Farm Machinery Selection

Ag Decision Maker

File A3-28

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. To meet these goals several fundamental questions must be answered.

Machine Performance

First, 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.

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.

Ownership Costs

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

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.

A detailed procedure for estimating machinery ownership and operating costs can be found in *AgDM Information File A3-29* **Estimating Farm Machinery Costs** *(PM 710)*.

Labor Cost

As machinery capacity increases, the number of hours required to complete field operations over a given area naturally declines. Estimates of time requirements for completing machinery operations are found in *AgDM Information File A3-24* **Estimating the Field Capacity of Farm Machines** *(PM 696)*.

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.

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."

Total Machinery Costs

Figure 1 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

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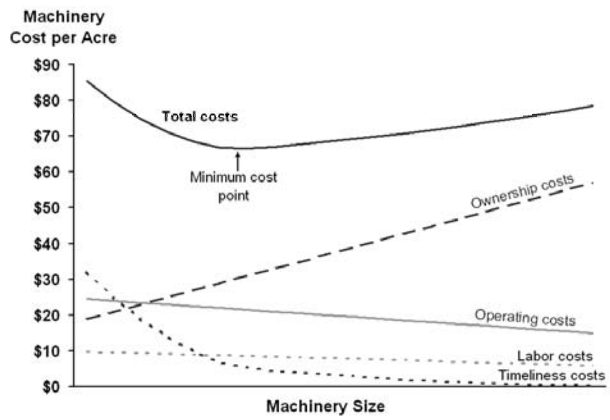
selection, then, is to select machinery in the size range where total machinery costs are lowest.

Figure 1. 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.

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.

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.

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.

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.

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. *AgDM Information File A3-25* **Fieldwork Days in Iowa** *(PM 1875)* lists the number of suitable field days expected for different periods of the year in each of the nine crop reporting districts in Iowa. As a rule of thumb, weather 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.

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 fixed 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.

Planting and Harvesting Dates

Long-term studies indicate that corn yields typically start to decline significantly when planting occurs after May 10 to 14, as shown in Figure 2. The exact dates will vary from year to year. About 50 percent of Iowa's corn is normally planted by this time. One reason for the decline in yield for late-planted corn is that fewer "heat units" are available during the growing season, and this influences the rate of crop development.

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. In most of Iowa, if soil conditions and temperatures are favorable, starting to plant the last ten days of April should be advantageous. In May, the major consideration should be the condition of the seedbed.

There is some risk with early planting. Replanting may occasionally be required, but the long-term benefits far outweigh this cost. An added benefit from early-planted corn is lower grain moisture levels at harvest and reduced drying costs.

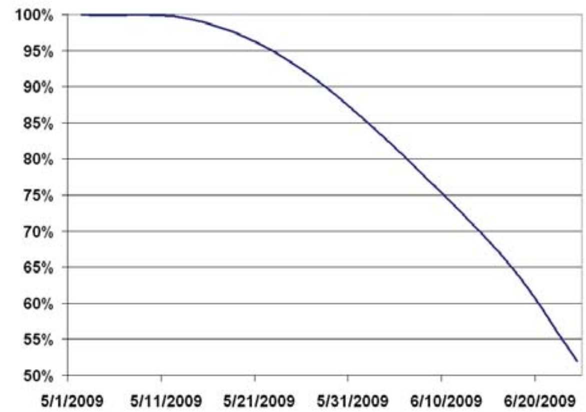
Most of the same things can be said about planting soybean varieties. The ideal time for planting adapted soybean varieties is between May 1 and May 15. Yields can be expected to decline in most years if planting occurs after about May 20, as Figure 3 shows.

Timeliness losses at harvest are due primarily to more dropped ears, field shattering and cracked beans. These losses must be balanced against the cost of artificially drying grain harvested at a moisture level higher than that required for safe storage. Some harvesting losses occur because combining speed is too high or the machine is poorly adjusted.

How Large Should Machinery Be?

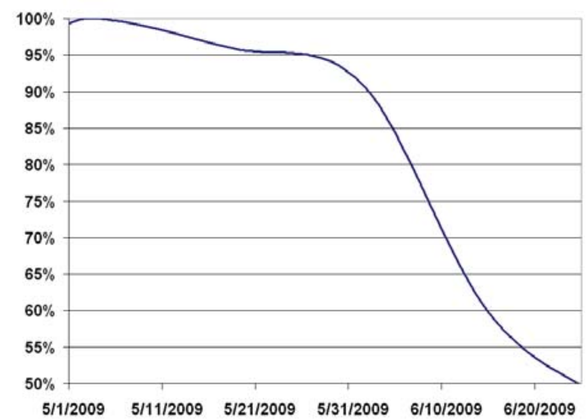
One way to measure the capacity of a set of machinery is by the number of work days required to complete field operations. This depends on the number of crop acres, machinery operations performed, size of the machinery in use, and availability of labor.

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



Source: PM 1885 Corn Planting Guide

Figure 3. Estimated soybean yield as percent of maximum, by planting date.



Source: PM 1851 Soybean Replant Decisions

In research conducted recently at ISU, total machinery costs for Iowa grain farms, including the value of timliness losses, were estimated for a number of different machinery combinations. The effects of variations in the number of crop acres and labor supply, were compared.

Under each set of circumstances the machinery set for which total costs were lowest, including yield losses due to poor timelines, was identified. In some cases, several machinery sets gave nearly identical minimum costs. In approximately 80 percent of the cases tested, the least-cost machinery sets were able to complete all tillage and planting operations in about 20 to 25 field days. A good rule of thumb for farmers who wish to have sufficient machinery capacity to reduce risk, as well as maintain total costs at a low level, is to be able to complete tillage and planting in about 20 field days.

Where less than one full-time person is available to operate machinery, a goal of 25 to 30 days for completing planting and tillage will most often minimize costs. On the other hand, farms with 2 or 3 full-time machinery operators available could aim to complete this work in less than 20 days.

The machinery sets which minimized total machinery costs were most often able to complete harvesting of corn and soybeans in 25 to 30 field days. As with spring work, operators for whom risk reduction is important should use the lower end of this range as a goal, although yield losses from late harvesting are generally not as severe as from late planting.

A number of different machinery combinations may allow fieldwork to be completed in the same number of days. In putting together a machinery set, it is also important to correctly match machinery sizes and tractor power. Using tractors with horsepower in excess of that required for the implement being pulled results in excessive depreciation and interest costs, while using too little horsepower may cause faster engine wearout.

Some farms may not have enough crop acres to justify owning a full line of machinery, particularly for harvesting. Custom hiring or leasing certain machinery operations may lower total costs as well as provide more flexibility in the amount of machinery capacity. For a detailed discussion of custom hiring, leasing, and renting farm machinery see *AgDM Information Files A3-33* **Combine Ownership or Custom Hire** *(PM 786)* and *A3-21* **Acquiring Farm Machinery Services** *(PM 787)*.

Field Capacity

To project the number of field days required, it is necessary to know the field capacity for each implement. Field capacity usually is measured in acres accomplished per hour, and is affected by three variables: width, speed and field efficiency.

Width refers to the effective working width of the implement, excluding overlapping, and is measured in feet.

Speed, which is measured in miles per hour, refers to a safe operating speed under normal working conditions. This does not take into account slowing down to turn at the end of a field.

Field efficiency is the actual field capacity that can be achieved as a percentage of the maximum theoretical capacity without overlapping, slowing for turning or stopping to adjust machinery, fill containers, empty hoppers, and make minor repairs.

The formula for estimating field capacity (in acres per hour) is:

$$\frac{\text{width (ft) x speed (mph) x field efficiency (\%)}}{8.25^{1}} = \text{field capacity (A/hr)}$$

For example, assume a 24-foot tandem disk can be pulled at 6 miles per hour with a field efficiency of 80 percent. Its estimated field capacity is:

$$\frac{\text{24 feet x 6 mph x 80\%}}{8.25} = \text{14 acres per hour}$$

Suggested values for estimating field capacities can be found in Table 1, and in *AgDM Information File A3-24*, **Estimating Field Capacity of Farm Machines** *(PM 696)*.

To estimate the field capacity needed to complete a certain field operation in a set number of field days, use the following formula:

$$\frac{\text{acres to cover}}{\text{(days available x hours of field time per day)}} = \text{field capacity needed}$$

For example, to combine 900 acres of corn in 20 field days, harvesting 12 hours per day, would require a field capacity of:

$$\frac{\text{900 acres}}{\text{(20 days x 12 hours/day)}} = \text{3.75 acres per hour}$$

The minimum implement width then can be found by inverting the formula for field capacity:

$$\frac{\text{(8.25 x field capacity)}}{\text{(speed x field efficiency)}} = \text{width}$$

[1] *The factor 8.25 is a conversion factor calculated by 43,580 sq. feet per acre / 5,280 feet per mile.*

For the example, if the combine operates at 3 miles per hour with 70 percent field efficiency, the minimum width is:

$$\frac{(8.25 \text{ x } 3.75 \text{ acres/hour})}{(3.0 \text{ miles per hour x } 70\%)} = 14.7 \text{ feet}$$

The minimum width is about the size of a six-row, 30-inch corn head.

AgDM Decision Tool A3-24, **Estimating the Field Capacity of Farm Machines**, can be used to estimate the acreage capacity of a machinery implement.

Matching Tractor Power and Implement Size

For tillage and planting implements the size of the machine that can be used is often limited by the size of the available tractor. The horsepower needed to pull a certain implement depends on the width of the implement, the ground speed, draft requirement, and soil condition. The general formula for estimating the required horsepower measured at the power take-off (PTO) is:

$$\frac{\text{width (feet) x speed (mph) x draft (lb./ft.) x soil factor}}{375} = \text{PTO hp}$$

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	5.0	320	220 - 430 per foot
Medium soil	4.5	500	350 - 650 per foot
Heavy soil	4.5	800	580 - 1,140 per foot
Clay soil	4.0	1200	1,000 - 1,400 per foot
Chisel-plow			
(7-9 in. deep)	5.0	500	200 - 800 per shank
Disk			
Single gang	5.5	75	50 - 100 per foot
Tandem	5.5	200	100 - 300 per foot
Heavy or offset	5.0	325	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)	5.0	250	60 - 300 per foot
Row crop	4.5	80	40 - 120 per foot
Rotary hoe	7.5	84	30 - 100 per foot
Subsoiler (16 in. deep)			
Light soil	4.5	1500	1,100 - 1,800 per
Medium soil	4.5	2000	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	70	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

Source: Hunt, Donnell. Farm Power and Machinery Management, 9th edition, ISU Press, 1995, and Bowers, Wendell, Machinery Management, Deere and Company, 1987.

The soil factors are as follows:

	2WD	4WOA	4WD
firm soil	1.64	1.54	1.52
tilled soil	1.75	1.61	1.56
sandy or soft soil	2.13	1.82	1.67

Table 1 shows estimated draft requirements for various implements. For example, a 24-foot tandem disk being pulled at 6.0 mph in firm soil with a draft requirement of 200 pounds per foot of width would need the following PTO horsepower:

$$\frac{(24\ \text{ft. x } 6.0\ \text{mph x } 200\ \text{lb./ft. x } 1.5)}{375} = 115\ \text{PTO hp}$$

For some implements the width and the draft requirements are measured in terms of the number of teeth, shanks or rows rather than feet.

AgDM Decision Tool A3-28, **Matching Tractor Power and Implement Size**, can be used to match the size of a tractor to the size of an implement.

Estimating the Number of Field Days Required

The following worksheet can be used to estimate the number of field days required for tillage, planting and harvesting for a particular farming operation.

Column 1. List all the field operations to be done before planting. Include fall and spring tillage, application of chemicals, and sowing of small grain or forages. Do not include custom hired operations.

Column 2. List the total acres to be covered by each operation. Remember, if some acres have the same operation performed on them more than once, multiply the number of acres by the times over.

Column 3. List the sizes of the machines used for all operations.

Column 4. List the field capacity of each machine in acres per hour. Suggestions can be found in Table 1 or *AgDM Information File A3-24* **Estimating Field Capacity of Farm Machines** *(PM 696)*, or by using the following formula:

$$\frac{\text{width (ft) x speed (mph) x field efficiency (\%)}}{8.25} = \text{field capacity (A/hr)}$$

It may be more convenient to skip directly to column 6 and enter the number of acres covered per day, if this is known.

Column 5. Enter the number of labor hours available per day in the field to perform each tillage and preplant operation. Do not count time spent on repairs, transportation of machinery, livestock activities, etc. For planting and harvesting, enter the number of hours per day the planter or combine can be used.

Column 6. Multiply column 4 by column 5 to estimate the number of acres covered per day for each operation. Decide if this is a reasonable figure based on experience.

Column 7. Estimate the number of field days needed for each operation by dividing column 2 by column 6. Then find the total for each group of field operations.

Use extra lines to estimate how the number of field days required can be adjusted. Adjustments can be made by changing machinery size, number of field operations, number of acres covered, proportion of acres in each crop, hours available for fieldwork, or by custom hiring some operations.

This worksheet can also be used to estimate the number of field days required for harvesting forages. This can be compared to the expected number of field days available in the appropriate period, as shown in *AgDM Information File A3-25* **Fieldwork Days in Iowa** *(PM 1874)*.

AgDM Decision Tool A3-28, **Estimating Field Capacity of Farm Machinery**, can be used to estimate the number of field days required to complete field operations.

Field Days Worksheet Example—600 acres of corn, 600 acres of soybeans.

(1) Type of Operation	(2) Total Acres to be covered by Implement	(3) Your Implement Size	(4) Field Capacity Acres Per Hour	(5) Labor Available for Fieldwork Hours/Day	(6) Acres Covered Per Day (Col. 4 x Col. 5)	(7) Field Days Needed (Col. 2/Col. 6)
All Tillage and Pre-plant Chemical Application						
Apply nitrogen	600	15 ft.	6.5	12	78	7.7
Chisel plow	600	20 ft.	10	16	160	3.8
Tandem disk	1,200	27 ft.	15	16	240	5.0
Field cultivate	1,200	27 ft.	19	16	304	3.9
Planting						
Plant corn	600	12-30	13	16	208	2.9
Plant soybeans	600	12-30	13	16	208	2.9
					Total	26.2
Harvesting						
Harvest soybeans	600	18 ft.	4.6	10	46	13.0
Harvest corn	600	6-30	3.8	12	46	13.0
					Total	26.0

Field Days Worksheet

(1) Type of Operation	(2) Total Acres to be covered by Implement	(3) Your Implement Size	(4) Field Capacity Acres Per Hour	(5) Labor Available for Fieldwork Hours/Day	(6) Acres Covered Per Day (Col. 4 x Col. 5)	(7) Field Days Needed (Col. 2/Col. 6)
All Tillage and Pre-plant Chemical Application						
Planting						
Plant corn						
Plant soybeans						
					Total	
Harvesting						
Harvest soybeans						
Harvest corn						
					Total	

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