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USING FARM MACHINERY EFFECTIVELY

AGRICULTURAL EXPERIMENT STATION
R. DENNIS ROUSE, DIRECTOR

AUBURN UNIVERSITY
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USING FARM MACHINERY EFFECTIVELY

ELMO RENOLL[1]

SINCE FARM MACHINERY is so vital to Agriculture, it is important that it be used to the best possible advantage. This is especially important now as machines become faster, larger, more expensive, and more energy consuming than earlier models.

Farm machinery cannot be engaged in productive work 100 percent of the field time. Delays occur that result in lost time and reduced machine capacity. Time spent making field adjustments or repairs, adding seed, fertilizer, chemicals and water, and turning at row ends should be held to a minimum to gain maximum machine capacity.

At least two items play an important role in field machine capacity. One is machine management. Management includes when, where, and how the machine is used, crop type and size, flow of material to and away from the machine, as well as mechanical condition of the machine.

The second involves physical condition of the field. This includes field size and shape, topography, row length and arrangement, terrace layout, row-end turning space, and field surface and turn space conditions.

This publication presents data from a study dealing with farm machine performance rates as influenced by row length, field size, terrace arrangement, machine size, row-end conditions, and managerial ability.

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[1]Professor, Department of Agricultural Engineering.

Machines in the study were conventional row-crop types and included 4-row, 6-row, 8-row, and 12-row sizes. Machine operators were typical of those found on Alabama farms.

Various field sizes and conditions were included. Fields ranged from 8 to 200 acres having rows 400 to 2,500 feet long.

Data were obtained by time-record methods. This included time and activity records by manual observation as well as self-recording clocks attached to the various implements.

ROW END TURNING

The amount of time used for turning at row ends can be an important part of total machine field time. Space available for turning and the condition of the turn area influence the turning pattern as well as the time needed.

Turn Space and Pattern

Width of the turn area will usually dictate the kind of turning pattern used. Minimum time per turn usually results when the turn space is large and smooth enough for the machine to make an easy semi-circle turn. Narrow turning space which requires

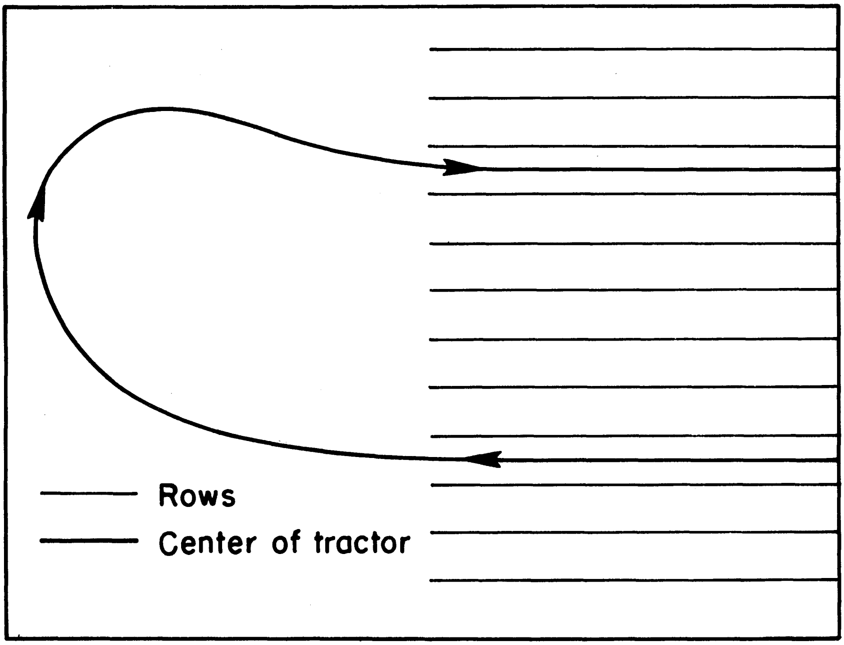


FIG. 1. Field edge space is wide enough for an easy turn. Semicircle turn requires minimum turning time and helps reduce operator fatigue and tractor wear.

backing the machine will increase turning time. Two common turning patterns for tractors doing row-crop work are shown in figures 1 and 2. The space in figure 1 is large enough for an easy turn. In figure 2 the turn space is too narrow to turn without backing the machine. This turn requires 50 percent more time than the semicircle turn.

Turning space needed for tractor mounted cultivators and planters is somewhat a function of the front-wheel arrangement of the tractor. This is especially true for tractors handling machines less than about 20 feet wide. A tricycle tractor requires less turning space than a wide-wheel tractor.

Minimum space for a semicircle turn should be 2½ times its length for a tricycle tractor and 3½ times for a wide-wheel one. The minimum space required for a semicircle turn for large row-crop machines such as combines and cotton pickers is twice the machine length.

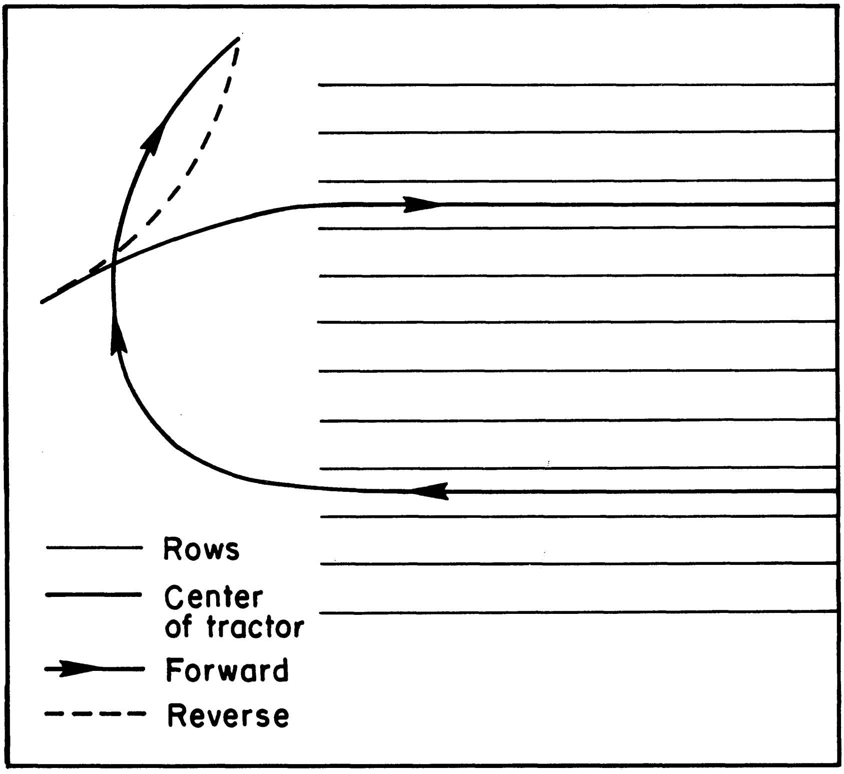


FIG. 2. A common turning pattern when turning space is too narrow for a single semicircle turn. Such turns require about 50 percent more time than the turn in figure 1.

TABLE 1. EXAMPLE OF THE INFLUENCE OF VARIOUS SURFACE CONDITIONS ON TURNING TIME

Implement	Smooth field turn area	Rough turn area	Sloping turn area	Terrace turn area	Good road turn
	Sec.	*Sec.*	*Sec.*	*Sec.*	*Sec.*
4-row planter	13.2	17.6	14.0	18.0	12.5
4-row cultivator	12.0	16.1	12.3	15.4	10.2
2-row cotton picker	17.7	23.5	20.0	19.0	18.2

Fields having irregular shapes and varying row lengths present additional turning problems. In many of these fields the rows do not intersect the field boundary at a right angle. In such conditions, the turn shown in figure 3a is easier to complete and requires less time and space than the turn in figure 3b.

Surface Condition and Turning Time

Surface conditions as well as obstructions in the turning area will influence turning time, table 1.

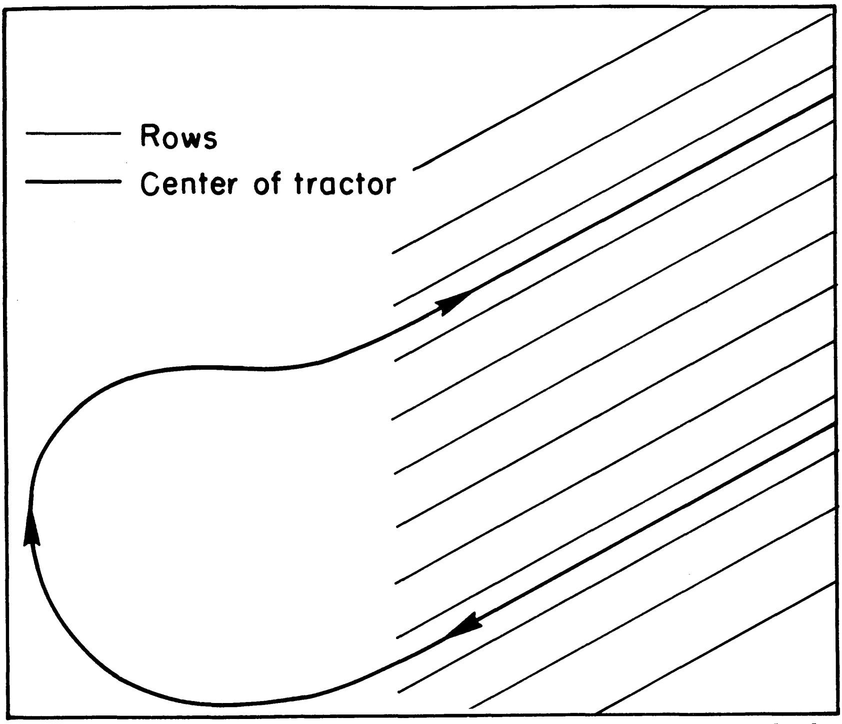


FIG. 3a-b. Turn shown in Fig. 3a is recommended where rows are not perpendicular to the field edge. This turn requires less time and space and makes lining up the machine on the next rows easier than if the turn pattern in figure 3b is used.

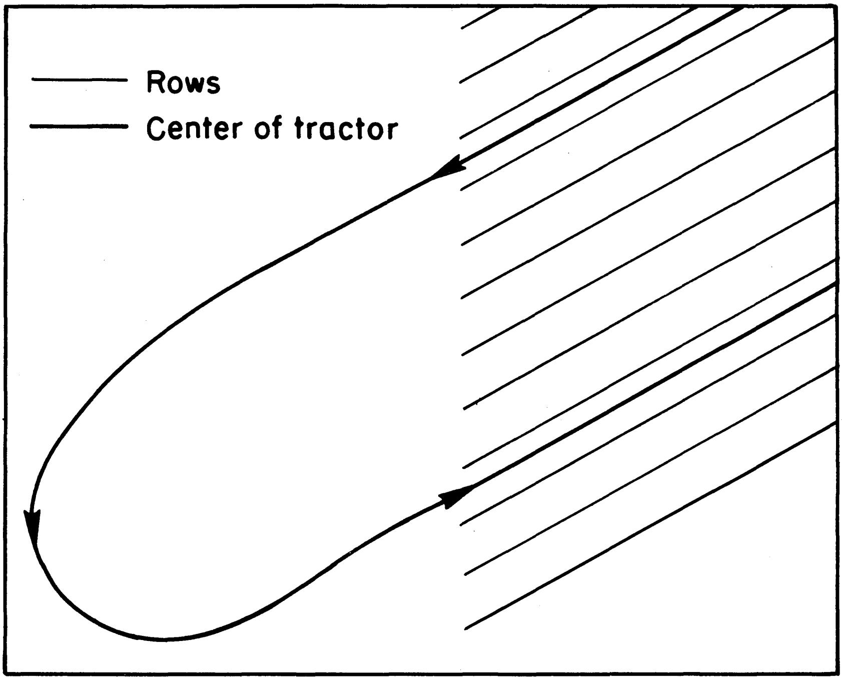


FIG. 3b

Turning on a smooth field surface or a good field road requires minimum turning time. A turning area that is rough, or involves a terrace, or a steep slope requires more time. This time increase can be considerable and in the case of the 4-row cultivator in table 1 represents an increase of as much as 58 percent.

Turning time greatly influences the capacity of the machine. Total turning time per acre is influenced by row length and as row length increases turning time decreases and machine capacity increases. As farm machinery operating speeds increase, time spent turning becomes increasingly important as indicated in figure 4.

ROW LENGTH

Row length is influenced by various things including row arrangement, field size, and terracing system.

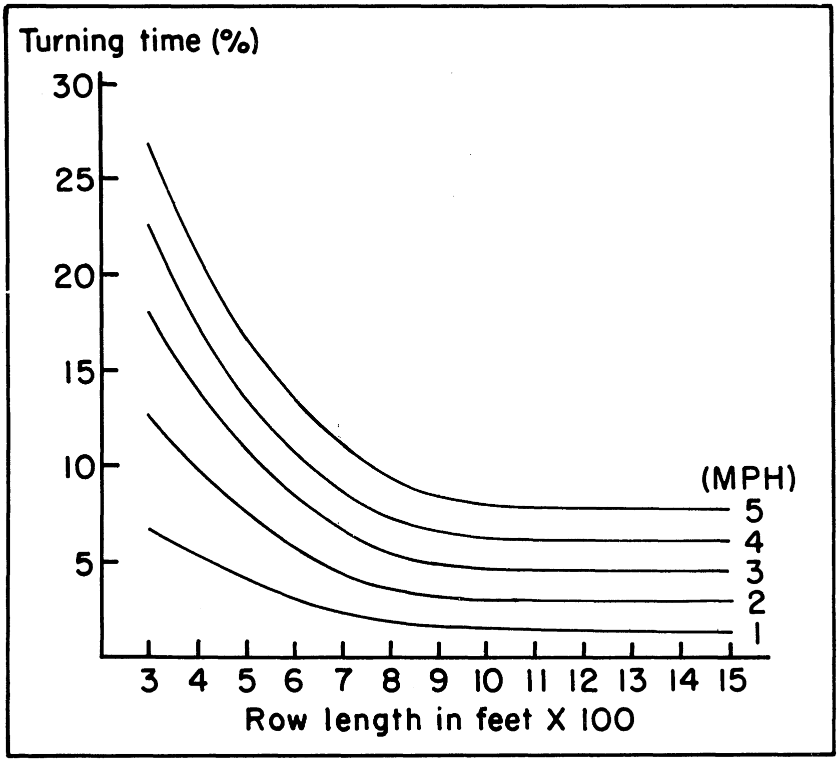


FIG. 4. Percent time spent turning, speed of operation and field row length are interrelated. As machine ground speed increases row length becomes increasingly more important.

Importance of Row Length

Field operation studies suggest that a turning time of 6 to 10 percent can be obtained when fields have reasonable row length and good turn conditions. A turning time of more than 10 percent is excessive for most operations.

Field size, row length, and machine size also are interrelated. For efficient operation large farm machines need big fields with long rows. When changing from 4-row to 6-row or 8-row machines, serious consideration should be given to ways of increasing row length and field size. If field machine efficiency is to be kept high for these larger machines, they should be used in fields where the majority of the rows exceed 700 feet.

TABLE 2. 4-ROW CULTIVATOR CAPACITY FOR THREE FIELD CONDITIONS

	Capacity	Row end turning time	Field length	Average speed
	Acres/hr.	*Pct.*	*Ft.*	*Mph.*
Nonparallel terraces	5.0	14.0	1,250	4.0
Parallel terraces	6.4	8.0	1,175	4.5
No terraces	7.6	8.0	1,125	5.3

Terrace and Row Arrangement

Field row length is also influenced by terraces and other soil conserving structures. The number of terraces as well as terrace layout influence row arrangement, row length, and machine acre-per-hour capacity. Table 2 presents data for a 4-row cultivator operating under three field conditions including no terraces, parallel terraces and nonparallel terraces. Percent turning time is highest for the nonparallel area. This area also has the lowest average speed and lowest effective cultivator capacity. Parallel terraces should be used where practical. In fields where conventional terraces must be used, consideration should be given to terrace arrangements that minimize short rows between terraces.

Some fields that need terracing cannot be parallel terraced. In some fields row length can be increased by placing rows crosswise to the major field slope but not necessarily parallel to the terraces. In this arrangement some rows cross the terraces at an angle. Two such row arrangements are shown in figures 6 and 7 and a more conventional arrangement with rows parallel to the terraces is indicated in figure 5. The row arrangement in figure 6 has the fewest rows and figure 5 the most. Figure 6 has the largest number of rows covering the entire field length. Figure 6 has all turns at the field edge while the other two each have some turns within the field.

Turning at field edges is usually easier and thus should reduce wear on the tractor and fatigue on the operator. Within-the-field turns usually cause more crop damage than field-edge turns.

Rows that run across terraces can present some problems. Operating across terraces requires machines that are flexible and some current models are too rigid for such use. Planter and cultivator sidesway as these machines cross the terrace can cause crooked rows and plowed-up plants. Machines crossing

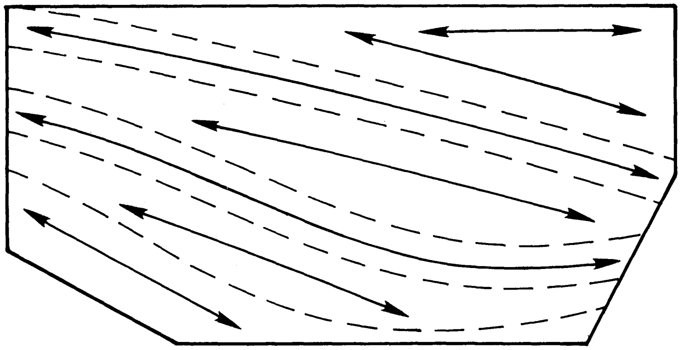


FIG. 5. Conventional row arrangement with most rows parallel to the terraces. Note the large number of short rows.

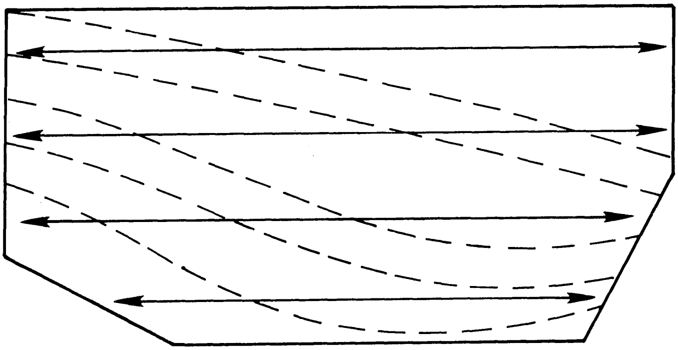


FIG. 6. Rows parallel to one edge of the field and crosswise to the major field slope. All rows cross the terraces.

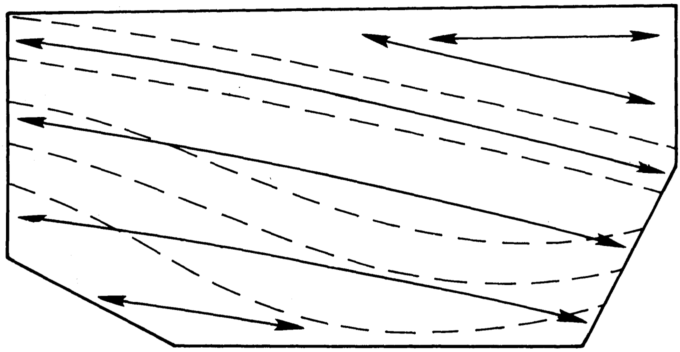
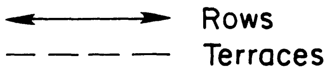


FIG. 7. Most rows are parallel to the upper terraces. In this arrangement some rows cross the terraces.



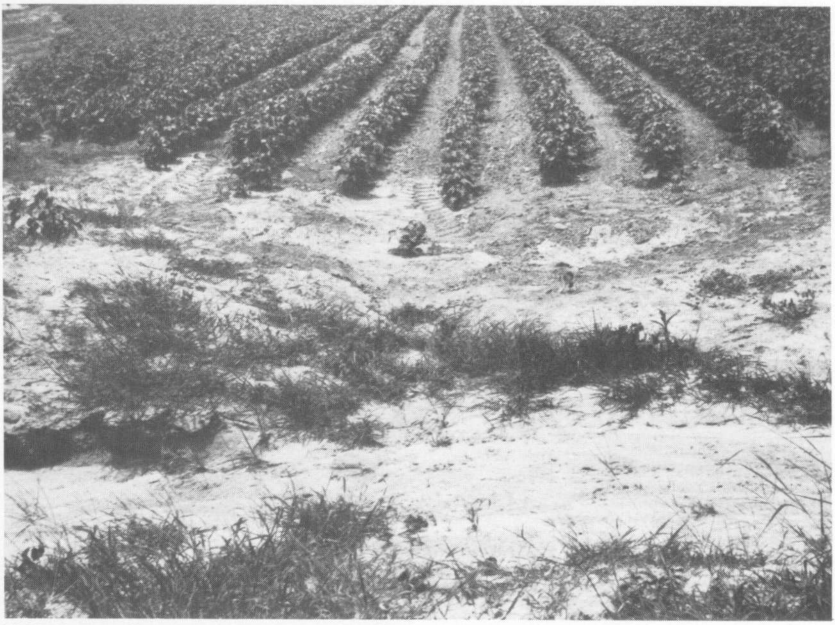


FIG. 8. Rough turning space at row ends increases machine turning time and reduces machine capacity.

FIG. 9. Turning areas that are smooth and wide reduce turning time and operator fatigue.

the terraces tend to move some soil from the terrace ridge into the channel and thus can reduce the effectiveness of the terrace. Wet weather conditions can also present problems.

Field Size and Shape

The geometric shape and the physical size of fields will influence the capacity of machines used on them. Field row length is frequently a function of field shape and size.

An example of the importance of field shape is indicated in a study of a 4-row cultivator operating at 4 mph on two fields, each containing 10 acres. One field was nearly square and had rows 660 feet long. Cultivator capacity was 5.7 acres per hour. The other field was rectangular in shape with 1,300-foot rows and had a cultivator capacity of 6.2 acres per hour.

Combining several small fields into a large one is another way to increased machine capacity. In a recent study two fields, A and B, were originally operated as small separate fields with short rows. A 6-row cultivator had a capacity of 6.7

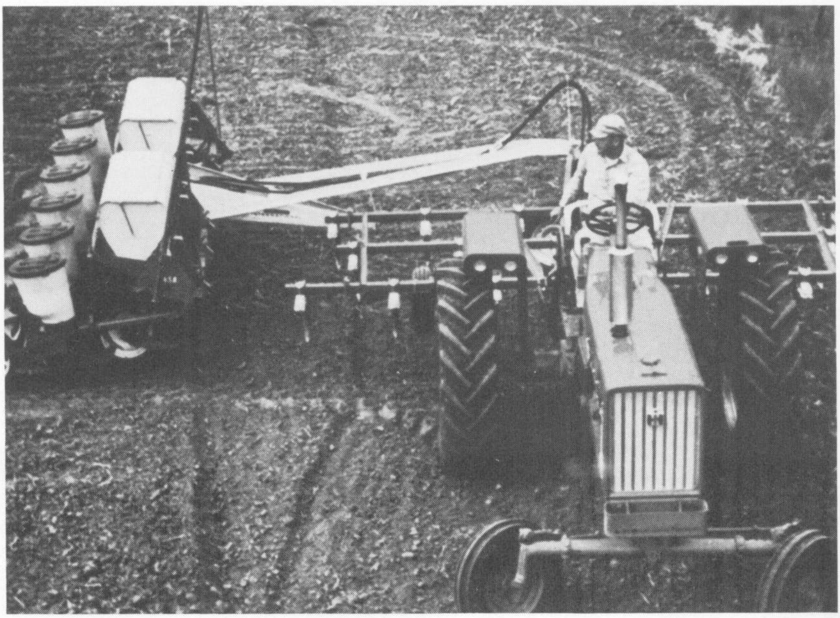


FIG. 10. Turning machines in a semi circle pattern minimizes turning time and reduces tractor wear.

acres per hour in field A and 6.9 in field B. When these two fields were consolidated into one larger field and rows rearranged the cultivator covered 7.3 acres per hour.

OPERATION ANALYSIS

Operational analysis is another procedure useful in obtaining efficient machine utilization and increased machine capacity. This is essentially a study of the total crop-production system including machines, fields, and management. These items are examined individually and collectively to determine their influence on machine performance rates.

An operation analysis involves three basic items. The first is to obtain an accurate time record of all activities relating to a specific machine operation in a field. An example of this would be a complete field-time record of cotton planting and would include the increments of time related to each major segment of the total planting operation, table 3.

The second item of the operation analysis involves dividing the time record into primary and support functions, table 4. In a planting operation, placing seed in the ground is the primary function. Support functions include turning, adjustments, and adding seed, chemical and fertilizer. Each component operation is expressed as a percent of total field time.

The third item involves a detailed analysis of the information obtained in items one and two. This includes a careful examination of each segment of the operation to determine if the time for any appears to be excessive when compared to average values from reasonably efficient operations. Typical support-function values, expressed in percent of total field time, for some common row-crop operations are given in table 5.

TABLE 3. PLANTING OPERATION TIME RECORD FOR A 4-ROW PLANTER

Operation	Total time	
	Hr.	*Min.*
Total field operation time	8	0
Actually placing seed in ground	3	12
Adjustment and down time	0	24
Adding seed	0	31
Adding fertilizer	1	37
Adding chemicals and water	1	56
Turning time	0	20

TABLE 4. PLANTER OPERATION ANALYSIS FOR A 4-ROW PLANTER

Operation	Total time
	Pct.
Primary Function	
Actually placing seed in ground	41
Support Functions	59
Adjustments and down time	5
Adding seed	6
Adding fertilizer	20
Adding chemicals and water	24
Turning time	4

This analysis takes into account physical conditions of the field, the machines used, and any managerial decisions that might have influenced the time record. After a detailed analysis is completed, changes in future operational procedures are recommended for those segments which show the greatest possibility for improving the efficiency of the total operation.

The value and use of operation analysis can be illustrated with the planting data. In table 4 support functions use 59 percent of the total field operating time. In relatively efficient planting operations support functions use 31 to 49 percent, table 5. Since support function time is excessive, these items need to be examined individually. In efficient planting operations, adding fertilizer uses 10-14 percent of the total field time and adding spray chemicals uses another 7-9 percent. In the cotton planting example the values were 20 and 24 percent respectively. This suggests that changes need to be made which will reduce the time required to handle these items.

Times used for turning and adjustment, in the cotton planting example, are in the range for efficient operations. In cases where turning time is excessive, the farm manager should examine field size, row arrangement, terrace layout, row length, and physical condition of the turn area to determine if changes can be made to reduce total turning time and thus improve efficiency.

If planter adjusting time is excessive there may be several management problems. These might include poor seedbed preparation, improper planter set-up before going to the field, or improper operator training which could result in a trial-and-error approach to planter adjustment. Planter maintenance, repair, calibration, and major adjustment should be completed prior to the start of planting.

TABLE 5. TYPICAL FARM MACHINERY SUPPORT-FUNCTION VALUES EXPRESSED IN % OF TOTAL FIELD TIME

Machine Operation	Support-function values					
	Adjustments	Other delays	Add seed	Add fertilizer	Add spray chemicals	Turning time
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Plant (4-row)	3-7	3-4	3-5	10-14	7-9	5-10
Cultivate (4-row)	5-7	3-4				5-10
Plant (6-row)	3-8	3-5	3-5	10-14	7-9	5-10
Cultivate (6-row)	5-8	3-5				5-10
Spray (12-row)	3-5	2-3			6-9	5-10
Harrow	1-3	0-1				5-10
Harrow and apply chemicals	2-4	0-1			10-12	5-10
Plow (4-bottom)	2-5	1-3				5-10
Plow (6-bottom)	3-6	1-3				5-10

FIG. 11. Large self-propelled machines frequently need 20 to 30 feet of turning space.

FIG. 12. Large fields and long rows are conducive to high field machine efficiency and increased machine capacity.

FIELD MACHINE INDEX

Field machine index (FMI) indicates how well adapted a specific field is for the use of machinery on it. It involves row-end turning conditions and row length and their influence on actual field production time and total row-end turning time.

The FMI is the ratio of the productive machine time to the sum of productive machine time plus the row-end turning time. Productive time is the actual time a machine is doing its specific job. For a planting operation, this would be the time actually spent placing seed in the ground. Time used for support functions, such as filling hoppers, making adjustments, and other "down time" is omitted before the FMI is calculated.

The maximum FMI is 100. A field that has a field machine index of 95 is better adapted to machine use than a field with an index of 85.

Determining the Index

Three basic items of information are needed to determine the field machine index: (A) total time used to complete the field operation, (B) total support function time, not including turning and (C) total turning time.

The FMI formula is expressed as follows:

$$\text{FMI} = \frac{\text{A - B - C}}{\text{A-B}} \times 100$$

Where A, B, and C correspond to the items listed above.

A cultivation operation is used as an example to illustrate the concept. Item (A) is the total cultivating time, expressed in minutes, required to cultivate the field. Item (B) is support function time in minutes and includes such items as adjusting sweeps, cleaning sweeps and rest stops. Item (C) includes total time spent turning at row ends while cultivating the field, table 6.

TABLE 6. TIME FOR EACH SEGMENT OF CULTIVATION OPERATION

Segment of operation	Time used
	Minutes
(A) Total time to cultivate field	2,000
(B) Total support function time (not including turning time)	100
(C) Total time turning	152

The FMI is obtained by making the necessary substitutions and calculations indicated.

$$FMI = \frac{A - B - C}{A - B} \times 100 =$$

$$FMI = \frac{2{,}000 - 100 - 152}{2{,}000 - 100} \times 100 =$$

$$FMI = \frac{1{,}748}{1{,}900} \times 100 = 92$$

Using the Index

One of the chief uses of the FMI is to determine the suitability of a field for machinery use. A farm manager who has a choice of planting some fields and leaving out others could use the FMI concept and plant those fields best suited for machinery use. For such comparisons to be valid the same machine and ground speed must be used on all fields involved.

In like manner, a farmer interested in improving field conditions for machinery use could examine the fields with low index values and make the necessary changes for improvement.

The FMI for a specific machine operation on a particular field is correlated with machine capacity. For example, a high FMI indicates high acre-per-hour machine capacity. Thus FMI is useful in predicting machine capacity and for determining machinery needs and hours of use.

It should be pointed out that the FMI for a specific machine on a particular field is also correlated with indexes for other machines used on that same field. If the FMI is relatively low for one machine operation it tends to be low for other operations on that same field.

Fields which are reasonably well suited for machinery use will have a field machine index of 88 or more. Fields having index values less than 88 should be examined for possible ways to increase average row length, and to improve turning space and conditions.

ACKNOWLEDGMENT

The author wishes to express thanks to W. T. Dumas and the staff of the Agricultural Engineering Research Unit and to Donald M. Smith, formerly of the Department of Agricultural Engineering for assistance with this project. Appreciation is expressed also to numerous agricultural engineering students who helped collect data.

APPENDIX

Calculating Machine Capacity

The following methods are commonly used to determine machine capacity in acres per hour:

Method I. Simple method used to get a quick approximation.

$$C = \frac{W \times S}{10}$$

C = Capacity (acres/hour)
W = Machine width (feet)
S = Ground speed (mph)

This method allows for 17.5 percent nonproductive and down time.

Example: 4-row cultivator, 40″ rows
Speed - 5 mph

$$\text{Machine width} = \frac{4 \times 40}{12} = 13.3 \text{ feet}$$

$$\frac{13.3 \times 5}{10} = 6.6 \text{ acre/hour}$$

Method II. A more accurate method of predicting acres per hour.

$$C = \frac{5{,}280 \times S \times W \times E}{43{,}560 \times 100} = \frac{SWE}{825}$$

C = Capacity (acres/hour)
S = Ground speed (mph)
W = Machine width (feet)
E = Field efficiency in percent (Typical values for field efficiency can be found in appendix table 3)

Example: 4-row cultivator, 40″ rows
Speed - 5 mph
Width - 13.3 feet
Efficiency - 80%

$$\frac{5 \times 13.3 \times 80}{825} = 6.4 \text{ acres/hour}$$

Calculating Speed in Miles Per Hour

The following methods can be used to calculate speed of operation in miles per hour.

Method I. Use when speed in feet per minute is known.

$$\frac{F \times 60}{5{,}280} = M$$

M = Speed (mph)
F = Feet traveled in one minute

Example: Cultivator travels 264 feet in one minute

$$\frac{264 \times 60}{5{,}280} = 3.0 \text{ miles per hour}$$

The values in appendix table 1 were compiled in this way.

APPENDIX TABLE 1. CONVERSION TABLE FEET PER MINUTE AND MILES PER HOUR

Feet per minute	Miles per hour	Feet per minute	Miles per hour	Feet per minute	Miles per hour
176	2.0	361	4.1	535	6.1
185	2.1	370	4.2	543	6.2
194	2.2	379	4.3	552	6.3
202	2.3	387	4.4	561	6.4
211	2.4	396	4.5	570	6.5
220	2.5	405	4.6	578	6.6
229	2.6	414	4.7	588	6.7
237	2.7	422	4.8	596	6.8
246	2.8	431	4.9	605	6.9
255	2.9	440	5.0	614	7.0
264	3.0	449	5.1	622	7.1
273	3.1	458	5.2	631	7.2
282	3.2	468	5.3	640	7.3
292	3.3	476	5.4	649	7.4
299	3.4	484	5.5	658	7.5
308	3.5	493	5.6	666	7.6
317	3.6	502	5.7	675	7.7
325	3.7	510	5.8	684	7.8
334	3.8	519	5.9	693	7.9
343	3.9	528	6.0	702	8.0
352	4.0				

Method II. Use when time in seconds to cover a distance of 100 feet is known.

$$\frac{68.5}{T} = M$$

M = Speed (mph)
T = Time in seconds to travel 100 feet

Example: Planter travels 100 feet in 20 seconds

$$\frac{68.5}{20} = 3.4 \text{ miles per hour}$$

The values in appendix table 2 were compiled in this way.

APPENDIX TABLE 2. CONVERSION TABLE SECONDS PER 100 FEET AND MILES PER HOUR

Seconds per 100 ft.	Miles per hour	Seconds per 100 ft.	Miles per hour	Seconds per 100 ft.	Miles per hour
69.0	1.0	22.7	3.0	13.6	5.0
62.0	1.1	22.0	3.1	13.3	5.1
56.8	1.2	21.3	3.2	13.1	5.2
52.5	1.3	20.6	3.3	12.9	5.3
48.6	1.4	20.0	3.4	12.6	5.4
45.4	1.5	19.5	3.5	12.4	5.5
42.6	1.6	18.9	3.6	12.2	5.6
40.1	1.7	18.4	3.7	12.0	5.7
37.9	1.8	17.9	3.8	11.8	5.8
35.9	1.9	17.5	3.9	11.6	5.9
34.1	2.0	17.0	4.0	11.4	6.0
32.3	2.1	16.6	4.1	11.2	6.1
31.0	2.2	16.2	4.2	11.0	6.2
29.6	2.3	15.8	4.3	10.9	6.3
28.4	2.4	15.5	4.4	10.7	6.4
27.3	2.5	15.1	4.5	10.5	6.5
26.2	2.6	14.8	4.6		
25.3	2.7	14.5	4.7		
24.3	2.8	14.2	4.8		
23.5	2.9	13.9	4.9		

APPENDIX TABLE 3. MACHINERY PERFORMANCE DATA

Machine	Speed	Typical range for field efficiency
	Mph.	*Pct.*
Tillage		
Moldboard or disk plow	3.5-6	70-90
Chisel plow	4-6	70-90
Subsoiler	3-5	70-90
Harrow		
Single disk	3-6	70-90
Tandem disk	3-6	70-90
Offset or heavy tandem disk	3-6	70-90
Spring tooth	3-6	70-90
Spike tooth	3-6	70-90
Rotary hoe	5-10	70-85
Rolling cultivator	5-8	70-85
Field cultivator	3-8	70-90
Row crop cultivator (sweep)		
First cultivation	1.5-3	70-85
Later cultivation	3-5	70-85
Fertilizer and chemical application	3-5	70-85
Fertilizer spreader, pull-type	3-5	60-75
Anhydrous ammonia applicator	3-5	60-75
Planting		
Row crop, seed only	3-6	55-75
Row crop, seed & fertilizer	3-6	50-70
Row crop, seed & fertilizer & chemicals	3-6	50-65
Grain drill	2.5-6	65-85
Harvesting		
Mower	5-7	75-85

(continued)

APPENDIX TABLE 3 (*continued*) MACHINERY PERFORMANCE DATA

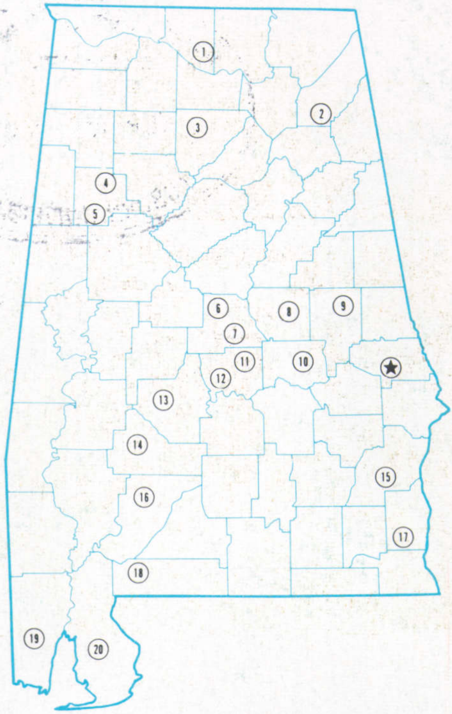
Machine	Speed	Typical range for field efficiency
	Mph.	*Pct.*
Mower-conditioner, cutterbar type	4-6	60-85
Mower-conditioner, flail type	4-6	60-85
Self-propelled mower-conditioner-windrower	3-6	55-85
Hay conditioner	5-7	75-85
Rake	4-6	70-85
Combine		
Small grain	2-4	65-75
Corn	2-4	65-75
Corn picker	2-4	60-80
Cotton picker (spindle machine)	1.5-3	65-75

APPENDIX TABLE 4. ROWS PER ACRE FOR VARIOUS ROW SPACINGS

Row length in feet	Row spacing					
	40 in.	38 in.	36 in.	30 in.	28 in.	20 in.
	Rows/acre	*Rows/acre*	*Rows/acre*	*Rows/acre*	*Rows/acre*	*Rows/acre*
400	32.8	34.4	36.3	43.6	46.7	65.5
600	21.8	23.0	24.2	29.0	31.1	43.5
800	16.4	17.5	18.2	21.9	23.5	32.8
1,000	13.0	13.8	14.5	17.4	18.6	26.0
1,200	10.7	11.4	12.1	14.5	15.5	21.5
1,400	9.2	9.8	10.3	12.4	13.3	18.4
1,600	8.2	8.6	9.1	10.9	11.7	16.4
1,800	7.2	7.6	8.0	9.6	10.3	14.4
2,000	6.5	6.9	7.2	8.6	9.3	13.0

Alabama's Agricultural Experiment Station System
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Lower Coastal Plain Substation, Camden.
15. Forestry Unit, Barbour County.
16. Monroeville Experiment Field, Monroeville.
17. Wiregrass Substation, Headland.
18. Brewton Experiment Field, Brewton.
19. Ornamental Horticulture Field Station, Spring Hill.
20. Gulf Coast Substation, Fairhope.