LESSION - 17

TRACTOR AND IMPLEMENT SELECTION FOR DIFFERENT AGRICULTURAL OPERATIONS

Putting together an ideal machinery system is not easy. Equipment that works best one year may not work well the next because of changes in weather conditions or crop production practices. Improvements in design may make older equipment obsolete. And, the number of acres being farmed or the amount of labor available may change. Because many of these variables are unpredictable, the goal of the good machinery manager should be to have a system that is flexible enough to adapt to a range of weather and crop conditions while minimizing long-run costs and production risks

POINTS TO BE CONSIDERED IN SELECTING A FARM MACHINERY

To do better farm machinery selection, the following fundamental things must be understood

1. Machine Performance

Each piece of machinery must perform reliably under a variety of field conditions or it is a poor investment regardless of its cost. Tillage implements should prepare a satisfactory seedbed while conserving moisture, destroying early weed growth and minimizing erosion potential. Planters and seeders

should provide consistent seed placement and population as well as properly apply pesticides and fertilizers. Harvesting equipment must harvest clean, undamaged grain while minimizing field losses. The performance of a machine often depends on the skill of the operator, or on weather and soil conditions. Nevertheless, differences among machines can be evaluated through field trials, research reports and personal experience.

2. Machinery Costs

Once a particular type of tillage, planting, weed control, or harvesting machine has been selected, the question of how to minimize machinery costs must be answered. Machinery that is too large for a particular farming situation will cause machinery ownership costs to be unnecessarily high over the long run; machinery that is too small may result in lower crop yields or reduced quality.

3. Ownership Costs

Machinery ownership costs include charges for deprecation, interest on investment, property taxes, insurance and machinery housing. These costs increase in direct proportion to machinery investment and size.

4. Operating Costs

Operating costs include fuel, lubricants and repairs. Operating costs per acre change very little as machinery size is increased or decreased. Using larger machinery consumes more fuel and lubricants per hour, but this is essentially offset by the fact that more acres are covered per hour. Much the same is true of repair costs. Thus, operating costs are of minor importance when deciding what size machinery is best suited to a certain farming operation

5. Labor Cost

As machinery capacity increases, the number of hours required to complete field operations over a given area naturally declines.

6. Estimating the Field Capacity of Farm Machines

If hourly or part-time hired labor operates machinery, it is appropriate to use the wage rate paid, plus the cost of any other benefits which may be provided, as the labor cost. If the farmer-owner or a hired worker who is paid a fixed wage operates machinery, then it is proper to value labor at its opportunity cost, or the estimated return it could earn if it were used elsewhere in the farm business, such as in livestock enterprises.

7. Timeliness Costs

In many cases, crop yields and quality are affected by the dates of planting and harvesting. This represents a “hidden” cost associated with farm machinery, but an important one nevertheless. The value of these yield losses is commonly referred to as “timeliness costs.”

8. Total Machinery Costs

Illustrates the effect that changes in machinery size have on each type of cost in a typical situation. For very small machinery (relative to crop acres), a slight increase in machinery size can lower timeliness and labor costs significantly, enough to more than offset the higher fixed costs. However, as machinery size continues to increase, the timeliness cost savings diminish, and eventually total costs begin to rise. One objective of machinery selection, then, is to select machinery in the size range where total machinery costs are lowest.

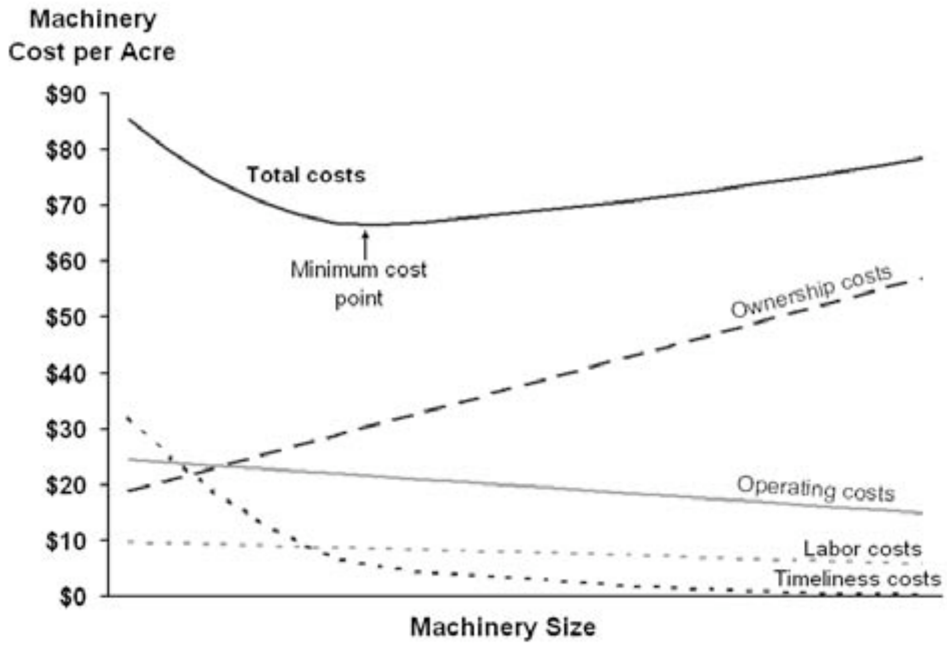

Fig1. Effect of increasing machinery size on machinery costs.

FACTORS THAT AFFECT THE SIZE OF MACHINERY NEEDED

Machinery recommendations must be based on the characteristics of each individual farm. The following factors influence machinery selection, and are discussed in order of importance.

1. Number of Crop Acres

As more crop acres are farmed, larger-scale machinery is needed to ensure that planting and harvesting are completed in a timely fashion. An alternative is to acquire a second unit of some machines, if an additional tractor and operator are available.

2. Labor Supply

The number of acres that can be completed each day is the most critical measure of machinery capacity, more than machine width or acres completed per hour. Increasing the labor supply by hiring extra operators or by working longer hours during critical periods may be a relatively inexpensive way of stretching machinery capacity. In addition, the cost of additional labor only needs to be incurred in those years in which it is actually used, while the cost of investing in larger machinery becomes “locked in” as soon as the investment is made. On the other hand, extra labor may not always be available when needed, and working long hours over several days can present a safety hazard.

3. Tillage Practices

The number of field days needed before planting is completed depends partly on the number of separate operations completed on each acre. Reducing the number of tillage practices performed or performing more than one practice in the same trip effectively decreases the amount of machinery capacity needed to complete field operations on time. Of course, machinery cost savings from reduced tillage must be compared to possible increased chemical costs and effects on yields.

4. Crop Mix

Diversification of crops tends to spread out the periods when timely completion of field operations is critical. For example, yield reductions due to late planting begin later for soybeans than for corn. Harvesting can also be completed over a longer time period. Thus, growing more than one or two crops reduces the machinery capacity needed for a given number of crop acres. However, it may also require purchasing additional types of machinery, especially for harvesting.

5. Weather

Weather patterns determine the number of days suitable for fieldwork in a given time period each year. Although actual weather conditions cannot be predicted far enough in advance to be used as an aid to machinery selection, past weather records can be used as a guide. As a rule of thumb, either is suitable for field work about 60 percent of the time in the spring and about 75 percent of the time in the fall. This does not take into account time off for holidays, Sundays or other occasions. Machinery selection should be based on long-run weather patterns even though it results in excess machinery capacity in some years and insufficient capacity in other years.

6. Risk Management

Fluctuations in the number and occurrence of suitable field days from year to year cause timeliness costs to vary even when the machinery set, number of crop acres and labor supply do not change. Investing in larger machinery can reduce the variability of net machinery costs by ensuring that crops are planted and harvested on time even in years in which there are few good working days. Machinery fixed costs would be higher with larger machinery, but they would not fluctuate as long as the machinery set did not change. Farmers with high field cash flow needs, such as land mortgage payments, may be willing to pay more (in higher fixed machinery costs) than other operators for the insurance” of not suffering substantial yield losses due to late planting and harvesting in certain years.

7. Planting and harvesting dates

Long-term studies indicate that crop yields typically start to decline significantly when planting occurs after the recommended period, as shown in Figure 2. However the exact dates will vary from year to year. One reason for the decline in yield for late-planting is that “heat units” are available during the growing season gets reduced,

How early to start planting requires considerable judgment. Ideal conditions would be a soil temperature of 50°F (10°C) or above at planting depth and a favorable five-day weather forecast. If soil conditions and temperatures are favorable, starting to plant should be advantageous.

Timeliness losses at harvest are due primarily to more dropped ears, and field shattering. Some harvesting losses occur because combining speed is too high or the machine is poorly adjusted.

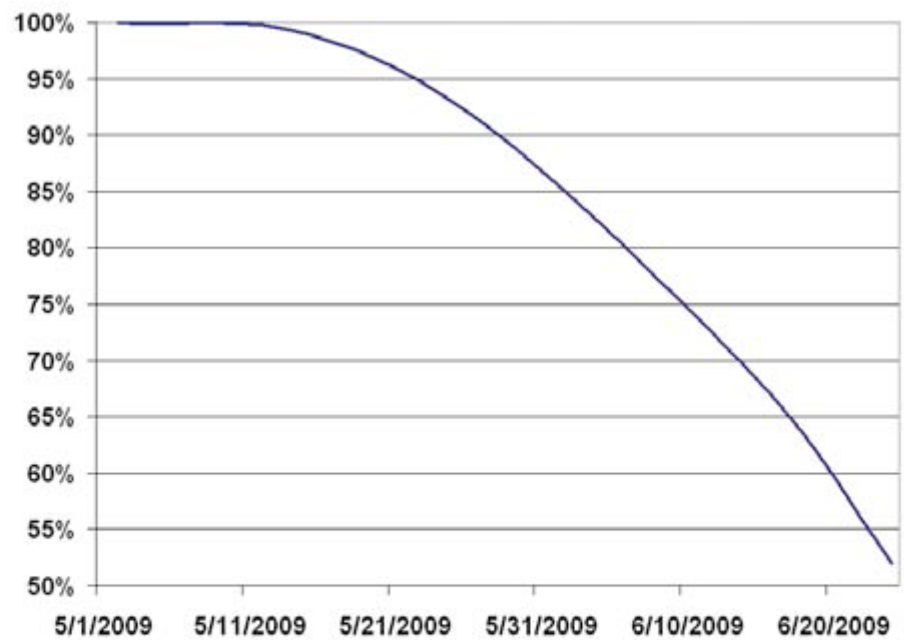

Figure 2. Estimated corn yield as percent of maximum, by planting date

MACHINE SIZE (HOW LARGE SHOULD MACHINERY BE?)

To select and match tractors and implements, one must need information about the capacity of the tractor and implement as well as the load that is likely to be imposed on the power unit.

Draft requirements will vary with implement design, soil type, and speed of operation and depth of operation. Therefore in any matching situation there is an inherent danger in specifying a machine's capacity or power requirement unless actual field efficiencies and draft requirements have been measured. Accept specifications, therefore, with some caution.

EFFECTIVE FIELD CAPACITY

The effective field capacity is the actual output achieved by a machine. It is a function of the proportion of the machine width utilised, the travel speed and the amount of time lost in the field during the operation. Time is lost to implement blockages, working areas such as headlands more than once, adjustments, checking and minor repairs and excludes daily servicing requirements such as lubrication but would include the time taken to change points.

A practical way of determining field efficiency is to determine the theoretical time required to cover an area and compare this with the actual time taken.

$$\%\ \text{Field efficiency} = \frac{\text{theoretical time} \times 100}{\text{operating time}}$$

Typical field efficiency values for a range of different operations are listed in Table 1. The higher figures represent operations in larger fields where the number of turns is minimised.

Table 1: Field Efficiency

Operation	**Field Efficiency, %**
Tillage - primary and	70-85
Secondary working	65-85
Planting	60-80
Harvesting	50-70
Spraying	

DETERMINING THE SIZE OF MACHINE REQUIRED

To determine the size of machine required, it is necessary to estimate the time available for completing a particular task.

The starting point in any matching exercise is to determine the most critical field operation. This will vary from region to region and often between farms within any one region. It is often determined by the time available to get over the area between rainfall events. Local knowledge or a check of local rainfall records will usually help in this regard.

By knowing the time available and the operating speed, the required width can be calculated. In this calculation allowance has to be made for field efficiency. The formula then is:

$$\text{Width} = \frac{\text{area (ha)} \times 10\ \text{(constant)}}{\text{time (hr)} \times \text{speed (km/hr)} \times \text{field efficiency}}$$

Consider an example:

Establish the width of chisel plough that will allow the completion of 400 hectares in 8 days working 10 hours per day at 8 kilometers per hour, assuming a field efficiency of 80% (from Table 1)

$$\text{Width} = \frac{400 \times 10 \times 100}{(8 \times 10) \times 8 \times 80}$$

$$= 7.8 \text{ metres}$$

With this simplistic approach, the effects of any input (hours/day, speed or field efficiency) can be evaluated. Care should be taken not to over estimate either the time available to complete the task or field efficiency.

TRACTOR CAPACITIES

In a similar manner to selecting reasonable field efficiency for a tillage operation it is also necessary to look at the efficiency of the tractor in converting engine power to drawbar power. Little can be done to decrease power losses from the engine to the axle. Better maintenance and servicing will improve the efficiency of converting fuel energy into axle power but little else can be done to decrease energy losses.

However, when considering losses from the axle to the drawbar, energy is lost in order to create traction. These losses depend on the tractor type and weight, soil conditions, as well as the load being pulled.

It is important to remember that drawbar power is the product of pull and speed; where an infinite number of pull / speed combinations could be used to give the same power. Wheel tractors are designed to operate at higher speeds (greater than 8.0 km/h) and lower drawbar loads. If low forward speeds (under 5.5 km/h) and large pulls are to be consistently used, track layers should be considered.

Table 2 Typical Tractor Efficiencies

Tractor Type	**Rated Crank-shaft Power %**	**P.T.O. Power %**	**Drawbar Power (Maximum) %**	**Drawbar Power (Normal) %**
2WD	100	85	50	40-45
FWA	100	85	55	45-50
4WD	100	85	60	50-55
Track	100		75	65-70

Note: PTO and Drawbar Power are given as a percentage of Rated Crankshaft Power

ESTIMATING POWER REQUIREMENTS

Estimation of draft

In order to determine the draft requirement of an implement it is necessary to use a pull meter. Estimation of likely draft requirements can be taken from the table provided. However, these values will vary according to soil type, soil moisture, depth of working, ground speed and manufacturer.

Table 3 Estimating Draft Requirements

Implement	Draft per Unit Width (kN/m)
Chisel plough	4.5-5.5
Blade plough	4.0-4.5
Disc plough	5.0-6.0
Scarifier	4.0-4.5
Cultivator	3.0-3.5
Planter	2.5-3.5

A figure for total draft can be calculated by simply multiplying implement width by draft per unit width. Considering the example using the chisel plough, then:

Total draft = width (m) x draft / metre (kN/m)

= 7.8 x 5

= 39 kN (approx. 3900 kgf)

If a scarifier was used to replace the chisel plough, the draft per unit width would decrease to 4.5 kN/m and the resultant total draft would be 35 kN (3500 kgf). Remember this is draft or pull, not drawbar power.

Estimation of drawbar power

Drawbar power can be related to draft and speed, by using the formula below. Any one drawbar power level may be attained by a combination of pull and speed. That is, a large pull at a low speed could produce the same drawbar power as a small pull at high speed.

$$\text{Drawbar power} = \frac{\text{pull (kN) x speed* (km/hr)}}{\text{3.6 (constant)}}$$

Using the same chisel plough as in the previous example, the power requirements become:

$$\text{Drawbar power} = \frac{39 \times 8}{3.6}$$

= 87 kW (116hp).

*Speed has been determined by the initial assumption when working out the required implement width.

Note: Kilowatts (kW) x 1.34 = Horsepower (hp)

Horsepower (hp) x 0.746 = Kilowatts (kW)

At this point, it would pay to work through all of the tillage operations and determine the requirements for each, after closely considering the time available and field efficiency. The largest power requirement would be then used in determining engine power.

Estimating engine power

Once drawbar power has been calculated, a decision needs to be made about what type of tractor is to be used.

The selection decision between wheels or tracks is far too complex a topic to be covered in this chapter. Suffice to say that if set-up and matched correctly, the operating costs should be similar for either tractive type. The decision between two wheel drive and four wheel drive is much simpler as it is determined by the minimum available size of a 4WD and the maximum size of a 2WD (that is approximately 150 kW or 200 hp).

From Table 2, it is now possible to determine the size of tractor required. In using the comparative chart it would be unwise to determine engine size using the maximum power figure as conditions vary both from season to season and even within any one season. Having a little extra capacity is also a safeguard against overloading. A more realistic figure is the normal operation level.

Table 4: Tractor Crankshaft Power (Chisel plough example)

Tractor	**Drawbar HP/ Efficiency**	**Crankshaft Power (kW)**
2WD	(87 x 100)/40	=217 kW (290 hp)
FWA	(87 x 100)/45	=193 kW (259 hp)
4WD	(87 x 100)/50)	=174 kW (232 hp)
Tracklayer	87 x 100)/65	=134 kW (178 hp)

CONCLUSION

If a step by step approach is used when matching power units and implements, it is possible to eliminate the majority of guess work that is normally employed when a machinery purchase decision is made.

This approach is simplistic but does allow changes to any of the inputs. Care must be taken not to over estimate either the time available to complete the task or field efficiency.

APPENDIX

Table 1 shows estimated draft requirements for various implements

Table 1 . Default Values for Speed, Field Efficiency, and Draft Requirements.

Equipment Name	**Speed (mph)**	**Draft (lb. per unit of width)**	**Average Range**
Tillage			
Moldboard plow (16 in. bottom, 7 in. deep) Light soil Medium soil Heavy soil Clay soil	 5.0 4.5 4.5 4.0	 320 500 800 1200	 220 - 430 per foot t350 - 650 per foot 580 - 1,140 per foot 1,000 - 1,400 per foot
Chisel-plow (7-9 in. deep)	5.0	500	200 - 800 per shank
Disk Single gang Tandem Heavy or offset	 5.5 5.5 5.0	 75 200 325	 50 - 100 per foot 100 - 300 per foot 250 - 400 per foot
Field cultivator	5.0	300	200 - 400 per foot
Spring-tooth harrow	5.0	200	70 - 300 per foot
Spike-tooth harrow	6.0	50	20 - 60 per foot
Roller or packer	5.0	100	20 - 150 per foot
Cultivator Field (3-5 in. deep) Row crop	 5.0 4.5	 250 80	 60 - 300 per foot 40 - 120 per foot
Rotary hoe	7.5	84	30 - 100 per foot
Subsoiler (16 in. deep) Light soil Medium soil	 4.5 4.5	 1500 2000	 1,100 - 1,800 per 1,600 - 2,600 per

Heavy soil	4.5	2600	2,000 - 3,000 per
Planting			
Planter only	5.0	150	100 - 180 per row
Planter with attachments	5.0	350	250 - 400 per row
Grain drill	5.0	5.0	30 - 100 per foot
No-till drill	5.0	200	160 - 240 per foot
Applying Chemicals			
Anhydrous ammonia applic.	4.5	425	375 - 450 per shank