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FACT SHEET

CHOOSING EQUIPMENT SIZE FOR EFFICIENT ENERGY USE

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The cost of fuel represents more than 30 percent of the operating costs of owning and operating farm tractors. This proportion has increased significantly during the last 10 years and will continue to increase as fuel prices rise in the future. A Montana study [1] showed that about one-third of the tractors in that state were operated efficiently. The rest were operated at 60 to 80 percent capacity. Such unused capacity wastes fuel dollars. Engine loading greatly influences fuel consumption. Loading the engine to 80 percent or more of maximum engine power provides the best fuel economy and power utilization at full throttle. A half-loaded tractor, operated at the rated engine speed, provides only two-thirds the fuel economy of a fully loaded tractor. To minimize fuel costs, proper selection of tractor size is important for efficient operation and energy usage.

For tractor operations with a partial engine load, try throttling back and shifting to a higher gear to save fuel. Throttling back makes the engine work at a slower, more efficient speed. Shifting to a higher gear keeps the ground speed the same with the reduced engine speed.

Example. Nebraska tractor test data for a 156 PTO horsepower tractor

50 percent load:

Rated RPM	7.0 gal/hr	72.6 horsepower at 5.9 mph
Reduced RPM	5.4 gal/hr	72.9 horsepower at 5.9 mph

Selecting machine size involves fitting the proper size equipment to the amount of work for a given period of time. Ask these questions:

- How many acres will be farmed?
- How many days are available to prepare the soil and plant the crop?
- How much yield will be lost if the crop is not planted during the optimum period?

Estimate Field Capacity

To fit machine size to the amount of work to be completed in a specific length of time, it is necessary to calculate field capacity. Field capacity is a function of equipment width, equipment speed and field efficiency given by this formula:

$$FC = \frac{\text{Width (ft)} \times \text{Speed (mph)} \times FE}{8.25}$$

Where: FC = field capacity
FE = field efficiency
8.25 = a constant

Field efficiency takes account of set-up time, turning time and other operations which are not actual work time. Field efficiency is given as a ratio of actual work time divided by operation time. For instance, a five-bottom, 16-inch plow operating at 4.4 mph theoretically can cover 3.56 acres per hour. When nonworking time is included, using an estimated field efficiency of 0.8, the field capacity is 2.84 acres per hour. Field efficiency varies with different implements and different field conditions. Table 1 shows field efficiencies of several implements and recommended field speeds.

Calculate Operation Time

To determine how large a machine is needed, determine capacity needed to complete the operation within a specified period of time. To do this, carefully select the calendar period and correctly estimate the number of hours you can work during that period. This estimate is a function of the operation to be performed (plowing, planting or harvesting) and the weather conditions during that

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[1] William E. Larsen, "Efficiency of Utilization of Four-Wheel Drive Tractors," Department of Agricultural Engineering, Montana State University, Bozeman, Montana 59717.

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period. It is best to plan for very conservative weather conditions during critical farming operations. For example: If 450 acres of cotton need to be planted in 38-inch rows within a 14-day period, allow for one heavy rain causing a 4-day delay during that period, leaving 10-working days to complete the planting. Considering weather and mechanical delays typical during the planting season, 8 working hours per day would be reasonable. Use the following method to determine the width of the planter. First, calculate field capacity required. The field capacity is found to be 5.63 acres per hour by multiplying 8 working hours per day times the 10 days to complete planting and dividing that into 450 acres.

$$\frac{\text{450 acres}}{\text{8 hours/day} \times \textit{10 days}} = \text{5.63 acres/hr}$$

Next, calculate required implement width needed with the field capacity formula:

$$\mathbf{FC} = \frac{\text{Width (ft)} \times \text{Speed (mph)} \times \text{Fe}}{8.25}$$

From Table 1, using a 0.75 field efficiency and a 3.5 mph field speed, the width of the planter needed is found to be 17.7 feet.

$$\text{5.63 acres/hour} = \frac{\text{Width (ft)} \times \text{3.5 mph} \times 0.75}{8.25}$$

or

$$\text{Width (ft)} = \frac{\text{5.63 acres/hour} \times 8.25}{\text{3.5 mph} \times 0.75}$$

Width = 17.7 ft

Table 1: Equipment field speeds and field efficiences.

	Speed (mph)	Field Efficiencies (FE)
Tillage Implements	3—6	.70—.90
Rotary tiller and row cultivators	1—4.5	.70—.90
Fertilizer and chemical application	3—5	.60—.75
Planters — row crops with fertilizer and herbicides	3—6	.50—.85
Grain drill	2.5—6	.65—.85
Cutterbar mower	5—6	.80—.90
Mower-conditioner	2—4.5	.88—.90
Side delivery rake	4—6	.85—.90
Balers	2.5—5	.70—.90
Forage harvesters	1.5—5	.50—.75
Combines	2—3.5	.65—.80
Cotton pickers	1.5—3.0	.60—.80
Cotton strippers	2—3.5	.60—.75

Source: 1981-82 Agricultural Engineers Yearbook

To determine the number of planters needed, divide width in feet by row spacing in feet.

$$\frac{\text{17.7 ft}}{\text{3.2 ft}} = \text{5.5 or 6 row planter}$$

This field capacity formula may also be used to determine the field capacity of an implement of known width.

In this example, under "ideal" conditions, the 450 acres of cotton could be planted in 7 days using 10-hour days with a six-row planter. There are many factors which can change the amount of time available for an operation; weather, soil conditions, and mechanical breakdowns. Too conservative use of these factors results in equipment sizes much larger than they need to be. Accurate records on days and hours of work in the field give valuable information after a few years, or if you are unfamiliar with an area, consult the local county Extension office for rainfall and temperature records.

Determine Tractor Size

To determine proper horsepower ranges of tractors needed for energy-efficient farming operations, consider your most demanding field operation. This is generally primary tillage applications (plowing or disking).

For example: To prepare 1,000 acres of land for spring planting with an offset disk in a 2-week period if local weather conditions allow 9 days with 10-hour working days, field capacity can be determined at:

$$\frac{\text{1,000 acres}}{\text{9 days} \times \text{10 hours}} = \text{11.1 acres per hour}$$

Implement width needed to perform the job in the desired number of days can be calculated by:

$$\text{Width (ft)} = \frac{\text{11.1 acres per hour} \times 8.25}{\text{5 mph} \times .85}$$

$$= \text{21.5 ft. or 22 ft. offset}$$

After the size of implement needed is determined, the tractor horsepower requirements can be calculated. The draft (the horizontal pull of an implement) is a function of the implement type, implement depth, soil type and soil moisture. Table 2 shows the draft in pounds per foot of implement required in several different soil types. Only primary tillage implements are listed in this table.

To determine horsepower requirements for a 22-foot offset disk in a sandy loam soil, first find the draft in Table 2.

Table 2: Typical draft (in pounds per foot of implement) *

Implement	Depth (in.)	Speed (mph)	Heavy (e.g. buckshot gumbo)	Moderately heavy (e.g. clay loam)	Average (e.g. loam)	Moderately light (e.g. sandy loam)	Light (e.g. sandy)
Moldboard plow	8	4-5	1250	1050	950	700	400
Chisel plow	8-12	4-5	800	650	500	350	200
Field cultivator	3-4	4-6	500	375	250	200	150
Tandem disk	2-4	4-6	400	325	250	175	100
Offset disk	3-6	4-6	600	500	400	300	200
Lister	5-6	3-5	1100/bottom	-	800	-	400

*These average values are subject to variation from soil moisture content, depth and speed of operation. Adjust values depending on particular situations.

Source: Oklahoma State University Extension Service and 1981 Agricultural Engineers Yearbook

$$\text{Draft} = \text{Width} \times 300 \text{ lb/ft.} = 6{,}600 \text{ lbs.}$$

The drawbar horsepower to do the job is then calculated:

$$\text{Horsepower} = \frac{\text{Draft} \times \text{speed (mph)}}{375}$$

$$\text{Horsepower} = \frac{6{,}600 \times 5 \text{ mph}}{375} = 88$$

This is the usable drawbar horsepower needed to pull the offset disk. However, we must convert this horsepower into PTO horsepower in which tractors are generally rated. Since the condition of the soil affects the pulling ability of the tractor, the usable drawbar horsepower as a percentage of PTO horsepower is:

PTO hp × 0.86 = Maximum drawbar horsepower
PTO hp × 0.67 = Usable drawbar horsepower in firm soil
PTO hp × 0.56 = Usable drawbar horsepower in tilled soil
PTO hp × 0.48 = Usable drawbar horsepower in soft or sandy soil

These factors may vary between four-wheel drive tractors, the use of radial tires and different wheel combinations. However, they are a good estimate of the ratio between rated PTO horsepower and usable drawbar horsepower. The tractor size then needed to develop 88 drawbar horsepower in firm soil is:

$$\text{PTO hp} = \frac{88}{0.67} = 131$$

Several tractor sizes are offered in this range. Check with your local dealer or Nebraska tractor test data for proper tractor models.

By sizing the principal tractor for primary tillage and cultivating operations, it will be overpowered for some operations. By using the throttle back—gear-up principle, energy efficient tractor operation can be accomplished.

Select Efficient Implement Width

The procedure for tractor sizing can be worked in reverse as well as that just discussed. A farmer often has the tractor available and would like to select the most efficient implement size to match his tractor. To do this, determine the following:

- Useful horsepower available for various field conditions
- Implement draft per foot
- Tractor speeds in the 4 to 6 mph range
- Proper implement width

For example: Select a moldboard plow for a 175 PTO hp tractor in moderately heavy soil, traveling at 5mph. In firm soil, drawbar horsepower is 0.67 of PTO horsepower; in heavy soil, draft per foot of moldboard width (Table 2) is 1,000 pounds per foot.

$$175 \text{ PTO hp} \times 0.67 = 117 \text{ usable drawbar hp}$$

$$\text{hp} = \frac{\text{Speed (mph)} \times \text{draft (lb)}}{375}$$

$$117 \text{ hp} = \frac{5 \text{ mph} \times 1000 \text{ lb per ft} \times \text{width (ft)}}{375}$$

$$\text{Width (ft)} = \frac{117 \times 375}{5 \times 1000} = 8.78 \text{ ft or } 105 \text{ inches}$$

A 6-by 18-inch plow would be satisfactory.

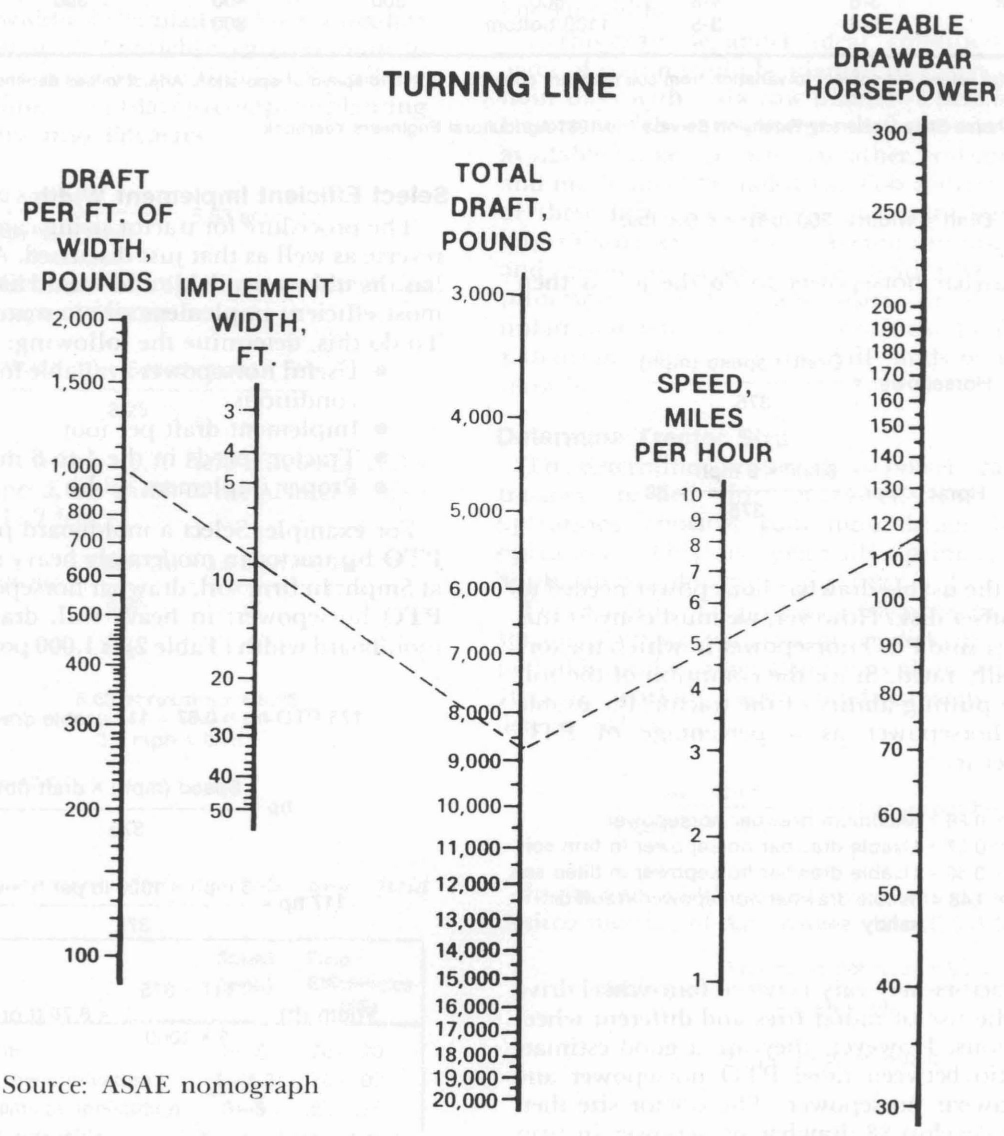
Match Implements

To match implements, use the nomograph (Figure 1) instead of equations and a calculator. Using the same example, enter 117 usable drawbar horsepower on the right hand scale and draw a straight line from this point through 5 miles per hour, intersecting the turning line at 8,800 pounds total draft. Draw another line from 8,800 pounds total draft to 1,000 lb/ft draft of the left hand scale. The implement width line is intersected at 8.8 feet.

This nomograph can be used to solve width, speed, soil resistance or horsepower, as long as the other three factors are known.

Proper matching of tillage tools to tractors can save money and energy. As a result, tillage tools may be pulled at a satisfactory speed under most conditions. By properly loading a tractor at the faster field speeds, the useful life of the tractor may be expected to almost double. Fewer breakdowns and a reduced cost per unit of work should be attained.

Figure 1. Nomagraph for estimating drawbar horsepower requirements for tillage equipment.



Source: ASAE nomograph

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