.42	0.42		
Drag harrow	0.28	0.28							
Spray*	*a*	0.11	*a*	*a*	*a*	*a*	*a*	*a*	0.11
Rotary plow								2.10	
Plant†	0.63	0.63	0.63	0.63		0.63	0.63	0.63	0.63
Plow-plant‡					2.00				
Total	4.27	4.80	2.73	2.45	2.00	2.17	2.31	2.73	0.74
No. of operations	6	8	2	2	1	3	4	2	2

***a = bandspray with planter.**
†30-inch rows
‡42-inch rows

systems, refer to MSU Extension Bulletins E-904, E-905, E-906, E-907, and E-956.

Tips on Energy Conservation

Energy requirements for tillage can be reduced in several ways on most farms. **First,** if the reason for tillage is not evident, don't do it. This represents the greatest possible saving in both energy and time. The most common reasons for tillage include (1) loosening a compacted soil, (2) killing weeds, insects and diseases, (3) incorporating fertilizer and lime, (4) effectively using livestock manure, (5) reducing soil erosion, (6) incorporating pesticides, (7) preparing for harvest by moving soil with the cultivator into the row, and (8) crop residue incorporation.

Second, don't till deeper than necessary for the job. If the purpose of moldboard plowing is to destroy weeds, insects, or diseases, don't plow any deeper than necessary to cover all crop residues completely.

Third, be certain your tractor engine and implements are properly adjusted and in good condition. This is especially important with units requiring high horsepower inputs because fuel conservation centers around **care, adjustment** and **operation** of tractors and equipment used.

Improper adjustment of moldboard plows increases the draft. An extra 15 percent of fuel may be wasted without adversely affecting the quality of plowing. However, gross maladjustment results in reduced quality of plowing and, therefore, requires additional fuel and time for extra secondary tillage.

Fourth, plowing speed directly affects fuel consumption. Recent models of moldboard plows are designed to be used at 4.0 or 4.5 mph. Excessively high-speed plowing moves soil sidewise a greater distance than necessary, resulting in increased draft and, therefore, fuel use.

Fifth, properly maintain all tractor and power units. Dirty or faulty spark plugs can increase fuel consumption up to 15 percent. An improperly tuned engine consumes extra fuel.

Sixth, don't overload the tractor, since this also results in excessive fuel use. When using a large tractor for light work, shift up to a higher gear, and then throttle back the engine to a lower rpm. **Never** throttle back to less than 50 percent of the rated rpm, and **never** throttle back to the point where the engine appears to be "laboring" or "lugging" to handle the load. This statement does not apply to work requiring the use of the power takeoff shaft.

And finally, assuming that gasoline and diesel fuel supplies are equally available, the use of diesel tractors results in some fuel saving. Three gallons of gasoline are required to plow the same area as would be plowed with two gallons of diesel fuel.

SUMMARY

Large amounts of agricultural residues are produced each year in Michigan, and when returned to the soil are a valuable supply of plant nutrients and soil organic matter, and have a stabilizing effect upon soil structure. When correctly used, they also reduce soil losses by wind and water erosion.

Incorporating crop residues into the soil requires considerable energy. Requirements for plowing may be in excess of 600 pounds per foot (width) of soil tilled and require up to 2 gallons of diesel fuel per acre.

An analysis of nine tillage systems used to produce corn showed that the number of separate field operations can vary from 1 to 8 and that total diesel fuel consumed can vary between 0.6 and 4.5 gallons per acre. The greatest savings are made when a specific operation can be eliminated. This is where the greatest potential lies for energy conservation in crop production today.

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