A tractor is an investment in power. It has the ability to complete a certain amount of work within a specific period of time. The more effective a tractor work during this time period, the more economical the cost of the tractor will be.

EFFECTIVE TRACTOR USE

PART V

12. FUEL USAGE AND SAVINGS

CHAPTER OBJECTIVES:

- ***To introduce the reader to the factors that influence the demand for fuel;***
- ***To describe in what way the field operations require fuel;***
- ***To explain how fuel can be used more effectively;***
- ***To discuss fuel saving ideas.***

The amount of fuel used for field operations depends on many factors, including correct tractor-implement matching, proper tractor ballasting, condition of the tractor and implements, depth of tillage, idle time and soil type or condition. The tillage practices used for a particular crop will be a major factor in the amount of fuel needed for a complete production cycle and will also lead to peak demands for fuel during certain months of the year.

The global demand for fossil fuel is always on the increase. The resources however, are limited and unless a suitable alternative is found very soon, fuel will increasingly become scarce and fuel prices will also increase substantially in the future. The farmer should therefore use fuel in the most effective way to enable him to apply his machinery in an economical way.

12.1. DEMAND FOR FUEL

Peak demands for gasoline and diesel fuel occur at various times of the year. The following two graphs represent the Nebraska agricultural gasoline and diesel fuel demands for a calendar year.

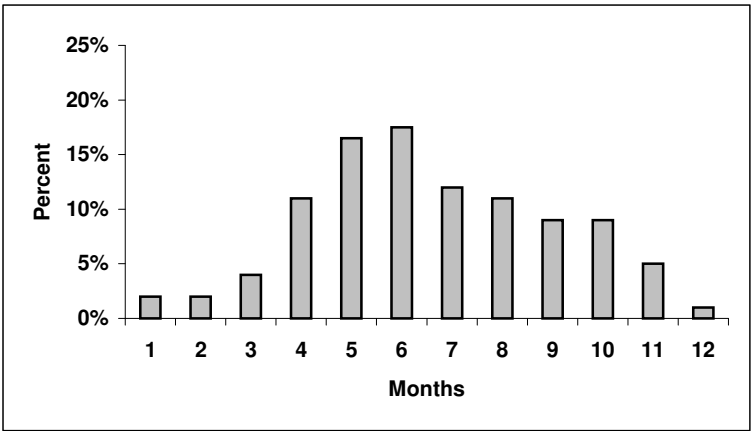

FIGURE 12.1: DIESEL FUEL DEMAND FOR FIELD OPERATIONS

The primarily spring tillage and planting takes place during May and June. According to Figure 12.1, these months are therefore the peak demand months for diesel fuel.

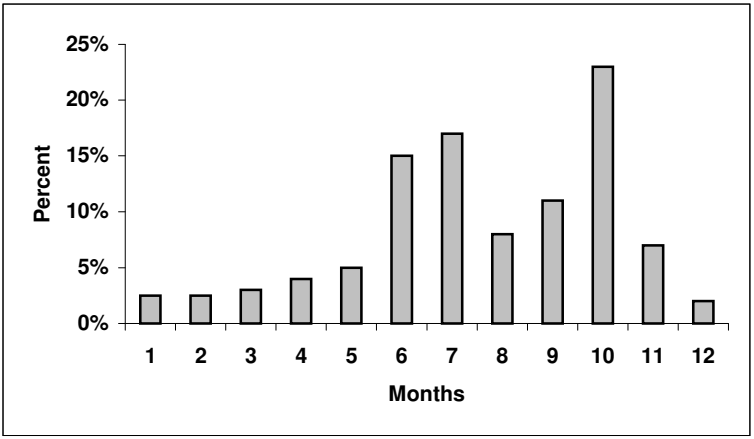

FIGURE 12.2. GASOLINE DEMAND FOR FIELD OPERATIONS

October is the peak demand month for gasoline because of the use of gasoline-powered combines. June and July are also high demand months due to a predominance of gasoline-powered haying equipment. For a particular farm, the timing and amount of fuel required will depend on the cropping practices and equipment used.

12.2. REQUIRED FUEL FOR OPERATIONS

Good estimates of fuel requirements are necessary for planning purposes. If fuel use records are available and reflect the soil conditions and management practice for a particular farm business, they should be used. Although it is possible to work out farm fuel requirements quite accurately, the following guidelines, explained in Chapter 9, can be used if specific fuel use records are not available:

- 0.30 litres per kW-hour at 60% draft for high draft requirements
- 0.35 litres per kW-hour at 45% draft for medium draft requirements
- 0.40 litres per kW-hour at 35% draft for low draft requirements

12.2.1. FUEL USE FOR FIELD OPERATIONS

If specific records are not available, average fuel use values presented in this section can also be used. The data were derived from a two-year study involving fuel usage of farmers throughout Nebraska. Average diesel fuel use values for common field operations are shown in Table 12.1.

TABLE 12.1: AVERAGE DIESEL FUEL USE

Operation	Row Crops Gal/A	Wheat and fallow Gal/A	Row Crops L/ha	Wheat and fallow L/ha
Disking	0.75	0.75	7.02	7.02
Field Cultivating	0.76	0.44	7.11	4.12
Chisel Plowing	1.16	0.62	10.85	5.80
Moldboard Plowing	2.24	1.36	20.95	12.72
Sweep Plowing	-	0.74	-	6.92
Springtooth Harrowing	0.66	0.55	6.17	5.14
Roller Pack	0.77	-	7.20	-
Planting				
Drilling	-	0.39	-	3.65
Lister	0.51	-	4.77	-
Rotary Bed	1.37	-	12.81	-
Surface	0.50	-	4.68	-
Till-Plant	0.60	-	5.61	-
Weed Control				
Cultivating	0.43	-	4.02	-
Rodweeding	-	0.54	-	5.05
Rotary Hoeing	0.25	-	2.34	-
Spraying	0.21	-	1.96	-
Harvesting				
Chopping silage	1.77	-	16.56	-
Combining (self propelled)	1.22	0.72	11.41	6.73
Sugar beets	1.54	-	14.40	-
Miscellaneous				
Chopping stalks	0.52	-	4.86	-
Ditching	0.49	-	4.58	-
Knifing Fertilizer	0.59	0.63	5.52	5.89

(To convert to gasoline, multiply by 1.42)

As a general rule, fuel use for wheat and fallow operations is less than that of row-crops (corn, sorghum, and soybeans). This is due mainly to shallower tillage depths and lighter soil types. The values presented are for a predominate loam soil. For lighter soils, sandy and sandy loams, the values must be reduced by 15 to 20% for primary tillage and 10 to 15% for secondary tillage or cultivation. For heavier soils, like clay loams or clay, the values should be increased by 35 to 45% for primary tillage and 15 to 20% for secondary tillage operations.

12.2.2. FUEL USE FOR HAYING OPERATIONS

Average diesel fuel use values for haying operations are given in Table 12.2.

TABLE 12.2: AVERAGE DIESEL FUEL USE FOR HAYING

Operation	Gal/A	L/ha
Mowing	0.57	5.33
Windrowing	0.59	5.52
Raking	0.33	3.09
Baling	0.47	4.40
Stacking	0.85	7.95
Chopping silage	0.97	9.07

The type of soil will not have any effect on the amount of fuel that is used for these operations.

12.2.3. FUEL USE FOR TRANSPORTING

Fuel use for transporting harvested crops and hay can also be estimated, as shown in Table 12.3.

TABLE 12.3: FUEL REQUIREMENTS FOR TRANSPORT

Commodity Hauling	First		Additional one	
	mile	kilometer	mile	kilometer
	Gal/A	L/ha	Gal/A	L/ha
Ear Corn	0.29	1.69	0.17	0.99
Shelled Corn	0.18	1.05	0.11	0.64
Soybeans	0.07	0.41	0.04	0.23
Small Grain	0.09	0.52	0.05	0.29
Hay, conv. bales	0.14	0.81	0.11	0.64
Hay, 1-ton stack	0.15	0.87	0.11	0.64
Hay, 3-ton stack	0.07	0.41	0.05	0.29
Haylage	0.2	1.16	0.2	1.16
Corn Silage	1.4	8.14	0.9	5.23

(Values are for trucks; if tractors and wagons are used, double the value.)
(To convert to gasoline, multiply by 1.42)

Fuel use values in all of the tables are given in diesel fuel gallons per acre or liters per hectare. The values are based on a per acre and per hectare basis and therefore vary because of the different yields from the various crops. If tractors and wagons are used for hauling, the fuel use values from the Table 12.3 must be doubled.

12.2.4. OVERALL FUEL REQUIREMENTS

The overall fuel requirements for a specific crop are summarized in Table 12.4.

TABLE 12.4: DIESEL FUEL USE ESTIMATION

	GALLONS			LITERS		
Operations in Sequence	**Fuel Use Gal/A**	**Area Acres**	**Total Gal**	**Fuel Use L/ha**	**Area Ha**	**Total Liters**
Knifing fertilizer	0.52	500	295	4.86	202	1117
Disking	0.75	500	375	7.02	202	1419
Disking	0.75	500	375	7.02	202	1419
Surface plant	0.5	500	250	4.68	202	946
Spray	0.21	500	105	1.96	202	397
Cultivate	0.43	250	108	4.02	101	409
Combine	1.22	500	610	11.41	202	2309
Transport (truck)	1.72	500	860	16.09	202	3255
TOTAL			**2978**			**11273**

A total of 500 acres or 202 hectares are planted to dry land corn. The production sequence is fertilizer application, two diskings, surface planting, spraying, and cultivation of half of the corn and finally, combine harvesting. The harvested corn is transported 15 miles (23 km) by truck to the elevator. According to Table 12.4, the annual diesel fuel requirement is 2,978 gallons when the fuel use for each operation is added together. This is equal to 11273 liters of diesel fuel required.

12.3. UTILIZING FUEL EFFECTIVELY

A tractor is an investment in power. It has the ability to complete a certain amount of work within a specific period of time. The more a tractor work to its full potential during this time period, the more economical the ownership cost of the tractor will be. As explained in a previous chapter, fuel cost amounts to 16% of total machinery cost for normal field operations. If the farmer can utilize the fuel more effective and even save on fuel usage, he can also make the operational cost more economical and save on machinery cost al together.

12.3.1. MAXIMUM POWER

The different costs, as explained in Chapter 9, for a John Deere 7510 tractor is summarized in Table 12.5.

TABLE 12.5: CALCULATION OF TRACTOR COST FOR A JOHN DEERE 7510

MODEL	**JOHN DEERE**		
DETAILS	**7510 MFWD**		
kW		85	
Hours per annum		500	
PRICE:	**Per kW**	**Total**	**Per hour**
Current list price	$ 823.53	$ 70,000.00	$ 14.00
Purchase price	$ 741.18	$ 63,000.00	$ 12.60
Remaining value after 10 years	$ 645.26	$ 54,847.27	$ 10.97
COST:	**Per kW**	**Per annum**	**Per hour**
Labor	$ 705.88	$ 60,000.00	$ 12.00
Ownership cost	$ 50.14	$ 4,262.31	$ 0.85
Maintenance cost	$ 4.75	$ 404.03	$ 0.81
Repair cost	$ 53.52	$ 4,548.92	$ 0.91
TOTAL COST	**$ 814.30**	**$ 69,215.26**	**$ 14.57**

According to Table 12.5, the purchase price of the specific tractor works out to be $741.18/kW. The annual cost to operate this tractor calculates to $814.30/kW. At an annual usage of 500 hours, the hourly cost is $14.57, without the cost of fuel. If the farmer uses this tractor at only 50% of the total power, the initial investment per kW will double and the annual cost per kW will also double. The most economical approach will therefore be to operate this tractor as close to its full power as possible. Doing as much as possible per hour or per kW will therefore save on tractor cost, according to Table 12.5.

Without fuel there will be no tractor power. As fuel supply increases, tractor power increases until maximum power is reached. At this point the engine will cut out if the fuel supply is increased even further. A typical tractor fuel consumption map is shown in Figure 12.3.

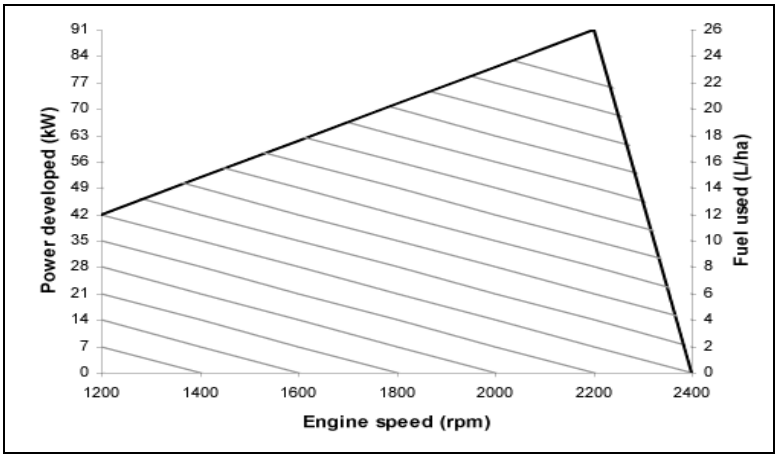

FIGURE 12.3: TYPICAL TRACTOR FUEL CONSUMPTION MAP

Increasing the engine speed from 1200 rpm to 2200 rpm causes the tractor power to increase from 42 kW to 84 kW where maximum power is reached. At this point about 24 liters of fuel will be used per hectare. Fuel usage is indicated as thin gray lines underneath the power/speed graph. If an effort is made to supply even more fuel beyond the maximum capacity of the tractor, the engine will cut out and there will be no power. Maximum power is seldom reached but this remains the point on which the tractor's power and therefore purchase price, is based.

12.3.2. PARTIAL LOADS

Tractors are normally purchased to complete that operation that requires the most power during the season. From an investment point, the tractor should therefore always works at maximum power. However, in many farming operations the tractor will be operating at well below maximum power like boom spraying and fertilizer spreading. There are also times when the tractor and implement are mismatched as a result of lighter soil conditions, recent updating of the tractor or when the implement has been sized with other considerations in mind.

When the tractor is inevitably operating well below maximum power, the farmer can take advantage of the situation to save time or fuel.

Gear Up and Throttle up

One option is to gear up and throttle up. Changing up a gear and travel faster can do this. When cultivating, this will result in increased pull or draft on the tractor but by working faster, the job will be done quicker, as can be seen in Table 12.6.

TABLE 12.6: INCREASED DRAFT AND FUEL CONSUMPTION BY DOUBLING WORKING SPEEDS WITH A RANGE OF IMPLEMENTS

	Draft at 75 mm depth*			
	At 6 km/h	At 12 km/h	Increase in	
Operation	Kg force per meter width		draft use (%)	fuel l/ha*
Disc plough	750	830	11	1.2
Offset discs	510	600	18	1.4
Scarifier	520	550	6	0.5
Chisel plough:				
- chisel points	450	570	27	1.8
- sweep points	580	800	38	3.3

* *Draft figures based on measurements made in a pasture paddock at Condobolin Agricultural Research and Advisory Station, Australia.*

** *Fuel consumption has been calculated for the average tractive conditions and assumes that a suitably sized tractor is used at each working speed.*

This option may not always be acceptable because of rough ground conditions, poor job finish, excessive equipment wear, risk of damage to equipment, or even operator safety. Excessive speed may also cause soil structural problems.

Gear Up and Throttle Down

Another option is to gear up and throttle down. This means change up to a higher gear and reducing engine speed so that the tractor maintains the same ground speed and thus, the same work rate. Because the same ground speed is

maintained, the pull on the tractor remains the same. The following general operating guidelines is applicable for gearing up and throttling down:

- Consider "Gear Up and Throttle Down" on light load operations (typically those requiring less than 65 % of full engine power).
- Stay within the engine rpm working range specified in the operator's manual.
- Select a faster gear to maintain travel speed and implement productivity while reducing engine rpm.
- Do not overload the engine. Check the engine response to the throttle setting and drawbar load.

A characteristic of diesel engines is that, up to a point, they maintain their pulling power when engine speed is reduced but operate in a more fuel-efficient area. This characteristic is used for gearing up and throttling down, as shown in Figure 12.4.

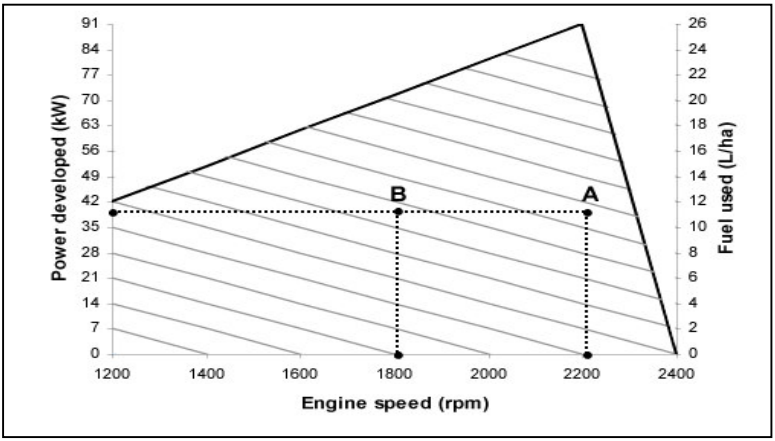

FIGURE 12.4: ADJUSTED TRACTOR FUEL CONSUMPTION MAP

When plotted on the tractor fuel consumption map, the tractor is working at 40 kW, low gear, high engine speed (2200 rpm) and is using just more than 10 liters of fuel per hectare at point A. As soon as it is geared up and throttled back at point B, the power stays at 40 kW but the engine speed drops to 1800 rpm. This causes the fuel usage to drop to 6 l/ha. The fuel saving is 4 liters per hectare and amount to 40% of normal fuel usage.

Care must be taken not to go too far with this idea. There are a few drawbacks with gearing up and throttling down. When engine speed is reduced, the reaction time of the tractor hydraulics will be slower and PTO speed is accordingly reduced. When PTO speed is reduced, the PTO-driven device may have unacceptable performance and reduced productivity. For some load conditions, reduced PTO speeds can reduce the PTO-driven unit's life and cause failure of drive lines. It is recommended to operate the tractor between the speed at which maximum torque occurs (lower limit), and the rated speed (high limit).

When gearing up and throttling down, always check for overloading by ensuring that:

- the engine will hold constant speed;
- the engine will return to its original working speed within 10 seconds after reducing speed by 500 rpm; and
- that the tractor will maintain its forward speed in a gear 15% faster.

12.3.3. OPERATING HINTS

Operating a tractor continuously at maximum power is the best way to get maximum return on the owner's investment. However, continuous full power operation may also result in reduced reliability, higher maintenance and repair costs or increased down time. The following points will help to operate the tractor economically and reliably:

- Do not operate continuously at greater than 80% of maximum power output;
- Ballast the tractor to achieve an acceptable wheel slip;

- Some implements impose high vertical loads on the tractor drawbar. This greatly increases rear axle loadings. Do not use this extra weight to make the tractor pull harder at speeds less than 7 km/h;

- With tillage, aim to work at speeds above 7 km/h. If there is a need to work slower, don't pull anything that the tractor can't pull comfortably at 7 km/h.

On PTO jobs, engine power output should still be less than 80%. Slower work, like baling, is not usually a problem as the transmission is not fully loaded.

12.4. FUEL SAVING IDEAS

The possibility of increasing prices for gasoline and diesel fuel make it worth considering ways to reduce farm fuel.

12.4.1. TRACTORS AND OTHER FIELD EQUIPMENT

Tillage uses more fuel per acre or hectare than almost any other field operation. Carefully evaluate the tillage plans and reduce tillage or the intensity of tillage wherever possible. Reducing tillage is also likely to provide the benefit of reducing soil erosion. The farmer must however, look at the whole cropping system and evaluate whether reducing tillage will create the need for other, more expensive operations.

Compacting the soil must be avoided by staying out of wet fields and by reducing passes with heavy equipment. Extra tillage and extra power (and thus more fuel) are needed to break up compacted soil.

Reduce the number of trips across the field by combining operations where possible. Consider modifying machinery so that they can perform multiple operations in one pass. Think about using a tractor with hitches on both the front and rear (several companies are selling hitches that can be mounted on the front of tractors) so that implements can be attached to both ends of the tractor.

Match the tractor to the load. Avoid using heavy, high-power tractors for operations that don't require much power.

If the farmer has to use a high-power tractor to pull a light load, gear up and throttle down. In this way quite a bit of fuel can usually be saved by running an under-loaded tractor in a higher gear but at a lower engine speed.

Inflate tires to an appropriate pressure. Inflation pressure is an important variable for traction efficiency, tire life and ride comfort, especially for radial tires. Check the owner's manual of the tractor or the tire distributor for suggestions on inflation pressure.

Add the appropriate amount of weight for the load. Tractor weight, or ballast, helps control the amount of drive wheel slippage. Drive tires should slip about 15% when the tractor is pulling a load in the field. Higher levels of slip cause excessive tire wear and poor fuel efficiency. Lower levels of slip indicate that the tractor is carrying too much weight, which wastes fuel and puts an extra load on the axles and power train. Ideally, weights should be added or removed to match the load when tractors are used for different field operations.

If possible without causing excessive soil erosion, fields can be laid out to minimize the amount of time spent turning around and the amount of time needed to haul loads of harvested crop back to the road. Try to minimize the amount of time spent driving tractors and other field equipment on the road. Try to keep tractors and other equipment in the field and use faster, more fuel-efficient vehicles to service vehicles in the field and to haul harvested crops to storage.

12.4.2. OTHER FARM VEHICLES

The farmer should use more fuel-efficient vehicles for making trips to fields or to town when he is not hauling heavy loads. Although heavy-duty pickups and trucks play an important role on farms, they are often used for trips that do not require their power and hauling capacity. These vehicles generally consume a lot of fuel per mile or kilometer and they consume a significant percentage of the liquid fuels used on farms. Much fuel could be saved by using smaller, fuel-efficient vehicles and by combining trips rather than making a separate trip for each need.

If the farmer is planning to buy large, heavy-duty trucks, he must consider diesel engines instead of gasoline. Although diesel fuel is often more expensive, one gets much more work out of a unit of diesel fuel than out of gasoline.

12.5. CONCLUSION

There are many factors that can influence the amount of fuel used for field operations. Good estimates of fuel requirements are therefore necessary for planning purposes. If fuel use records are available, they should be used. If specific records are not available, average fuel use values or guidelines can also be used.

A tractor is an investment in power. It has the ability to complete a certain amount of work within a specific period of time. The more a tractor work to its full potential during this time period, the more economical the ownership cost of the tractor will be. If the farmer can utilize the fuel more effective and even save on fuel usage, he can also make the operational cost more economical and save on machinery cost altogether.

The possibility of increasing prices for gasoline and diesel fuel make it worth considering ways to reduce the usage of fuel. The farmer should use fuel in the most effective way to enable him to apply his machinery in an economical way.

12.6. REFERENCES

Effective Farming, August 1996. *Why tractors like to work hard*. Eric de la Harpe, Department of Agricultural Engineering, University of Natal, South Africa.

Fuel Saving Ideas for Farmers. Bill Wilcke, Minnesota Extension Engineer & Jonathan Chaplin, Associate Professor, University of Minnesota, Biosystems and Agricultural Engineering Department. Minnesota/Wisconsin Engineering Notes, Spring 2000.

Fuel use for field operations. Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources, October 1981

Gear Up and Throttle Down -- Saving Fuel. Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources, June 1996

Gould, N., Lund, R. & Hill, J. 1999 : *Matching tractors and implements the economic way.* Agekon Internet seminar, June 4 1999. : *AN ECONOMICAL APPROACH TO AGRICULTURAL MACHINERY MANAGEMENT:* http://www.computus.info/machsem.