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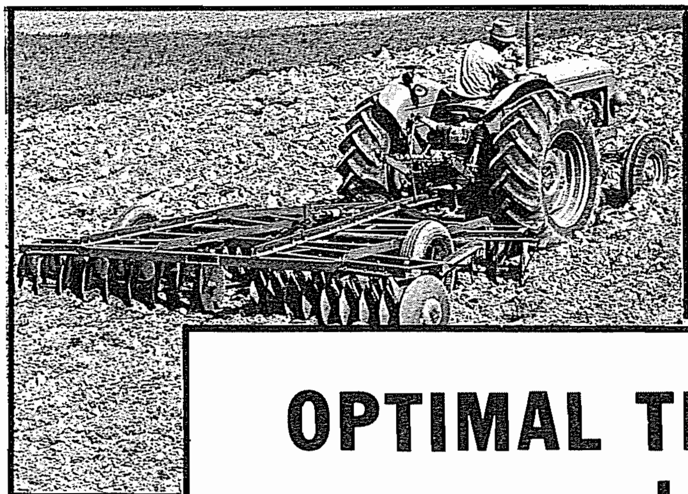
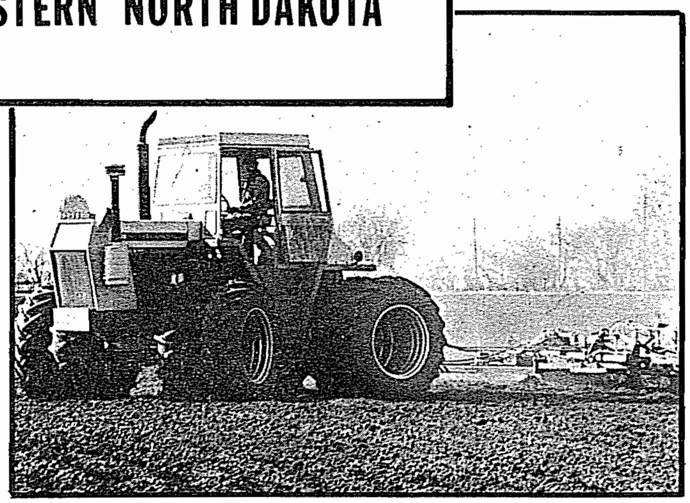


OPTIMAL TILLAGE and PLANTING EQUIPMENT for CENTRAL and WESTERN NORTH DAKOTA



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HIGHLIGHTS

This study uses some rather simple assumptions to budget optimal combinations of equipment for tillage and seeding operations in central and western North Dakota.

Maximum capacity tillage and seeding acreages were estimated for a variety of machinery combinations using assumptions on time available for seeding, standard tillage practices, and standard field efficiencies of tillage and seeding operations. The purpose of this analysis was to develop guidelines for machinery selection to minimize machinery investment, or on the other hand, to indicate the maximum acreage one could possibly operate with given equipment.

With one-man, one-tractor combinations, per acre machinery and labor costs decline as the size of the tractor is increased because labor costs decrease more than machinery costs increase. Obviously, this depends on the price of labor. However, costs tend to decrease as size of tractor increases.

The spring tillage and seeding operation was found to set the limit on acreage capacity of given equipment. Seeding was particularly a bottleneck with systems that did not include spring plowing. The inefficiency and cumbersome nature of large drills was found to limit the usefulness of large tractors. Tractors of 300 horsepower could probably pull up to 100 feet of drill but such drills would have poor field efficiency and would create problems in moving from field to field.

Hence, a better way to organize seeding operations is to have a smaller tractor pulling a drill and a larger tractor for tillage.

Performance of tillage operations during both day and night was compared with usual day time operations. However, since it was assumed that seeding could not be done at night and seeding capacity was the bottleneck in many cases, the night time operation simply allowed substitution of night labor and a smaller tractor for the large tractor for tillage. This substitution, due to higher labor costs, gave very little savings.

These estimates are optimistic in terms of capacity but are considered attainable.

OPTIMAL TILLAGE AND PLANTING EQUIPMENT COMBINATIONS FOR CENTRAL AND WESTERN NORTH DAKOTA

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Efficiency has always been important to farmers, but rising costs of labor and machinery increase the need for farmers to get maximum use from their inputs. Choosing the right combinations of equipment to match the land and labor available is one way to control production costs.

In recent years some farmers in North Dakota have converted to four-wheel drive tractors that have from 150 to 300 horsepower and cost up to $40,000.[1] Their aim is to reduce costs by substituting machinery for labor.

In this paper a rather simple approach is used to determine some optimal machinery-land-labor combinations. Given a set of assumptions on time available for operations, tillage operations needed, and machinery capacities, the maximum acreage capacity of various combinations is determined. These estimates are intended, not as average cost estimates, but as minimal costs achievable by optimally matching equipment and labor with land. These estimates should be considered as attainable goals rather than average current costs.

Only tillage and seeding operations are examined. Harvesting and grain hauling operations are not considered nor are costs of such operations examined here. It is assumed that these operations are independent from tillage operations. Grain trucks, which are primarily used for harvest operations, are assumed available for hauling seed and fertilizer. The possible need for tractors for harvest was ignored. The use of self-propelled swathers and combines makes the separation of tillage and harvest almost complete on many farms. The tractors budgeted in this paper would be available for harvest use but no hours of use are determined.

Area of Study

This analysis is primarily directed at farming operations in the western half or two-thirds of North Dakota. Tillage operations vary in this area but are fairly similar. Very little fall plowing is found in

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[1] As used in this paper, "horsepower" is taken as the manufacturer's advertised engine rating and not tested drawbar horsepower.

any part of the area. Summer fallow is a usual practice but varies from one-fourth to one-half of the cropland. Generally, the further west, the lower the rainfall and the greater dependence on summer fallow. Survey data indicate that the number of times over on fallow varies from 4.03 times in the southwest to 5.52 in the northwest central area. Generally, the number of times over increases with rainfall, being greater in the central part of the state than in the west, and will vary from year to year with differences in rainfall.[2]

Operations Performed

The basic sequences of tillage operations used in budgeting costs are outlined in Table 1. This sequence is assumed to apply regardless of what crop is grown and regardless of the percent of land in fallow. Budgets are prepared for a crop-fallow system and a crop-crop-fallow system.

Data indicate that there is an extreme amount of variation in operations performed prior to spring planting. About 59 percent of second year cropland is plowed and seeded with a pony drill in one operation and the remainder is tilled with various combinations of implements. This also varies across the area. In the northwest and northwest central areas the number of spring tillage operations prior to seeding averages about 2.4 compared to about 1.6 in the southwest and south central. In this report, all land used for crop after fallow is assumed to be tilled twice prior to seeding and second year cropland is budgeted two ways, once with a plow-pony drill and once with a field cultivator or disc tillage (see Table 1).

Fall tillage of stubble land was found to be extremely variable but as an average about one-third of stubble fields are tilled in the fall after harvest. This practice would vary primarily because of weed problems and moisture conditions.

Time Available for Tillage

Previous work indicates that for most of North Dakota, farmers would have 20 days available for spring operations in 19 out of 20 years.[3] Hence, in this paper it was assumed that 20 days was the maximum amount of time available for spring preplant tillage and planting.

Estimates of time available for summer fallow work or fall tillage work have not been made. Weather is generally not a problem in these

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[2] Based on reports by Held, L. J., and Johnson, R. G., and Schaffner, L. W., "Small Grain Production Practices and Size and Type of Machinery Used," Ag. Econ. Stat. Series No's. 12, 13, 14, 15. Ag. Econ. Dept., NDSU, April 1973.

[3] Olsen, Carl E. <u>et</u>. <u>al</u>. "Weather and Profitable Machinery Size," Circ. A-534. North Dakota State Experiment Station, August 1969.

TABLE 1. SEQUENCE AND NUMBER OF FIELD TILLAGE OPERATIONS.[1]

Summer Fallow	Crop After Fallow	Crop After Crop
Previous Fall	Previous Fall	Previous Fall
One-third of land tilled once with tandem disc or spike-tooth field cultivator.	None.	One-third of land tilled once with tandem disc or spike-tooth field cultivator.
Spring (May - June)	Spring	Spring
Two times over with chisel plow.	Once over with chisel plow, once over with tandem disc or field cultivator, drill.	(Alternate #1)[2]. Once over with chisel plow, once over with tandem disc or field cultivator, drill.
Summer (June-July-Aug.)		Spring
Three times over with field cultivator or tandem disc.		(Alternate #2)[2]. Plow-packer-pony drill. Harrow once.

[1]Based on reports by Held, L. J., Johnson, R. G., and Schaffner, L. W., "Small Grain Production Practices and Size and Type of Machinery Used," Ag. Econ. Statistical Series No.'s 12, 13, 14, 15. Ag. Econ. Dept., NDSU, April 1973.

[2]Data indicate that about 59 percent of second year cropland is planted with plow-packer-pony drill; hence, this is budgeted two ways.

seasons but wet weather in the summer fallow period not only reduces the time available for field operations but increases the need for tillage. In this paper a limit of 500 hours per tractor was placed on summer fallow operations. This estimate was quite arbitrary and may need further study. If anything, this estimate may be on the high side.

No time limits were placed on fall tillage operations. Generally, fall tillage is not critical. The small amount of fall tillage here assumed could quite easily be performed in the time available.

Field Efficiency

The field efficiencies of machines are standard engineering coefficients. With field cultivator, disc, and chisel plow operations, field efficiency was assumed to be 85 percent of the rated efficiency widths and speeds for all sizes of machinery. It is quite likely that field efficiency decreases with increasing size of implement but little data are available on this topic.

All seeding is assumed to be performed with a press drill with a fertilizer attachment. Field efficiency of drills was assumed to decrease slightly as size increases. To maintain the same level of field efficiency, an operator would have to spend the same percent of the time moving. As drill size increases, the volume of grain and fertilizer to be handled increases, thus the time required to fill the drill increases with size of drill and, hence, moving time is reduced. To offset the increased time required for drill filling, a mechanical drill filling system including a fertilizer bin and two augers was included for systems calling for drills of 24' or more. With this system, field efficiencies were assumed to vary from 71 percent for 14' drills down to 64 percent for 48' drills. Without mechanical drill filling equipment the field efficiencies of a 36' drill was estimated at only 55 percent.

Annual Machinery Cost

In the following budgets an estimate is presented on the per acre average investment in equipment and an annual per acre cost estimate. The annual cost estimate includes depreciation, repairs, interest, insurance, and fuel. Depreciation and repair costs were estimated on an hourly basis according to engineering formula described in the footnote to Table 4. Interest is 8 percent of average investment. Fuel costs for tillage and planting operations were estimated, using the assumptions detailed in Table 2. Nebraska tractor test data were used in preparing these estimates. All tractors were assumed to be diesel powered.

Labor Costs

Labor use for machine operations was estimated by adding 10 percent to tractor hours. This 10 percent is an allowance for time spent fueling, greasing, adjusting equipment, and travel to and from fields.

TABLE 2. DIESEL FUEL USE AND COST PER HOUR.

Tractor Size Engine H.P.	Diesel Fuel (gal./hour)	Fuel Cost[2] ($/hour)	Fuel & Lub. Cost[3] ($/hour)
65	4.3	.80	.92
75	4.9	.91	1.05
90	5.8	1.07	1.23
110	7.0	1.30	1.50
130	8.2	1.52	1.75
175	10.9	2.02	2.32
200	12.4	2.29	2.63
250	15.4	2.85	3.28
300	18.4	3.40	3.91

[1]Based on random sample of Nebraska test reports. Diesel fuel consumption increases .6 gal./hour for each additional 10 p.t.o. h.p.

[2]Diesel fuel cost of 18.5¢/gallon.

[3]Lubrication cost = 15 percent of fuel cost.

A rate of $2.50 per hour is charged for this operator time. In budgets which include night time operations, a 10 percent differential is added ($2.75/hour).

The reader is cautioned that these costs are only for tillage and seeding operations and include no harvest costs nor any of the other production costs of farming.

Machinery Combinations

The tractors and machinery combinations studied and their field capacities are presented in Tables 3 and 4. Assumptions regarding the capacities and costs are given in the footnotes to these tables. In addition to the nine basic sizes of tractors and their complements of machinery, combinations of two or more tractors and needed machines were developed and budgets prepared. Ownership costs and operating costs of these machines are presented in Table 5.

In all machinery combinations the interest and insurance costs of an appropriate sized harrow are included even where its use is not specified. Tractor costs for harrowing are included only with plowing of second year cropland on the one-third fallow system. Also, the interest and insurance costs of a tandem disc are included in each combination. The size of the disc is the same as that of the field cultivator. A disc is included for the sake of flexibility and it is assumed that the operator could substitute the disc for the field cultivator at the same per hour repair, depreciation, and fuel costs.

TABLE 3. MACHINERY COMBINATIONS.

Tractor Size h.p.[1]	Chisel plow or tool bar (ft.)	Field cultivator or tandem disc (ft.)	Press drill (ft.)	Plow packer & drill (no. bottoms)	Harrow (ft.)
	Maximum Size of Implement[2]				
65	12	14	24	4-14"	40
75	14	16	28	4-16"	50
90	16	20	36	5-16"	60
110	20	24	42	6-16"	70
130	24	27	48	7-16"	80
175	32	38	48	11-14"	100
200	36	44	48	14-14"[3]	100
250	45	55	48	16-16"[3]	100
300	55	66	48	16-18"[3]	100

[1]The horsepower definition here used is the manufacturer's advertised engine horsepower.

[2]Implement use determined by assuming approximately 5.5 h.p. required per foot of chisel plow, 4.5 h.p. per foot of field cultivator, or tandem disc, 13.5 h.p. per foot of plow, packer and pony drill, 2.75 h.p. per foot of press drill, and 1.6 h.p. per foot of harrow. Drills larger than 48' not considered.

[3]No pony drill.

TABLE 4. FIELD CAPACITIES OF SPECIFIED MACHINERY.

Machine	Field Capacity acres/hour	Field Capacity hours/acre
	(speed = 4.5 m.p.h.)	
Chisel plow or tool bar[1]		
12'	5.5	.182
14'	6.4	.156
16'	7.3	.137
20'	9.2	.109
24'	11.0	.091
32'	14.7	.068
36'	16.5	.061
45'	20.6	.049
55'	25.2	.040
Field cultivator or tandem disc[1]	(speed = 5.0 m.p.h.)	
14'	7.1	.141
16'	8.2	.122
20'	10.2	.098
24'	12.2	.082
27'	13.8	.072
38'	19.4	.052
44'	22.4	.045
55'	28.0	.036
66'	33.7	.030
Press drills[2]	(speed = 4.0 m.p.h.)	
14'	4.8	.210
16'	5.4	.185
20'	6.4	.156
24'	8.2	.122
28'	9.4	.106
36'	11.8	.085
42'	13.3	.075
48'	14.8	.068
Plow-packer-pony drill[3]	(speed = 4.0 m.p.h.)	
4-14"	1.6	.623
4-16"	1.8	.545
5-16"	2.3	.442
6-16"	2.7	.368
7-16"	3.1	.320
11-14"	4.3	.232

[1]Field efficiencies of tillage implements equal 85 percent of width x speed.

[2]Field efficiency of press drills varied from 71 percent for 14' drill down to 64 percent for 48' drills. Based on "Efficiencies of Field Operations," Paul M. Retzlaff, M.S. Plan B Paper on file in Ag. Engineering Department, NDSU.

[3]Field efficiency of plow-packer and pony drill were estimated at 71 percent for smaller plows dropping to 69 percent for largest plows.

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TABLE 4. FIELD CAPACITIES OF SPECIFIED MACHINERY (CONTINUED)

Machine	Field capacity acres/hour	Field capacity hours/acre
Plow-packer[4] (bottoms)		(speed = 4.5 m.p.h.)
6-14"	2.8	.349
7-16"	3.8	.262
8-16"	4.4	.229
12-14"	5.7	.175
14-14"	6.7	.150
16-16"	8.3	.120
16-18"	10.0	.100
Melroe type harrow[5]		(speed = 5.0 m.p.h.)
40'	21.8	.046
50'	27.3	.037
60'	32.7	.031
70'	38.2	.026
80'	43.6	.023
100'[5]	54.5	.017

[4]Without pony drill, speed increased to 4.5 m.p.h. and field efficiency of 75 percent assumed.

[5]Field efficiency is estimated at 90 percent. With 200 h.p. and larger tractor, field speed increased to 5.5 m.p.h. and acreage to 60.0 per hour.

TABLE 5. OWNERSHIP COSTS AND VARIABLE OPERATING COSTS OF MACHINERY.

Implement	Size	Investment New	Investment Average[1]	Depreciation per hour[2]	Repair Costs per hour[3]	Annual Int. & Ins. Costs[4]
		Dollars				
	h.p.					
Tractors	65	7,150[5]	3,933	.54	.72	330
	75	8,250	4,538	.62	.83	381
	90	9,900	5,445	.74	.99	457
	110	12,100	6,655	.91	1.21	559
	130	14,300	7,865	1.07	1.43	661
	175	19,250	10,588	1.44	1.93	889
	200	22,000	12,100	1.65	2.20	1,016
	250	27,500	15,125	2.06	2.75	1,271
	300	33,000	18,150	2.48	3.30	1,525
Chisel plow	12'	1,200[6]	660	.43	.58	55
	14'	1,400	770	.50	.67	65
	16'	1,600	880	.58	.77	74
	20'	2,200	1,210	.79	1.06	102
	24'	2,640	1,452	.95	1.27	122
	32'	3,520	1.936	1.27	1.69	163
	36'	4,320	2,376	1.56	2.07	200
	45'	5,400	2,970	1.94	2.59	249
	55'	6,600	3,630	2.38	3.17	305
Field cultivator	14'	1,050[7]	578	.38	.50	49
	16'	1,200	660	.43	.58	55
	20'	1,600	880	.58	.77	74
	24'	1,920	1,056	.69	.92	89
	27'	2,160	1,188	.76	1.04	100
	38'	3,230	1,777	1.16	1.55	149
	44'	3,960	2,178	1.43	1.90	183
	55'	4,950	2,723	1.78	2.38	229
	66'	5,940	3,267	2.14	2.85	274
Tandem disc	14'	1,680[8]	924	.60	.81	78
	16'	1,920	1,056	.69	.92	89
	20'	2,400	1,320	.86	1.15	111
	24'	3,000	1,650	1.08	1.44	139
	27'	3,375	1,856	1.22	1.62	156
	38'	4,750	2,613	1.71	2.28	219
	44'	5,720	3,146	2.06	2.75	264
	55'	7,150	3,933	2.57	3.43	330
	66'	8,580	4,719	3.09	4.12	396

TABLE 5. OWNERSHIP, COSTS AND VARIABLE OPERATING COSTS OF MACHINERY (cont.)

Implement	Size	Investment New	Investment Avg.[1]	Depreciation per hour[2]	Repair Costs per hour[3]	Annual Int.& Ins. Costs[4]
		Dollars				
	h.p.					
Press drills	14'	3,500[9]	1,925	2.63	2.92	162
	16'	4,000	2,200	3.00	3.33	185
	20'	5,100	2,805	3.83	4.25	236
	24'	6,240	3,432	4.68	5.20	288
	28'	7,560	4,158	5.67	6.30	349
	36'	9,900	5,445	7.43	8.25	457
	42'	11,550	6,353	8.66	9.62	534
	48'	13,440	7,392	10.08	11.20	621
Moldboard plow-packer & pony drill	# and Size					
	4-14"	2,800	1,540	1.51	1.79	129
	4-16"	3,200	1,760	1.72	2.05	148
	5-16"	3,512	1,932	1.86	2.22	162
	6-16"	4,234	2,329	2.23	2.66	196
	7-16"	5,128	2,820	2.62	3.15	237
	11-14"	6,778	3,728	3.58	4.27	313
Moldboard plow and packer	# and Size					
	6-14"	2,361	1,299	.85	1.13	109
	7-16"	3,153	1,734	1.14	1.51	146
	8-16"	3,727	2,050	1.34	1.79	172
	12-14"	4,722	2,597	1.70	2.27	218
	14-14"	5,518	3,035	1.99	2.65	255
	16-16"	7,454	4,100	2.68	3.58	344
	16-18"	7,952	4,374	2.86	3.82	367
Harrow	Size					
	40'	1,454	800	.52	.70	67
	50'	1,643	904	.59	.79	76
	60'	1,850	1,018	.67	.89	86
	70'	2,150	1,183	.78	1.03	99
	80'	2,450	1,348	.88	1.18	113
	100'	3,050	1,678	1.10	1.46	141
Mechanical drill filler		1,007	554			228[10]
Drill transport trailer[11]	Size					
	28'	993	546			135[10]
	36'	1,427	785			194
	42'	1,750	963			238
	48'	1,937	1,065			263

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FOOTNOTES TO TABLE 5:

[1]Average investment equals 55 percent of new price.

[2]Depreciation per hour determined because of large variations in annual use of machines in budgets examined. Expected service life of tractors was 12,000 hours. All tillage implements were 2,500 hours and 1,200 for drills. ASAE Agricultural Engineers Yearbook, 1967. Per hour depreciation = 90 percent of original purchase cost ÷ service life in hours, page 225.

[3]Repair costs assumed to equal 120 percent of new costs on tractors and tillage implements for life of implement and 100 percent on drills. Ag. Engineers Handbook, 1967, page 255.

[4]Includes interest at 8 percent of average investment and insurance at .4 percent of average investment.

[5]Tractor cost (new) assumed to equal $110 per engine h.p. at all sizes.

[6]Chisel plows vary in price (new) from $100 per foot to $120 per foot. Larger implements were more expensive because of hydraulic wing lift units and hitch.

[7]Field cultivator varied in price (new) from $75 per foot to $90 per foot. Larger implements were more expensive because of hydraulic wing lift units and hitch.

[8]Tandem disce varied in prices (new) from $120 to $130 per foot.

[9]Press drills varied in prices (new) from $250 per foot on 14' drills to $280 per foot on 48' drills. Costs per foot increase with size due to cost of hitch.

[10]No per acre costs estimated on drill filler and drill transport trailer. Cost figure given includes all ownership costs on an annual basis.

[11]Trailer assumed needed to transport drills of 28' or wider.

Given the size of machine, the sequence of operations needed, and the time available for field operations, budgets were prepared which simply indicate the maximum acreage of cropland that could be handled with the various sets of equipment and costs of operation at the maximum capacity size.

Results for One-Man, One-Tractor Combinations

It was discovered rather quickly that the most limiting time period was during spring operations. During the spring a 12-hour day was assumed, hence, 240 hours of spring operations were assumed and this was found to be the most restraining factor.

The seeding operation itself was found to be particularly restricting for the one-man, one-tractor system (Table 6). A maximum drill width of 48' was imposed. This was perhaps too lenient in that drills of this size are not common because these are rather clumsy implements to move from field to field. In recognition of this factor, a trailer for moving the drill was required for all drills of 28' or wider.

In addition, on the one-man, one-tractor combinations, the size of drill was not determined by the power supply but more on the basis of fitting to other machinery components. For instance, with the 65 h.p. tractor only a 14' drill was budgeted although this size tractor could be expected to pull up to 24' of press drill. The 14' was chosen to allow double hitching of disc or cultivator and drill.

Time requirements for determining the acreage that could be operated assumed seeding as a separate operation. Perhaps some time could be saved by doing the second spring tillage and seeding in one operation. Total field efficiency with both operations would, however, be less than as budgeted but the difference in results would not be great.

Spring seeding thus appeared to be the main bottleneck in determining the maximum acreage of land that could be operated with a given one-man, one-tractor system.

With these one-man, one-tractor combinations and a rotation of half-fallow-half-crop, total maximum cropland acreage averages about 13.8 acres per tractor horsepower with tractors from 65 to 130 horsepower. Above that size it began to decline, reaching 11.6 at the 300 h.p. size. The decline is due to the seeding bottleneck mentioned above. Total tractor hours were about 615 hours, again declining slightly at the large size and for the same reason. Of these 615 hours, 240 were used in the spring planting season, about 350 in the summer for summer fallow tillage and about 25 hours in the fall on stubble tillage.

Annual machine costs increase as size increases due to the higher cost per foot of width of some implements and because of the declining field efficiency of large implements, primarily drills. Offsetting the

TABLE 6. MACHINERY COMBINATIONS, MAXIMUM CAPACITY ACREAGE AND COSTS (ONE-MAN, ONE-TRACTOR COMBINATIONS)

	Tractor Size (h.p.)								
	65	75	90	110	130	175	200	250	300
Machinery Inventory									
Chisel plow	12'	14'	16'	20'	24'	32'	36'	45'	55'
Field cult. and disc	14'	16'	20'	24'	27'	38'	44'	55'	66'
Press drill	14'	16'	20'	24'	28'	36'	42'	48'	48'
Harrow	40'	50'	60'	70'	80'	100'	100'	100'	100'
Plow-packer, pony drill	4-14"	4-16"	5-16"	6-16"	7-16"	11-14"	14-14"[1]	16-14"[1]	16-18"[1]
				1/2 fallow					
Max. cropland cap. (acres)	900	1,036	1,228	1,534	1,784	2,342	2,682	3,138	3,478
Total machine invest. ($)	8,820	10,128	12,348	15,740	18,967	25,376	29,348	35,440	40,455
Machine invest./acre ($)	9.80	9.78	10.06	10.26	10.63	10.84	11.07	11.29	11.63
Annual machine cost/acre[2] ($)	3.44	3.42	3.51	3.62	3.72	3.85	3.86	3.95	4.00
Labor cost/acre[3] ($)	1.88	1.62	1.36	1.10	.95	.71	.62	.51	.44
Machine plus labor cost/acre ($)	5.32	5.04	4.87	4.72	4.67	4.56	4.48	4.46	4.44
				1/3 fallow (no plowing)					
Max. cropland cap. (acres)	675	777	921	1,151	1,338	1,757	1,989	2,354	2,609
Machine invest./acre[4] ($)	13.07	13.04	13.41	13.68	14.17	14.45	14.76	15.05	15.51
Annual machine cost/acre ($)	3.78	3.76	3.87	3.98	4.14	4.21	4.29	4.39	4.50
Labor cost/acre[3] ($)	1.78	1.54	1.30	1.05	.90	.67	.59	.49	.43
Machine, plus labor cost/ac. ($)	5.56	5.30	5.17	5.03	5.04	4.88	4.88	4.88	4.93
				1/3 fallow (with plowing)[5]					
Max. cropland cap. (acres)	623	714	864	1,057	1,222	1,644	1,773	2,111	2,354
Total machine invest.[6] ($)	10,360	11,888	14,280	18,069	21,787	29,104	32,383	39,540	44,829
Machine invest./acre ($)	16.63	16.65	16.53	17.09	17.83	17.70	18.26	18.73	19.04
Annual machinery cost/acre ($)	4.39	4.37	4.30	4.52	4.68	4.66	4.87	5.01	5.07
Labor cost/acre[3] ($)	1.91	1.66	1.38	1.13	.97	.72	.65	.54	.47
Machine. plus labor cost/acre ($)	6.30	6.03	5.68	5.65	5.65	5.38	5.52	5.55	5.54

[1]No pony drill, seed separate.

[2]Includes depreciation, repairs, fuel, lubrication, interest and insurance.

[3]Labor hours = 110% of tractor hours at $2.50 per hour.

[4]Total per farm machinery invest. is the same as for the 1/2 fallow system above. Per acre costs are higher because fewer acres operated.

[5]Plow land that was cropped the previous year.

[6]Additional investment in plow, packer, and drill.

higher machinery costs, operator labor costs decline quite sharply as size of tractor increases, from $1.88 per acre for the 65 h.p. tractor down to $.44 per acre for the 300 h.p. tractor. The total of these two costs decline from $5.32 per acre at 65 h.p. to $4.44 per acre at 300 h.p. Costs per acre decline very little after 200 h.p. due to the seeding bottlenecks mentioned.

With a rotation of one-third fallow and no spring plowing, the spring planting capacity is the same as for one-half fallow systems. Total acreage is less because less land is fallowed. Per acre interest and insurance costs are higher because fewer acres are operated. Per acre annual machinery costs range from $3.78 with a 65 h.p. tractor to $4.50 with a 300 h.p. tractor. Labor costs per acre declined as before so that total costs per acre decline with increasing tractor size.

With this rotation and tillage plan, total crop acreage ranges from 10 acres per h.p. with a 65 h.p. tractor down to 8.7 acres per h.p. with a 300 h.p. tractor. Total tractor hours are only about 445 hours at 65 h.p. ranging down to 411 hours at 300 h.p.

With a rotation of one-third and plowing of second year cropland, the added tillage requirements further reduce spring planting capacity. Acres per horsepower ranges from 9.6 at 65 h.p. down to 7.8 at 300 horsepower. Per acre costs are higher due to the larger tillage requirements and the lower acreages. With this rotation and tillage plan, total tractor hours range from 440 hours with small tractors down to 406 hours with 300 h.p. tractors.

The reader should be cautioned here not to use these results to make decisions regarding the proper rotation or tillage system for his farm. Although a system with no plowing here shows lower per acre costs, no comparison is made of differences in yields. The plowing method is higher cost but it may well give greater returns per acre and greater farm profits. The results presented here should be used to make comparisons between sizes of equipment for a given system of rotation and tillage rather than between systems.

It is interesting to note that fuel costs were very similar regardless of the sizes of tractor for a given rotation and tillage system. With one-half fallow systems, fuel costs ranged from $.59 to $.63 per acre; with the one-third fallow and no plowing fuel costs were slightly lower at $.57 to $.61; and with one-third fallow and plowing, fuel costs were $.61 to $.67. The difference between systems is understandable. The one-third fallow system requires less tillage per acre of cropland due to the reduced fallow, and the plowing adds fuel costs.

Results for Two-Man, Two-Tractor Combinations

To overcome the bottleneck of limited seeding capacity relative to tillage capacity, a second set of machinery complements were budgeted where two men were combined with two tractors (Table 7). In these examples one large tractor is used to perform all of the spring tillage and a smaller tractor on a drill does all the seeding.

Several combinations of small and large tractors were experimented with but it was found that the costs would be minimized by matching the seeding capacity of the small tractor with the tillage capacity of one larger tractor. In these budgets, the small tractor can seed as many acres in 240 hours as the large tractor can till twice in the same length of time. These assumptions are recognized as being rather simplistic but hopefully they are still useful.

With these two-tractor combinations, some economies were gained in machinery use. Only one drill and only one chisel plow were included in each combination. Also, of course, the large tractors were not tied down to pulling drills that under-utilized their capacity and total acreage could be much greater for the investment. Hence, estimates of per acre machinery investment are lower.

With the one-half fallow system both tractors would have to be used for summer fallow use. The large tractor was limited to 500 hours during this season and the remainder would have to be performed by the smaller tractor. With the one-half fallow system annual tractor hours would be about 775 hours on the large tractor and about 440 hours on the smaller tractor. The large tractor is used 240 hours in the spring, 500 during the summer, and 35 in the fall. The smaller tractor is used 240 hours in the spring and about 200 hours on summer fallow operations.

The maximum acreage that can be operated varies from 3,934 acres to 7,058 acres with the one-half fallow system. This averages about 16.5 acres per tractor horsepower. In comparison, on the one-man combinations the range was from 13.8 down to 11.6 acres per horsepower. Hence, per acre machinery costs are somewhat lower here due to lower per acre investment. The annual machinery costs here run from $3.31 to $3.39 compared to $3.42 to $4.00 with the one-man combinations.

With the one-third fallow system all summer fallow tillage could be handled with the large tractor. This means that the small tractor is used only 240 hours in the spring for seeding and no investment is needed in tillage implements for the small tractor. Even with the low annual use of the small tractor, per acre annual machinery costs here were $3.37 to $3.60 compared to $3.78 to $4.50 on the one-man combinations (one-third fallow, no plowing).

With the one-third fallow system and plowing, the large tractor is budgeted to do all the spring tillage, both plowing and other tillage. The small tractor is budgeted for seeding and harrowing. It was not required that the harrowing be done within the 240 hour spring time limit specified. The budgets indicate that the small tractor would be used for about 200 hours for seeding and 35-40 hours for harrowing. Hence, the size of farm here was not limited by the seeding capacity but by the tillage capacity of the large tractor. For the plowing system, lower

TABLE 7. MACHINERY COMBINATIONS, MAXIMUM CAPACITY ACREAGES, AND COSTS (TWO-MAN, TWO-TRACTOR COMBINATIONS)

	Tractor Sizes (h.p.)			
	65 & 175	75 & 200	90 & 250	130 & 300
Machinery Inventory				
Chisel plows (2) sizes	12'&32'	14'&36'	16'&45'	24'&55'
Field cult. & disc, sizes	14'&38'	16'&44'	20'&55'	27'&66'
Press drill (1), size	24'	28'	36'	48'
Harrow (1), size	40'	50'	60'	80'
Plow[1] (1), # of bottoms, width	12-14"	14-14"	16-16"	16-18"
		1/2 fallow		
Max. cropland capacity (acres)	3,934	4,528	5,648	7,058
Total machine invest. ($)	27,795	32,986	41,078	52,486
Machine invest./acre ($)	7.06	7.28	7.27	7.44
Annual machine cost/acre	3.34	3.31	3.33	3.39
Labor cost/acre ($)	.84	.74	.60	.49
Machinery plus labor cost/ac. ($)	4.18	4.05	3.93	3.88
		1/3 fallow (no plowing)		
Max. cropland capacity (acres)	2,950	3,396	4,236	5,293
Total machine invest.[2] ($)	25,633	30,500	37,998	47,990
Machine invest./acre ($)	8.69	8.98	8.97	9.07
Annual machine cost/acre ($)	3.37	3.50	3.54	3.60
Labor cost/acre ($)	.74	.65	.52	.42
Machinery plus labor cost/ac. ($)	4.11	4.15	4.06	4.02
		1/3 fallow (with plowing)		
Max. cropland capacity (acres)	2,442	2,812	3,510	4,236
Total machine invest.[3] ($)	28,230	33,535	42,098	52,364
Machine invest./acre ($)	11.56	11.93	11.99	12.36
Annual machine cost/acre ($)	3.91	4.04	4.08	4.21
Labor cost/acre ($)	.83	.72	.58	.48
Machinery plus labor cost/ac. ($)	4.74	4.76	4.66	4.69

[1]No pony drills used in these combinations. Seed in separate operation with small tractor and press drill. All plowing done by largest tractor.

[2]No tillage implements needed for small tractor. Small tractor only used for seeding.

[3]Same as above plus investment in plow and packer.

costs would have been obtained if the machinery combinations were changed to expand the spring tillage capacity relative to the seeding capacity. For instance, with the 200 h.p. tractor (second combination) a 65 h.p. tractor and 24' drill could handle all the seeding. This change, from a 75 h.p. tractor and 28' drill to the 65 h.p. tractor and 24' drill would reduce costs by about 5 cents per acre.

On both of the one-third fallow systems, the small tractor is under-utilized in total for the year since it is used only during the spring and not needed for summer fallow operations. Total hours on the small tractor is only 240 per year. This is rather low. Since we charged depreciation on an hourly basis we have most likely undercharged for depreciation on the small tractor. Doubling the depreciation change for the small tractor would only add about 5 to 6 cents per acre to total machinery cost. This amount should be added to these machinery costs unless the tractor is used for other purposes on the farm such as in grain or hay harvest for livestock uses.

Results for Three-Man, Two-Tractor Combinations

One way to reduce machinery investment per acre is to run tractors day and night. Tillage operations could be performed at night as satisfactorily as in the day time. This may mean hiring extra help.

In this group of combinations the size of the larger tractor has been reduced considerably and instead it is run 440 hours in the spring instead of only 240 hours. Here we combined a 90 h.p. tractor with a 65 h.p. tractor compared to a 175 h.p. tractor in the previous set of combinations. Night time use of the large tractor is also allowed for summer fallow tillage if needed. In this set of budgets, night time operations are charged at a rate of $2.75 per hour for operator time compared to $2.50 for day time operations.

The maximum acreage capacities for the various rotations and tillage practices are about the same here as estimated for the two-man, two-tractor combinations (Table 8).

With the one-half fallow systems, the small tractor is fully utilized (500 hours) for summer fallow and the large tractor is run about 700 hours on summer fallowing. Hence, about 200 hours are assumed to be night time operations and charged $2.75 per hour. Total tractor hours for the one-half fallow system are about 700 to 740 hours on the small tractor and 1,150-1,200 hours on the large tractor. This is more hours on the large tractor than normal.

With the one-third fallow system and no plowing, no tillage either in spring or in summer fallow is performed by the small tractor. The large tractor is used for 440 hours in the spring and about 520-540 hours in the summer, so 20-40 hours would be at night rates. Total tractor hours would be 240 hours on the small tractor and 1,000-1,040 on the large tractor.

TABLE 8. MACHINERY COMBINATIONS, MAXIMUM CAPACITY ACREAGES, AND COSTS (THREE-MAN, TWO-TRACTOR COMBINATIONS)[1]

	Tractor Sizes (h.p.)			
	65 & 90	75 & 110	90 & 130	130 & 175
Machinery Inventory				
Chisel plows (2) sizes	12'&16'	14'&20'	16'&24'	24'&32'
Field cult. & disc	14'&20'	16'&24'	20'&22'	27'&38'
Press drill (1) size	24'	28'	36'	48'
Harrow (1) size	40'	50'	60'	80'
Plow[2], # of bottom, size (1) width	6-14"	7-16"	8-16"	12-14"
	1/2 Fallow			
Max. cropland capacity (acres)	3,740	4,512	5,400	7,104
Total machine invest. ($)	19,406	23,757	28,688	39,634
Machine invest./acre ($)	5.19	5.26	5.31	5.58
Annual machine cost/acre ($)	2.96	3.08	3.03	3.21
Labor cost/acre[3] ($)	1.43	1.20	1.00	.75
Machinery cost, labor cost/ac.($)	4.39	4.28	4.03	3.96
	1/3 fallow (no plowing)			
Max. cropland capacity (acres)	2,805	3,384	4,050	5,328
Total machine invest.[4]($)	17,244	21,271	25,608	35,138
Machine invest./acre ($)	6.15	6.29	6.32	6.59
Annual machine cost/acre ($)	3.05	3.24	3.14	3.38
Labor cost/acre[3] ($)	1.21	1.02	.85	.64
Machinery cost, labor cost/ac.	4.26	4.26	3.99	4.02
	1/3 fallow (with plowing)			
Max. cropland capacity (acres)	2,259	2,913	3,366	4,476
Total machine invest.[5] ($)	18,543	23,005	27,658	37,735
Machine invest./acre ($)	8.21	7.90	8.22	8.43
Annual machine cost/acre ($)	3.63	3.53	3.72	3.82
Labor cost/acre ($)	1.38	1.12	.95	.71
Machinery cost, labor cost/ac.($)	5.01	4.75	4.67	4.53

[1]Large tractor used both day and night for maximum spring use of 440 hours. Large tractor also used at night for summer fallowing.

[2]No pony drill used in these combinations. One plow used with largest tractor.

[3]Day labor at $2.50/hour, night labor at $2.75/hour.

[4]With this rotation no tillage implements needed for small tractor.

[5]No tillage implements for small tractors includes plow for large tractors.

With one-third fallow and plowing, tillage requirements are high in the spring. Hence, with the big tractor doing all of the spring tillage the small tractor is used for seeding only 185 to 200 hours and about 35 hours on the harrow. As with the two-man, two-tractor system, here the spring bottleneck is the tillage and not the seeding; the tillage capacity should be increased relative to seeding capacity.

Costs could be reduced slightly by changing the size of implements when spring plowing is required. With spring plowing the total tractor hours for the small tractor would only be 220-240 hours and about 920-940 hours on the large tractor.

Comparisons of total per acre costs indicate that the three-man, two-tractor systems generally have higher costs than the two-man, two-tractor system for comparable size and cropping systems. These comparisons will be presented in Tables 10-12 and discussed more fully later.

Results for Four-Man, Three-Tractor Combinations

A set of still larger capacity machinery combinations were budgeted where one large tractor, to be used day and night, is matched with two smaller tractors which do the spring seeding and help if needed with the summer fallow.

With one-half fallow systems the large tractor is used 440 hours in the spring, 700 hours in the summer, and 60-65 hours in the fall. The two small tractors are used 235-240 hours in the spring and 500 hours on summer fallow.

With one-third fallow and no plowing, no tillage implements are needed for either small tractors. The large tractor can handle all the spring tillage and the summer fallow if it is used about 535 hours. Total tractor hours are only 235-240 hours each on the two small tractors and 1,020-1,040 on the large tractor.

With one-third fallow and plowing, the spring tillage requirements would again be the bottleneck. In these combinations a chisel plow was added for the smallest tractor which is used for about 70-90 hours to help with spring tillage.

Hence, the large tractor is used for 440 hours in the spring for tillage and the smallest tractor for 70-90 hours. The middle size tractor is used for 240 hours for seeding and the small tractor seeds for 150-170 hours.

All summer fallow tillage can be performed by the large tractor in about 465 hours.

TABLE 9. MACHINERY COMBINATIONS, MAXIMUM CAPACITY ACREAGES, AND COSTS (FOUR-MAN, THREE-TRACTOR COMBINATIONS)[1]

	Tractor Sizes (h.p.)			
	65,65,175	65,75,200	75,90,250	110,110,300
Machinery Inventory				
Chisel plows (3) sizes	12',12',32'	12',14',36'	14',16',45'	20',20',55'
Field cult., discs[2]	14',14',38'	14',16',44'	16',20',55'	24',24',66'
Press drills (2) sizes	24',24'	24',28'	28',36'	42',42'
Harrow (1) size	40'	40'	50'	70'
Plow[3] (1), # bottoms, size width	12-14"	14-14"	16-16"	16-18"
		1/2 fallow		
Max. cropland capacity (acres)	7,334	8,300	10,176	12,570
Total machine invest. ($)	36,952	42,011	51,926	65,081
Machine invest./acre ($)	5.04	5.06	5.10	5.18
Annual machine cost/acre ($)	3.03	3.11	3.13	3.17
Labor cost/acre ($)	1.01	.90	.74	.59
Machine & labor cost/acre ($)	4.04	4.01	3.87	3.76
		1/3 fallow (no plowing)		
Max. cropland capacity (acres)	5,500	6,225	7,632	9,428
Total machine invest.[4] ($)	33,552	38,419	47,680	58,899
Machine investment/acre ($)	6.10	6.17	6.25	6.25
Annual machine cost/acre ($)	3.16	3.25	3.31	3.35
Labor cost/acre ($)	.74	.67	.55	.45
Machine & labor cost/acre ($)	3.90	3.92	3.86	3.80
		1/3 fallow (with plowing)		
Max. cropland capacity (acres)	4,755	5,445	6,780	8,175
Total machine investment ($)	36,809	42,114	52,550	64,483
Machine invest./acre ($)	7.74	7.73	7.75	7.89
Annual machine cost/acre ($)	3.59	3.65	3.70	3.72
Labor cost/acre ($)	.87	.77	.62	.50
Machine & labor cost/acre ($)	4.46	4.42	4.32	4.22

[1]Large tractor used both day and night for maximum spring use of 440 hours. Large tractor also used at night for summer fallowing.

[2]No disc included for middle size tractor.

[3]No pony drill used in these combinations. Plow used with largest tractor only.

[4]No tillage implements needed for two smaller tractors.

Results for All Machinery Combinations for One-Half Fallow

The budget results for all machine combinations examined for the one-half fallow system are summarized in Table 10. Here we present the maximum acreage capacity, total average machinery investment, and annual per acre machinery and labor costs for each combination studied. Given the land one has to farm, one can choose the machine complement needed; or a given machinery complement, one can determine how much land one could handle and thus how much additional land an operator could try to rent or purchase.

With one-tractor combinations, per acre machinery and labor costs continue to decline as size of tractor is increased because labor costs are reduced more than machinery costs increase. As reported earlier, the seeding bottleneck limits the acreage capacity of the one-tractor system.

The two-tractor systems show considerable economies over the one-tractor systems. For instance, if a farmer was operating about 3,500-4,000 acres he could choose from either of the following:

1. 4-75 h.p. tractors and associated equipment.
2. 1-300 h.p. tractor.
3. The 65 and 175 h.p. two-man system.
4. The 65 and 90 h.p. three-man, two-tractor system.

With four 75 h.p. tractors his per acre costs would average about $5.04 per acre. With one 300 h.p. tractor his costs would be $4.44 per acre which is a considerable saving. Additional savings can be obtained by using the 65-175 h.p. two-man combination. With this system his costs would be about $4.18 per acre.

The three-man, two-tractor systems generally show higher costs than the two-man, two-tractor system. Substitution of night labor for machinery investment does not appear profitable. However, if the pay rate for day labor was $1.50/hour or less, the three-man system with night use gives lower costs.

The four-man, three-tractor systems do not actually give any lower costs than the two-man, two-tractor systems for a farm size of about 2,000 acres. With 10,000 acres, one would have to go to more than two tractors and one should try to keep labor costs down by use of large tractors.

Regardless of the machinery combinations, the fuel costs per acre differ very little. They range from $.54 to $.63 with most combinations showing fuel costs of $.55 to $.57 per acre.

TABLE 10. COMPARISON OF RESULTS WITH VARIOUS MACHINERY COMBINATIONS FOR ONE-HALF FALLOW SYSTEMS.

Machinery Combinations h.p.	Maximum Acreage Capacity (acres)	Total Machinery Investment (dollars)	Annual Machinery Cost[1] ($/acre)	Cost of Labor[2] ($/acre)	Machine cost and labor ($/acre)
One-man, one-tractor					
65	900	8,820	3.44	1.88	5.32
75	1,036	10,128	3.42	1.62	5.04
90	1,228	12,348	3.51	1.36	4.87
110	1,534	15,740	3.62	1.10	4.72
130	1,784	18,967	3.72	.95	4.67
175	2,342	25,376	3.85	.71	4.56
200	2,652	29,348	3.86	.62	4.48
250	3,138	35,440	3.95	.51	4.46
300	3,478	40,455	4.00	.44	4.44
Two-men, two-tractors					
65 & 175	3,934	27,795	3.34	.84	4.18
75 & 200	4,528	32,986	3.31	.74	4.05
90 & 250	5,648	41,078	3.33	.60	3.93
130 & 300	7,058	52,486	3.39	.49	3.88
Three-men, two-tractors					
65 & 90	3,740	19,406	2.96	1.43	4.39
75 & 110	4,512	23,757	3.08	1.20	4.28
90 & 130	5,400	28,688	3.03	1.00	4.03
130 & 175	7,104	39,634	3.21	.75	3.96
Four-men, three-tractors					
65,65,& 175	7,334	36,952	3.03	1.01	4.04
65,75,& 200	8,300	42,011	3.11	.90	4.01
75,90,& 250	10,176	51,926	3.13	.74	3.87
110,110,&300	12,570	65,081	3.17	.59	3.76

[1]At maximum capacity acreage.

[2]Labor hours = 110 percent of tractor hours, day labor at $2.50/hour.

Results for All Machinery Combinations for One-Third Fallow With No Plowing

Table 11 presents a summary of budget results for the one-third fallow system with no plowing. Almost the same conclusions can be drawn here as with the one-half fallow system. The two-man combinations show considerable savings over one-man combinations. Here the three-man, two-tractor combinations show costs very similar to the two-man, two-tractor combination. In this case very little fallow work would have to be performed at night. If labor rates are any lower than here assumed, the three-man system would possibly give lower costs.

Here the four-man, three-tractor systems give lowest costs but not a great deal lower than the two-man, two-tractor system.

With all combinations, fuel costs range between $.50 and $.61 per acre with most being between $.51 and $.54.

Results for All Machinery Combinations for One-Third Fallow with Plowing

Again, substantial cost savings are possible through use of larger tractors and with use of two-tractor systems. With spring plowing of second year cropland, spring tillage requirements tend to be the bottleneck rather than seeding. Actually, improvements in these systems could be made by increasing the tillage capacity relative to the seeding capacity, i.e., combine the 65 h.p. tractor and a 24' drill with the 200 h.p. tractor instead of the 175 h.p. tractor. (Move up one size on the large tractor or down one on the small tractor.) With such changes, all of the two-tractor system could show slightly lower costs than here budgeted (5-6 cents per acre).

Fuel costs with this rotation system range between $.56 and $.67 per acre with most in the $.56 to $.59 range.

TABLE 11. COMPARISON OF RESULTS FOR VARIOUS MACHINERY COMBINATIONS FOR ONE-THIRD FALLOW SYSTEMS (NO PLOWING).

Machinery Combinations h.p.	Maximum Acreage Capacity (acres)	Total Machinery Investment (dollars)	Annual Machinery Cost[1] ($/acre)	Cost of Labor[2] ($/acre)	Machinery and labor cost ($/acre)
One-man, one-tractor					
65	675	8,820	3.78	1.78	5.56
75	777	10,128	3.76	1.54	5.30
90	921	12,348	3.87	1.30	5.17
110	1,151	15,740	3.98	1.05	5.03
130	1,338	18,967	4.14	.90	5.04
175	1,757	25,376	4.21	.67	4.88
200	1,989	29,348	4.29	.59	4.88
250	2,354	35,440	4.39	.49	4.88
300	2,609	40,455	4.50	.43	4.93
Two-man, two-tractors					
65 & 175	2,950	25,633	3.37	.74	4.11
75 & 200	3,396	30,500	3.50	.65	4.15
90 & 250	4,236	37,998	3.54	.52	4.06
130 & 300	5,293	47,990	3.60	.42	4.02
Three-men, two-tractors					
65 & 90	2,805	17,244	3.05	1.21	4.26
75 & 110	3,384	21,271	3.24	1.02	4.26
90 & 130	4,050	25,608	3.14	.85	3.99
130 & 175	5,328	35,138	3.38	.64	4.02
Four-men, three-tractors					
65, 65, & 175	5,500	33,552	3.16	.74	3.90
65, 75, & 200	6,225	38,419	3.25	.67	3.92
75, 90, & 250	7,632	47,680	3.31	.55	3.86
110,110,& 300	9,428	58,899	3.35	.45	3.80

[1]At maximum capacity acreage.

[2]Labor hours = 110 percent of tractor hours, day labor at $2.50/hour, night labor at $2.75/hour.

TABLE 12. COMPARISONS OF RESULTS FOR VARIOUS MACHINERY COMBINATIONS FOR ONE-THIRD FALLOW SYSTEM (WITH PLOWING OF SECOND YEAR CROPLAND).

Machinery Combinations	Maximum Acreage Capacity	Total Machinery Investment	Annual Machinery Cost[1]	Labor Cost[2]	Machinery and Labor Cost
h.p.	(acres)	(dollars)	($/acre)	($/acre)	($/acre)
One-man, one-tractor					
65	623	10,360	4.39	1.91	6.30
75	714	11,888	4.37	1.66	6.03
90	864	14,280	4.30	1.38	5.68
110	1,057	18,068	4.52	1.13	5.65
130	1,222	21,787	4.68	.91	5.65
175	1,644	29,104	4.66	.72	5.38
200	1,773	32,383	4.87	.65	5.52
250	2,111	39,540	5.01	.54	5.55
300	2,354	44,829	5.07	.47	5.54
Two-men, two-tractors					
65 & 175	2,442	28,230	3.91	.83	4.74
75 & 200	2,812	33,535	4.04	.72	4.76
90 & 250	3,510	42,098	4.08	.58	4.66
130 & 300	4,236	52,364	4.21	.48	4.69
Three-men, two-tractors					
65 & 90	2,259	18,543	3.63	1.38	5.01
75 & 110	2,913	23,005	3.63	1.12	4.75
90 & 130	3,366	27,658	3.72	.95	4.67
130 & 175	4.476	37,735	3.82	.71	4.53
Four-men, three-tractors					
65, 65, & 175	4,755	36,809	3.59	.87	4.46
65, 75, & 200	5,445	42,114	3.65	.77	4.42
75, 90, & 250	6,780	52,550	3.70	.62	4.32
110,110,& 300	8,175	64,483	3.72	.50	4.22

[1] At maximum capacity acreage.

[2] Labor hours = 110 percent of tractor hours, day labor at $2.50/hour, night labor at $2.75/hour.

Caution to Reader

Some particular cautions should be taken when interpreting the results presented here. This analysis is extremely incomplete in its scope. The original assumptions made in regard to time available for field work, operations performed, machinery capacity, and machinery prices are considered to be reasonable; however, these cost estimates are only partial. The reader must remember that these costs include only machinery and labor costs for tillage and seeding operations. Other machinery costs of harvest are not included. Other costs such as seed, fertilizer, herbicides, harvest labor, grain storage, and handling, and farm overhead are not included.

Also, the cost figures presented apply only for the acreages given. For any set of machinery here studied, the per acre costs would be higher if the acreage operated is less than the maximum capacity due to the fixed nature of costs such as interest and insurance. Depreciation costs were here estimated on a per hour basis, but if machinery hours are reduced considerably, the hourly cost of depreciation should be increased. Machinery depreciates both from wear and from obsolescence.

Also, as stated previously, these results should not be used by themselves to decide on rotations. A one-half fallow system may show lower per acre costs here than a one-third fallow system, but this alone can't be interpreted to mean that it is more profitable. Returns must also be examined.