Farm Energy IQ

Saving Energy in Field Operations

INTRODUCTION

Field operations consume 30% or more of the energy used in all U.S. crop and livestock production, and account for the majority of liquid hydrocarbon fuel use in agriculture. New technology, particularly that for diesel engines, power transmissions, and sensors/controls, has improved agricultural equipment efficiency. Other recent innovations in agronomy, designed to help cope with the changing balance of energy resources, can help lower energy consumption in field operations. This fact sheet presents an overview of how farmers can reduce fuel use in field crop operations.

Table 1 lists benchmarks for fuel use in various field operations. These data come primarily from Michigan, along with data from several other states, and are from the late 1970s. Unfortunately, no recent comprehensive studies are available. The values represent measured fuel use with the 1970s-era equipment and agronomic practices, as observed in on-farm research and energy auditing. Today, we would expect lower fuel usage because more efficient power units and management practices are widely available.

QUANTIFYING FUEL USE

The simplest way to determine fuel use is to top off the fuel tank of a tractor, complete the operation, and then immediately top off the tank again, noting the quantity of fuel added. Divide the gallons of fuel added by the acreage to get a value of gallons per acre (gal/acre) for the operation. For the most accurate results, quantify fuel use over as large an area as possible to reduce error in measuring the volume of fuel recognizing that it can be difficult to accurately determine fill level and that temperature can impact the fill volume.

Once you have a value of gal/acre for your field operation, you can compare this to the benchmarks in Table 1 to determine if your operation is on par with, or more or less energy efficient, than similar operations. Variations in agronomic practices, weather, and soil properties can cause significant variation in actual fuel use, even when best practices are implemented. However, if your fuel use in gal/acre is 10% or more above the benchmark for a similar operation, then you should try to determine the cause and remedy it.

Table 1. Diesel Fuel Consumption in Gallons per Acre for Field Operations

Operation	Michigan Farm Energy Audit * Average	Range High	Range Low	Average from other States**
Primary Tillage				
Moldboard Plow	1.81	3.50	0.90	1.87
Chisel Plow	1.36	3.50	0.80	1.09
Offset Disc	1.11	1.20	0.90	0.97
Subsoiler	1.54	2.30	1.10	1.56
Secondary Tillage				
Disc	0.93	3.30	0.30	0.65
Field Cultivator	0.78	1.80	0.30	0.68
Spring Tooth Harrow	0.73	1.80	0.20	0.48
Fertilizer/Chemical Application				
Pesticide Spraying	0.33	2.90	0.10	0.13
Chemical Incorporation	0.80	1.10	0.50	----
Spreading Fertilizer	0.30	0.50	0.10	0.19
Knife in Fertilizer	0.58	1.30	0.20	1.05
Planting				
Row Crop Planter	0.51	1.00	0.20	0.54
Grain Drill	0.56	2.31	0.10	0.33
Potato Planter	0.95	1.90	0.90	0.95
Broadcast Seeder	0.28	1.12	0.10	0.15
No-Till Planter	0.68	----	----	0.43
Cultivation				
Cultivator	0.39	1.90	0.10	0.42
Rotary Hoe	0.23	0.70	0.10	0.21
Forage Harvesting				
Mower/ Conditioner	0.72	1.80	0.30	0.66
Rake	0.46	1.26	0.20	0.24
Baler	0.65	2.90	0.10	0.69
Large Round Baler	0.80	---	---	---
Forage Harvester/Green Chop	1.57	2.00	0.20	1.87
Corn Silage Harvester	3.14	6.70	1.70	2.69
Crop Harvesting				
Small Grain or Bean Combine	1.23	1.80	0.70	1.01
Corn Combine	1.51	2.20	0.70	1.37
Corn Picker	1.84	3.00	1.20	1.10
Pull & Window Beans	0.52	1.10	0.30	0.34
Beet Harvester	1.37	1.90	0.90	1.91
Topping Beets	0.83	1.20	0.40	1.47
Potato Harvester	2.69	---	---	1.73
PTO Operated (gal/hr)				
Forage Blower	2.19	6.20	0.90	
Irrigation	3.41	4.40	1.10	
Grinding	3.84	6.90	2.20	

**Adapted from Helsel, Z. and T. Oguntunde. 1985. Fuel Requirements for Field Operations with Energy Saving Tips. In: Farm Energy Standards, Worksheets, Conservation C. Myers(ed). Michigan State University, East Lansing, MI*
***Iowa, Pennsylvania, Nebraska, Missouri, New York, Ontario, Oklahoma, North Dakota*

TRACTOR SELECTION AND MAINTENANCE

For tractors already owned, proper maintenance is imperative. Follow the owner/operator manual for optimal efficiency and safety. Consider tractor fuel efficiency (hp-hrs/gal and gal/hr) when comparing new or used tractors for purchase. Reports from the Nebraska Tractor Test Laboratory include fuel efficiency testing results (http://tractortestlab.unl.edu/testreports).

OPERATION STRATEGIES FOR FUEL EFFICIENCY

One of the most important concepts in driving a tractor efficiently is to use the appropriate gear ratio and engine RPMs. For optimal efficiency with manual transmission, use the highest gear ratio that gives the correct speed, and that will allow the engine to run without producing visible black smoke/soot. An RPM drop of greater than 10% of rated speed is also indicative of overloading. In cases in which it is necessary to use a tractor to pull an implement much smaller than it is capable of pulling, it can be effective to use a higher gear and lower RPM.

Many newer tractors have Continuously Variable Transmissions (CVTs or similar names) that eliminate the need to manually select a gear and RPM. These transmissions conserve energy by allowing the engine to run in its peak power band at all times, helping to compensate for momentary increases in engine demand when running over rough terrain or hills or through heavy soils. Hydrostatic Drive (HD), a third type of transmission is narrowly useful for situations in which it is necessary to vary speed within the field or load shuttling, but an HD transmission is usually a detriment to efficiency because it converts more mechanical energy to waste heat than does a gear drive or CVT.

Gear Up/Throttle Down

Use highest gear and lowest RPMs in older tractors (no visible soot)

Another good general energy-saving strategy is to keep a well-maintained small tractor on the farm for light duty tasks. Many bucket loaders and compact utility tractors are capable of performing mowing, spraying, and spreading operations. Because tractors rely on weight for traction, they are designed such that there is a direct relationship between the weight of the machine and its rated power. In cases in which load is significantly less than rated horsepower output of the tractor, energy is lost to the rolling resistance of the unnecessary weight. Thus, in general, more energy is wasted with a large tractor than it is with a smaller one. Therefore, it is generally best to use the smallest tractor that can do the job. On farms which produce many different crops each year, or which produce a large number of crops requiring different field operations, having tractors of several different sizes can be a good strategy for ensuring that every specialized implement matches a tractor of the right size.

FUEL CONSERVATION FOR ENGINE AND POWERED IMPLEMENTS

Where PTO-driven equipment is used, it is helpful to have a means of varying the gear ratio between the engine and PTO shaft, so that proper shaft speed can be maintained at lower, more energy efficient engine speeds. Many tractors built since 1990, especially larger ones, have different PTO gear ratios which can be selected. This feature is especially useful for situations in which it is necessary to use a large tractor to operate a small PTO-driven implement, or where the power demands of the PTO-driven implement will vary greatly throughout the field. Another technique is to modify the internal power transmission of the implement. Many PTO-driven implements use pulleys or sprockets to transmit power from the input shaft to the driven part, and when these pulleys differ in size, switching their positions may allow lower input-shaft speeds. Mowers and spreaders can usually be geared down in this manner while preserving acceptable performance. Additionally, many European-manufactured implements originally designed for 1000 RPM input shaft speeds may be geared differently by some U.S. manufacturers, and can benefit from installation of correctly sized pulleys.

In general, fuel is conserved when implements are powered by their own engines, rather than by the PTO of the tractor pulling them. This is because the dedicated engine can be sized, geared, and tuned for the specific needs of the implement. Additional savings result because the tractor engine does not need to be held at the RPM necessary to turn the PTO at a constant speed. Stationary engines (i.e., pony engines) factory-installed on implements are generally optimized for efficiency. To retain their efficiency, stationary engines must be properly maintained.

TRACTOR SIZE AND SPEED

A good rule of thumb for tillage equipment, or other equipment in which the primary demand of the tractor is to create a pulling force rather than PTO rotation, is that the tractor should be able to easily pull the equipment at 3 to 8 mph. If the tractor can easily pull the implement faster than 8 mph under normal conditions, then the tractor is probably too large for that operation. Spraying, cultivating, and harrowing are often performed with tractors that are significantly larger than necessary. As a result, fuel savings can be bountiful if a smaller tractor is used with these implements.

In general, the speed of a field operation is inversely correlated to its fuel efficiency. As an example, at higher speeds more energy is lost to flinging soil and to rolling resistance. As speed doubles, the energy lost to the soil being displaced by the tillage implement can quadruple. Lowering speed is not, by itself, a worthwhile strategy for reducing fuel usage, but if speed needs to be kept above 8 mph to make efficient use of a large tractor, than using a smaller tractor will usually decrease fuel usage.

OPTIMIZE WHEEL SLIP

On loose soil, tractors are designed to be most efficient when wheel slip is between 10 and 15%.

When wheel slip is greater than 15%, too much energy is expended shearing the soil which contacts the ribs, and in spinning the tire. When wheel slip is less, too much energy is expended in compacting the soil in front of the tire by carrying the heavier wheel load from ballasting. On hard surfaces or firm soil, wheel slip should be less than 10%.

To measure wheel slip, mark a drive tire conspicuously, where it can be seen from the operator's station, and count the number of revolutions in one field pass as the operation is in progress. Measure the circumference of the tire, around the major diameter of the ribs, and multiply by the number of revolutions. Divide this resulting value by the length of the field pass. If the result is more than 1.15, excessive wheel slippage is occurring; if the result is less than 1.10, then too little wheel slippage maybe occurring. The formula below shows what wheel slip should be:

$$1.10 < \left(\frac{\text{Wheel Circumference (ft) x Number of Rotations}}{\text{Field Pass Length (ft)}} \right) < 1.15$$

Add ballast or weight to drive tires to correct excessive wheel slip; and remove weight to correct for inadequate slippage. On 4WD tractors, if the front and rear tires are at different stages of wear and, hence, have different circumferences, each wheel may turn at slightly different speed and cause energy loss through friction. Replace either axle's tires with tires at the same stage of wear to reduce this loss dramatically. Be sure to use tires and rims of the size specified by the tractor manufacturer. Likewise, 4WD tractors present another unique set of efficiency dynamics. They usually save energy relative to 2WD tractors during primary tillage by reducing wheel slip and soil compaction. However, for secondary tillage and most field operations conducted after tillage, 4WD tractors may waste energy due to unnecessary weight and transmission use caused by gearing of the front axle and transfer case. This transmission loss can be nearly eliminated by disengaging the front axle when not needed. Only engage the front axle when wheel slippage at the rear axle is excessive, or when the front tires sink significantly in loose soil.

In recent years, tractors that have a track in place of either the rear wheels, or both front and rear wheels, have become increasingly popular. These tractors are less energy-efficient than wheeled tractors, due to the energy lost to moving and bending the track through the rollers, but in some operations they may lead to energy savings because of better tractive efficiency. Keep the track tightened and lubricated to factory specifications to minimize energy losses.

TILLAGE OPTIONS

Reducing the number of trips over a field reduces fuel use per acre. Reduced or no-till practices can be a great benefit to fuel conservation, leading to as much as a 75% savings in fuel used for field preparation (see Table 2 for examples). No-till, in particular, may require other energy investments, such as those for additional pesticides, but those additional investments amount to less than a gallon per acre equivalent of fuel.

Table 2. Fuel Consumption in Tillage Operations

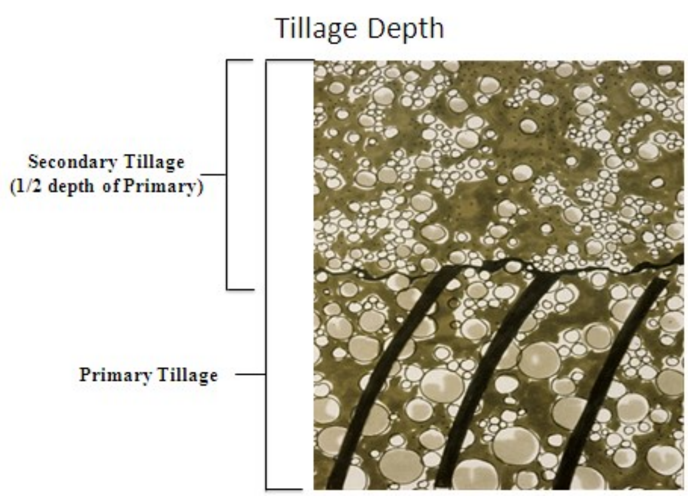
Tillage Systems					
----------------Diesel Fuel Gal/A----------------					
Traditional		**Reduced Tillage**		**No-Till**	
Plow	1.8				
Disc	.9	Chisel	1.4		
Disc	.9	Disc	.9		
Drag	.7	Drag	.7		
Plant	.5	Plant	.5	Plant	.6
Spray	.3	Spray	.3	Spray	.3
Total	**5.1**	**Total**	**3.8**	**Total**	**0.9**

Even with conventional tillage, savings can be achieved through good practices. Soils are often tilled more than is necessary for good aeration and soil health. Instead of disking or harrowing twice, for example, pull a small harrow or scarifier behind a disk and make a single pass. Other effective ways of combining field operations are pulling a cultipacker or sprayer behind a planter. Having equipment powered by a dedicated engine rather than by the tractor's engine is helpful in this respect.

Reduced tillage leads to not only energy efficiency in the operation, but also to a reduced need for future energy inputs because of reduced compaction (higher draft requirements are needed to break compacted soils) and wear on machinery. Try reducing the number of individual operations used to prepare fields as long as proper seed beds can be developed. An effective way to reduce energy inputs to primary tillage is to use a chisel plow where possible. Compared to moldboard plows, chisel plows require as much as ½ gallon per acre less to operate. Chisel plows have the added benefit of reducing future tillage needs because they do not create a plow pan that needs to be compensated for in management practices. Chisel plows may also reduce erosion because they leave more residue on the field surface. Whatever tillage tool is used, it should be properly adjusted to reduce draft and, thus, fuel consumption. Proper adjustment is particularly important with moldboard plows.

TILLAGE DEPTH

Depth of tillage is an often-overlooked factor in energy usage. As a rule, for every 1-in. increase in the depth of moldboard plowing, there will be an accompanying 0.15 gal/acre increase in fuel usage. There is usually little benefit to performing secondary tillage at a depth greater than half the depth of primary tillage or previous secondary tillage. The purpose of most secondary tillage operations is to produce a firm seedbed in the upper couple of inches and not a compacted soil profile. Shallow secondary tillage also maintains good aeration for root growth and may also reduce water loss and compaction, leading to better absorption and retention of water with less runoff.



FORAGE EQUIPMENT FUEL SAVINGS

Other non-tillage tools such as hay balers differ in horsepower requirements (and, hence, fuel consumption), to do similar work. For example, a big round baler may require up to 40 hp less than a big square baler for the same weight of hay. Having sharp knives and blades on forage harvesting equipment can also make a sizable impact of fuel use and provide for better cut forages.

FIELD EFFICIENCY AND CROP CONDITIONS

Field efficiency is the ratio of time spent in the field doing measurable work to time spent on non-productive activities such as turning and travel to and within the field. As a rule, the larger a field is, the higher is the field efficiency. You can achieve a higher field efficiency ratio in smaller fields by combining fields (typically by eliminating hedgerows) and making fields as long and narrow as possible. Especially with smaller fields, it is very important, where possible, to keep the field corners at right angles, to reduce the turning time needed to till somewhat triangular or odd-shaped areas.

Controlled wheel traffic is a strategy for managing tillage paths in which the tractor is driven in the same track every time it is run in the field. This technique reduces the total area of soil compaction, leaving only narrow compacted strips. Energy waste due to wheel slip on loose soil is reduced with controlled wheel traffic because tracks are firmer. Crops usually perform better under such practices; however, the technique may exacerbate drainage or runoff problems in the compacted strips of the field.

Crop conditions at the time of harvest can also influence energy inputs. In general, crops and fields should be as dry as possible at the time of harvest, both because wet crops are harder to move and because wet soil leads to poor traction and compaction. Harvesting drier crops has the added benefit of reducing inputs to post-harvest crop drying. Running less stover/residues through the combine is also helpful, for example, harvesting higher up from the soil surface on corn and cereal grains can reduce fuel consumption and often leads to cleaner grain.

OPTIMIZING FUEL HANDLING EFFICIENCY

Lastly, it is important to handle and store fuels properly. Storage tanks should be painted white or metallic gray and placed out of direct sunlight to minimize fuel evaporation. Keeping portable fuel cans in a cool place is also helpful. Fuel cans which contain leftover fuel after the season will benefit from using additives to keep fuel from spoiling due to water absorption or fuel breakdown. Lastly, using proper equipment, capping, and other devices will help reduce losses during storage, transfer and filling.

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Acknowledgement: C. McKittrick for initial draft of text

This project supported by the Northeast Sustainable Agriculture Research and Education (SARE) program. SARE is a program of the National Institute of Food and Agriculture, U.S. Department of Agriculture. Significant efforts have been made to ensure the accuracy of the material in this report, but errors do occasionally occur, and variations in system performance are to be expected from location to location and from year to year.

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