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ABSTRACT

Impact of Wage Rates On Optimal Machinery Complements

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The complex problem of choosing optimum machinery complements is approached using mixed integer linear programming. Wage rates and farm size are varied with the resulting optimal complements compared. Higher wage rates cause capital to be substituted for labor and it is evident that machinery costs per acre decrease as farm size is increased.

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Impact of Wage Rates On Optimal Machinery Complements

by

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A perennial problem faced by farmers is how to select their machinery complement: what implements, how many and what size. With farm costs increasing so dramatically, these questions assume paramount importance to the modern farmer. This paper considers briefly the changing environment faced by farmers and examines in more detail the impact of changing wage rates on the optimal machinery complements of wheat farms in North Central Oklahoma.

Farmers today face an environment characterized by sharply rising costs. Naturally these increasing costs are of great concern. According to data taken from wheat budgets prepared for North Central Oklahoma, total machinery costs increased from $13.18 per acre in 1973 to $22.30 per acre in 1975. This is a sharp increase but it must be taken in context with other cost increases to keep from overstating its relative importance. Machinery costs as a percent of total per acre costs increased from 22.4% to 26.5% during the same time period. Other costs have risen almost as quickly as machinery costs.

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The short-run outlook does not provide relief for farmers. Fuel prices, machinery prices, and labor wage rates are all rising. The differences between the relative increases in these prices is the area where the farmer has the most room to make adjustments. These adjustments may be reflected in the machinery he chooses and/or the mix of crops he decides to produce. The trends in farmer machinery selection reflect attempts to adjust to these relative cost changes. Farmers are selecting larger and larger machinery and technology has kept pace by supplying the 450 horsepower tractors that are now available. What does machinery of this size imply about machinery costs? Agricultural engineers point out that the energy required to perform specified tasks is the same no matter what size implement is used. This implies that, if implements are properly matched to tractor size, fuel consumption per acre is nearly constant no matter what the size of machinery.

If operating costs per acre, exclusive of labor, are nearly the same for large and small tractors with properly sized equipment, the decision of which to purchase should be determined primarily by the comparative allocation of fixed and labor costs. The cost of a 100 horsepower tractor is currently near $21,400, or $214 per horsepower. The cost of a 175 horsepower tractor is about $32,800 or about $187 per horsepower. The decreasing cost per horsepower alone implies that as acreages increase farmers should tend to move towards larger equipment if everyting else is equal. An additional impetus to the choosing of large machinery is the reduced amount of labor required.

If all the above facts are correct it is apparent that as farm size increases farmers should move towards larger machinery, as indeed they are. However, many relatively small farmers have large two-wheel or four-wheel drive tractors and equipment. How can these farmers justify them? Why do they use these very large implements and tractors which they know cost them more than small implements? Several standard reasons have been given: 1) the large machinery is a status symbol and the money required is available, 2) the farmer values his leisure time very highly, 3) he may be considering farm expansion, and 4) labor availability becomes less of a problem. There are probably other reasons as well.

The trade-off between labor-intensive operations and machinery-intensive operations is difficult for the farmer to analyze. Traditional wage rates are low relative to other segments of the economy. In addition, most farmers need only seasonal help. Because of these characteristics, and the fact that most farmers in a given area all need help at the same time, there are usually not enough laborers to go around.

Most farmers in Oklahoma operate tractors between 500 and 600 hours per year. Most laborers want a job year around. Preferably, they would work eight hours per day five days per week. This does not correspond well with the work habits of most farmers. In addition, if a worker is kept year around, he needs a livable income. For discussion, set this figure at $10,000 per year. If a worker works eight hours per day of a 6-day work week for 50 weeks per year he will work 2,400 hours per year. To obtain a $10,000 annual income on this basis the workers must be paid about $4.17 per hour. In Oklahoma, the prevailing wage rate is nearer $2.50 per hour ; therefore steady dependable workers will not be available over an extended period of time because it is not possible for them to maintain an adequate standard of living.

Consider the labor problem from the farmer's viewpoint. If he needs a tractor operated 600 hours per year and has approximately 200 hours of other chores, he only needs hired help one-third of the 2,400 hours the laborer is available. If the farmer decides he as going to keep the worker available by paying him a $10,000 annual salary, this amounts to paying him $12.50 per hour ($10,000/800 hours). If $12.50 were the more appropriate hourly wage rate, the optimal machinery complement would be substantially different than it would be for the typical $2.50 per rate.

The remainder of this paper analyzes the impact of alternative wage rates on optimal machinery complements for a North Central Oklahoma Wheat farm. Because the trade-off between labor-intensive operations and machinery-intensive operations is far from easy to analyze, a computer program has been developed to solve the problem. Application of the machinery selection program can provide a direct way for managers to choose the least cost set of machinery possible for a particular farm situation.

Toward this end, the remaining portion of this paper will be divided into three sections: 1) data requirements, 2) machinery selection algorithm, and 3) the results of the analysis.

Data Requirements

Optimal complement selection requires the following information: 1) the hours available for field work in each critical time period throughout the year, 2) an array containing the number of acres covered with each field operation in each time period, 3) the cost and computational parameters for each size of each machine from which the optimal complement will be chosen.

Hours Available

The factor having the most impact on field time availability over a period of time is weather, particularly rainfall. For any relatively short period during a year the number of work days available varies widely. To provide more information on the days available a study was conducted to develop some frequency distributions depicting field time available.[1] A subset of these distributions is presented in Table I. The table allows one to select a percentage of time he expects field work to be completed in the indicated time period. For example, if he chooses 90 percent, the numbers in that line of the table represent the number of days available to allow completion of field work nine years out of ten.

TABLE I

DAYS AVAILABLE FOR FIELDWORK IN NORTH CENTRAL OKLAHOMA ON CLAY-LOAM SOILS FOR EACH ONE-HALF MONTH USED IN THE ANALYSIS FOR ALTERNATIVE LEVELS OF TIMELINESS

	Timeliness Level		
Time Period	80%	90%	98%
June 1st 1/2	9.75	7.5	4.75
July 1st 1/2	11.75	10.5	8.25
Aug. 1st 1/2	12.25	11.0	8.25
Aug. 2nd 1/2	11.75	10.0	6.75
Sept. 1st 1/2	10.50	8.75	5.5
Sept. 2nd 1/2	9.25	6.75	4.0

Field Operations

To find an optimal machinery complement it is necessary to know what type of field operations are to be performed and when they are to be carried out. If one were working with an individual farmer, he could select the critical time periods during which various field operations might compete. For the purposes of this presentation, the enterprise budgets prepared for North Central Oklahoma were used. Each budget

[1]Reinschmiedt, Lynn L., "Study of the Relationship Between Rainfall and Fieldwork Time available and Its Effect on Optimal Machinery Selection", Unpublished Master's Thesis, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, 1973.

contains a list of all field operations and the month in which they are performed. Since this study utilizes one-half month periods it was necessary to determine in which half-month each operation occurs.

The farm chosen for analysis consists of all wheat. Table II gives the timing of each field operation performed. The situation analyzed involves clay-loam soils with two farm sizes, 480 and 1440 acres.

TABLE II

FIELD OPERATIONS FOR A NORTHCENTRAL OKLAHOMA WHEAT FARM

Time Period	Operation
1st 1/2 June	Tandem Disk
1st 1/2 July	Moldboard Plow
1st 1/2 August	Cultivate
2nd 1/2 August	Springtooth
1st 1/2 September	Springtooth
2nd 1/2 September	Drill

Machines Available

To find optimal machinery complements it is necessary to have a set of machines from which selections can be made. With the OSU budget generator[1] are associated a number of machinery complements containing the required information for computing machinery costs. These machinery complements are extensive and contain most machines and machine sizes that might be used. The optimal complement may be slected from a subset containing any machine in any of the fifteen Oklahoma State University

[1]Kletke, Darrel D., "Operations Manual for the Oklahoma State University Enterprise Budget Generator", Research Report P-719, Agricultiral Experiment Station, Oklahoma State University, Stillwater, Oklahoma.

Budget Generator Machinery complements or any machine in the fifty FEDS machinery complements.[1]

The Machinery Selection Algorithm

The optimizing algorithm is MPSX, the mixed integer, linear programming package supported by IBM. The machinery selection package consists of three parts. These are a matrix generator, the MPSX package, and a detailed report writer.

The Results

The solution algorithm was applied to several situations on a North Central Oklahoma wheat farm. Principle items varied were wage rate and farm size. Wage rates used were \$2.50 per hour and \$12.50 per hour. Farm sizes were 480 and 1440 acres.

Table III contains the optimal complement for one situation. For each machine the hours utilized in each time period is summarized along with the total annual usage. Tractor hours are computed at 1.1 times machine hours to allow for hitching, transport, and other operations when the implement is not operating. The hours available for field use of machines is given and can be used to determine bottleneck time periods. The constraining time period time in Table III is the first one-half of July. The 225 horsepower tractor is being used the maximum, 155.1 hours, and the 150 horsepower tractor is being used 140.4 hours.

Information in Table III illustrates the simplicity of the problem considered. In no period are there two different machines competing for

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[1]FEDS, Farm Enterprise Data System, is a program maintained by USDA at Oklahoma State University. Its purpose is to estimate costs and returns budgets for all principal crops in the United States.

TABLE III

Optimal Complement for 1440 Acre North Central Oklahoma Wheat Farm with a $12.50 Wage Rate and 100 Hours Free Labor in Each Time Period. Work is Completed 80% of the Time in the Correct Time Period with 10 Hours Workdays in Winter and 12 Hour Workdays in Summer.

Implement	Time Period						
	1st ½ June	1st ½ July	1st ½ August	2nd ½ August	1st ½ September	2nd ½ September	Total
	(Hours)						
28'4" Tandem Disk	105.4						105.4
8-16's MoldBoard Plow		127.7					127.7
12-16's MoldBoard Plow		141.0					141.0
34'6" Field Cultivator			95.7				95.7
48' Springtooth				66.7	66.7		133.4
13' Drill						4.6	4.6
3-13' Drills						92.5	
150 HP Tractor[1]		140.4	105.2	73.4	73.4	101.8	494.2
225 HP Tractor	115.9	155.1				5.01	276.0
Machine Hours Available	117.0	141.0	141.0	141.0	105.0	93.0	
Hired Labor	27.5	225.1	15.7	0.0	0.0	17.4	285.7
Total Annual Cost	34666.89						
Fixed Cost	22328.83						
Variable Cost	12338.06						

1 Tractor hours are 1.1 times machine hours.

tractor time which is allowed with the model. Also, only 5 of 24 possible time periods were used and only 5 of 10 possible machine types were included. The optimal complement of nine machines was selected from a total of 27 machines.

The first column of Table IV contains a solution for a 480 acre farm assuming a $2.50 wage rate. The next two columns have solutions for a 1440 acre farm with $2.50 and $12.50 wage rates being the only different assumptions. The final column will be discussed later.

Each of the solutions in Table IV utilizes up to 100 hours of owner or free labor. As a result, for the 480 acre farm only 119 hours are hired. Annual fixed costs are $8,683.00 per year and the resulting annual total cost per acre is $24.34. Because of the small amount of labor hired there is very little change when a $12.50 wage rate is assumed. If all labor were hired it is expected the complement change would have been substantial.

Because of the greater number of hours of hired labor required on the 1440 acre farm, the impact of the higher wage rate on the optimal complement is substanial. See the middle two columns of Table IV. In effect, one 225 horsepower tractor is used in place of two 100 horsepower tractors with each complement having in addition a 150 horsepower tractor. Three small tandem disks are replaced with one larger tandem disk and a 12-16's moldboard plow replaces 2 3-16's moldboard plows. Fixed costs increased from $20,213.00 to $22,329.00 annually while the hours of hired labor decreased from 643 to 286 hours per year. If the $2.50 complement had been kept with a $12.50 wage rate, total annual costs would have been $35,566.00 annually. Substituting capital for labor saves $1,899.00 annually.

The annual cost per acre for the $2.50 complement of the 480 acre farm is $24.34 while for the 1440 acre farm the cost is $20.93. Economies of

Table IV Annual Usage and Cost Comparison for Optimal Complements at 80% Timeliness Levels with 10-12 Hour Workdays for North Central Oklahoma 480 and 1440 Acre Farms

Acres in Farm	480		1440		1440		1440	
	2.50 Wage		2.50 Wage		12.50 Wage		12.50 Wage With Transfer[4]	
	Width	Hours[1]	Width	Hours[1]	Width	Hours[1]	Width	Hours[1]
Tandem Disk	11'5"	86	11'5" (3)	86ea	28'4"	105	28'4"	105
Moldboard Plow	8'	141	4' (2)	141ea	10'8"	128		
Moldboard Plow	4'	20	10'8"	128	16'	141	16'	226
Field Cultivator	12'6"	88	34'6"	96	34'6"	96	34'6"	96
Springtooth	15'	142	48'	133	48'	133	60'	107
Drills	13' (2)	47ea	13'	5	13'	5		
Drills			39'	93	39'	93	39'	95
Tractor	50HP	472	100HP (2)	1337ea	150HP	494		
Tractor	100HP	157	150HP	420	225HP	276	225HP	691
Hours Hired Labor[3]	119		643		286		231	
Annual Fixed Cost	$8,683		$20,213		$22,329		$15,698	
Labor Cost	299		1,607		3,572		2,886	
Transfer Cost	-		-		-		1,133	
Other Variable Cost	2,702		8,316		8,766		9,528	
Total Annual Cost	11,684		30,136		34,667		29,245	
Annual Cost/Acre	24.34		20.93		24.07		20.31	

[1]Number of machines is one unless otherwise specified in parentheses.

[2]Tractor Hours equal 1.1 times implement hours.

[3]Labor hours equals tractor hours time 1.1. Hired labor equals total labor minus 100 hours free labor in each period.

[4]Plowing and drilling are limiting operations. By allowing nighttime work at additional cost of $2 per acre this complement obtained.

size apparently result in approximately a $3.41 per acre saving when moving from 480 to 1440 acres.

The complements discussed to this point have required work to be completed 80% of the time in the correct time period. Also assumed have been 10 hour workdays in the winter and 12 hour work days in the summer. The fourth complement on Tables IV relaxes the 12 hour work day assumption. The complement in Table III consists of two tractors, a 150 horsepower tractor and a 225 horsepower tractor. From the table it is obvious that two tractors are needed in the first half of July and the second half of September to complete the plowing and drilling operations. If instead of working 12 hours per day during the first half of July and second half of September we allowed working nights, the optimal complement would change. In the fourth complement of Table IV working nights resulted in substantial changes in the machinery complement and its costs. The average cost per acre when wage rates are $12.50 per hour dropped from $24.07 to $20.31 even though a $2.00 per acre penality charge was made for each acre covered in the nighttime hours.

Working nights decreased the number of tractors required from two to one. A farmer willing to hire help to keep a tractor running 24 hours per day can farm a 1440 acre farm with one 225 horsepower tractor using 591 hours of hired labor per year. The biggest impact of moving to a one tractor complement is the decreased investment required. Annual fixed costs dropped from $22,329.00 to $15,698.00.

Summary

As the costs of owning and maintaining machinery complements increase, farmers are going to be more interested in selecting complements that satisfy their needs at a minimum cost. Farmers can affect the costs of their machinery by their way they select the percent of time they wish to get field work done in the appropriate time interval, the hours they are willing to work each day, and by the way the select cultural practices. This information along with weather data and the potenial machines which can be used are required before the algorithm used in this study can determine optimal machinery complements.

The results of the labor cost study presented here indicate that as labor costs increase relative to machinery costs, farmers may substitute capital for labor. More specifically, it is expected that there will be larger implements, fewer but larger tractors, and decreased labor requirements. In this analysis the wage rate has been used as a proxy for labor availability. If $12.50 per hour is sufficient to attract and keep hourly labor, farmers will buy larger machinery to minimize the amount of labor that must be kept available. In addition, more use of machinery at nights will lead to reduced costs.

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