AN ECONOMIC EVALUATION OF SOME ALTERNATIVE METHODS OF HARVESTING GRASS SILAGE

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By

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A THESIS

Submitted to the College of Agriculture Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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ABSTRACT

The purpose of this study was to provide data on performance rates of forage harvesting machinery and to develop synthetic cost data and partial budgets for harvesting and storing grass silage by alternative methods.

Data were obtained by means of a survey, on a "time and motion study" basis, of grass silage harvesting and storing operations on a roughly stratified sample of 71 South-Central Michigan dairy farms using specified forage harvesters and blowers in specified combinations of machinery, labor and power.

Performance rates varied with size and type of machine, size of crew and storing methods. Overall average performance rates for harvesting and storing green material from field to storage were 9.1 tons per hour with an average of 9.6 tons per hour for direct cut and 8.6 tons per hour for wilted material. The typical outfit consisted of 3 men, 2 wagons and 3 tractors. Average potential blower capacity for all types was 18.7 tons per hour for direct cut and 14.6 tons per hour for wilted material with rates for PTO models of 27.1 and 23.4 tons per hour respectively. In all cases, the potential performance rates for forage harvesters and blowers, given the associated equipment, on the operations observed, were below the manufacturer's claims for the various machines.

Data from the survey, and a review of work by the physical scientists into the efficiency of the different types of machines and

the nutritive losses and feed wastages which occur with the various methods of conserving grass silage, were used to develop synthetic cost data and partial budgets for harvesting and storing grass silage for different sized dairy herds on farms similar to those in the survey.

The assumption, made in this study, that marginal costs are constant over the whole range of output for a given system, prevented true economic optima or machinery capacity (where MVP = MFC) from being determined. Instead "guesstimates" of this point -- referred to as "capacity limits" -- were made, beyond which it was considered "uneconomical" to operate the system.

Recommendations, based on the survey results and the synthetic data, include the use of custom hiring services and trench silos for small herds, sharing of equipment and self feed bunker silos for medium sized herds, and ownership of motor mounted forage harvesters with large upright silos having mechanical unloaders and feed bunks for the large herds.

The limitations of the study point to the need for more interdisciplinary research work into the various economic and technical aspects of grass silage conservation. In particular, the technicians should provide further data on the nutrient losses and wastages that occur with the various systems of harvesting, storing and feeding grass silage and the agricultural economists should undertake exact measurement studies into the labor and machinery requirements at all stages of the operations. The "true marginal cost" of harvesting and storing grass silage by alternative methods could then be derived, and economic optima or machine capacity determined.

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CHAPTER I

INTRODUCTION

Many recent articles and speeches have stressed the fact that dairy herds of the future will have to increase in size if they are to remain economic units. An analysis of the problem of low labor incomes in dairying, - with possible solutions, - has been presented by Fuller.[1/]

Some herds of the future may well be of a 100-cow size and upwards, operated by one man and maintained in a loose-housing, parlor milking set up with milking rates of 50 to 60 cows per man hour. Duckham[2/] envisions complete electronically controlled milking operations.

Low feeding costs will be essential in these future organizations. It has been proved, ad nauseum, that grasses and legumes are the cheapest source of feed for herbiverous stock. Large quantities of such feed will need to be conserved with the aid of only a small labor force. Difficulties arise in harvesting and storing forage in the uncertain weather which occurs in June. A study of weather data from the U. S. weather station at East Lansing, Michigan, for a 45-year period reported by Hoglund[3/] shows that for any day a farmer mows hay during the period June

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1/ E.I. Fuller, Some Labor Efficient Dairy Farm Operations Designed for Michigan Conditions, Department of Agricultural Economics, Michigan State University, Ag. Econ. 674, April, 1957.

2/ A. N. Duckham, "Agriculture in the Early Atomic Age", Agricultural Review (U.K.), Vol. III, No. 5, August, 1957.

3/ C. R. Hoglund, The Economics of Alternative Forage Systems, Department of Agricultural Economics, Michigan State University, Ag. Econ. 674, April, 1957.

10 to 15 that the odds are 3 to 1 against the occurrence of good weather for three consecutive days.

Harvesting of grass silage is suggested by Hoglund, Fuller and many others, (including the present writer) as one way of handling large quantities of high quality forage in the typically rainy spring weather of Michigan and other such areas (e.g. Great Britian). If grass silage is to occupy a high place in the farm plan it is essential that the product be of high feeding value and that the cost per feed unit compare favorably with alternative feedingstuffs.

Work at Beltsville 1/ shows that more nutrients can be obtained from forage crops by harvesting them as silage rather than as field cured hay. Labor and equipment requirements, in terms of per ton of dry matter preserved, are about the same for both methods.

The Problem

The problem facing the farmer is how to conserve as large a quantity of grass silage as possible within the limited time period available commensurate with high feeding quality and an economical level of costs. Fellows 2/ has stressed the lack of research into the economics of forage production and criticised much of what has been undertaken on the grounds that it consists mainly of such statements as "the average cost of harvesting with a forage harvestor was $8 per ton whereas the average cost with another system was $4 per ton."

1/ J. B. Sheperd, et.al., "Grassland", USDA, Year Book of Agriculture, 1948

2/ I. F. Fellows, "Economics of Grassland Farming in the North East", Journal of Farm Economics, Vol. 34, 1952.

Such facts are of little use to a farm operator without reference to the conditions and assumptions of the study. To organize a combination of men and machines to harvest the required quality of silage it is essential that operators have reliable performance data available. Considerable variations exist between data from past surveys and manufacturers' claims. These latter claim performance rates for forage harvesters between 20 and 30 tons per hour. A rate as high as 45 tons per hour[1/] is claimed for one recently introduced model. Capacity for the complete operation is more important than that of individual machines. Performance results from previous surveys are summarized in Appendix Table 1 and range from rates of 1.4 tons to 10.0 tons per hour for harvesting grass silage from field to storage.

Objective

The objective of the study is to provide data on current performance rates, and costs and profits from partial budgets which can be used by farm operators to aid them in the decision making process involved in determining the optimum combination of men and machinery required to maximise profit when harvesting and storing a given quantity of grass silage.

Procedure

Performance data were obtained by observing grass silage harvesting

1/ With direct cut material this would require the 8' chopper to travel continually at 4 MPH in a 11 ton crop of alfalfa with no delays for turning at headlands etc. To achieve this rate with wilted material would require 4 windrows each round and need 2 mowers and windrowers to maintain this supply? For the basis of this computation c/f R.T. Burdick, A New Technique of Field Crop Labor Analysis, Colorado Agricultural Experiment Station Technical Bulletin 30, June, 1947.

operations on a sample of Southern Central Michigan dairy farms, and recording the labor and machinery requirements on a "time and motion study" basis.

Various economic factors were considered. Since quality factors have to be taken into account, relevant studies from other agricultural disciplines were reviewed.

The data from the survey and the review of existing work were then used to construct the synthetic cost curves and partial budgets.

CHAPTER II

ECONOMIC CONSIDERATIONS

The main economic considerations are related to the various cost concepts. Costs of harvesting grass silage are influenced by such factors as

1) Crop being ensiled - the relative proportion of legumes and grasses in the mixture, etc.

2) Period of time available for harvesting.

3) Total quantity made or acreage to be covered.

4) Capacity and performance of the machines.

5) Adaptability of machinery to varying soil and topographical conditions.

6) Power available.

7) Other use of machinery either for other crops on the farm or for custom work.

8) Relationship between labor and machinery costs

9) Quantity of labor available and that needed to be hired.

Fixed Assets

As Bradford and Johnson[1/] point out, "cost concepts are difficult concepts," Most of the difficulties encountered in pricing inputs involve fixed inputs which usually do not have market prices as separate

1/ L. A. Bradford and G. L. Johnson, Farm Management Analysis, John Wiley and Sons, New York, 1953.

items. They are fixed and, therefore, worth what they will produce in their present employment. What they are worth in their present employment depends on a variety of factors including (1) prices received for products that they are used to produce, (2) the amount and quantity of variable inputs (working capital) used and (3) production techniques employed. Ordinarily market conditions do impose upper and lower restrictions on variations in the worth of a fixed asset; i.e. if the worth of a fixed asset becomes sufficiently high, it becomes advantageous to add more of it in which case it is no longer fixed; conversely if the worth falls sufficiently low it becomes advantageous to start selling the asset. The upper limit is often over 50 percent higher than the lower.

One method of pricing fixed assets is to use replacement costs. Use of replacement costs causes costs to be overestimated. Still another procedure is to not price fixed assets at all but, instead, to subtract from gross income all cash expense and call the remainder return to fixed assets and profits. Great difficulty is experienced in interpreting the results of subtracting from this remainder arbitrary charges for portions of the fixed assets. This difficulty is avoided by refraining from making arbitrary charges against incomes for fixed assets. In other words settle for an estimate of farm earnings as this figure can correctly be interpreted to represent returns to management, fixed investments and the operator's labor and can be reached without pricing the fixed assets. For those instances in which it is felt desirable, for traditional or other reasons, to price fixed assets, either (1) estimates of the dollar productivity of the fixed assets or (2) arbitrarily fixed asset prices falling between replacement and opportunity cost, can be used.

Many of the problems encountered in the study hinged around this 'fixed

asset' concept. The operator's and regular hired labor are often 'fixed' for the farm as a whole. Existing harvesting machinery is often 'fixed' and so to a considerable extent is any given method of harvesting and storing silage once the operations have commenced. This point will be discussed later in Chapter V.

Cost Concepts

In order to make meaningful cost computations the following information is required. First, the nature of the production relationship, for the length of run under consideration, must be known. This implies that the fixed inputs are known in quantity as well as by quality or name. This also implies that the method of production to be employed is known. The second requirement is that the prices of the variable inputs be known. This price requirement is necessary in order to meet the third requirement, that the variable inputs be combined in least cost combination. From the pertinent set of least cost combinations, it is possible to compute total variable costs, average variable costs and marginal costs. Knowledge of fixed factors and their prices (or product prices) make it possible to compute average fixed costs per unit of output and total fixed costs for any level of output. Total fixed costs can be added to total variable costs for the any level of output to arrive at total costs and average total costs for that level of output.

Total variable costs (TVC) represent the sum total of expenditures on the variable inputs for any level of output. They are short run costs. The inputs involved are those inputs which are variable in the length of run under consideration.

Average variable costs (AVC) are total variable costs divided by output.

Marginal costs (MC) deal only with variable costs; no fixed costs enter into marginal costs. Marginal cost is the cost of producing an additional unit of output at a given level of output. Fixed costs are not included because they are fixed and hence are neither increased nor decreased by additional production.

Total fixed costs (TFC) are meaningful only in the length of run which fixes the components of such costs. In a given length of run the components or inputs making up total fixed costs are committed to the production of the product under consideration. The services of such inputs are worth, in their fixed position, exactly what they will produce.

Average fixed costs (AFC) are total fixed cost divided by output.

Total cost (TC) is the sum of total fixed and total variable costs.

Average total costs (ATC) are total costs divided by output.

Capital Considerations

In deciding the type and quantity of machinery to use, farmers are influenced by the availability of capital. Thus, one short of capital may forego otherwise desirable machinery purchases since land and soil improvements, or livestock investments may be more profitable. The logical aim of a profit maximising farmer is to allocate capital in such a way so as to get equal marginal returns from the last dollar spent on each enterprise on the farm.

Size of Machines

Capital considerations are also involved in determining the optimum size of a machine. In addition such factors as total annual use and capacity within a given time period also have to be considered.

One general rule in determining size is the value of labor and other resources saved per unit of comparable output by a larger machine, should more than offset the additional cost involved. In the case of grass silage, the value of other resources saved may include the increased feeding value made possible by harvesting a larger quantity of the forage at its optimum stage of productivity in terms of food nutrients. In figuring costs, alternative opportunities have to be considered; for instance, buying a smaller machine may free capital for more profitable investment in fertilizers or livestock.

The size of a machine and hence the amount of investment depends on the subjective value attached to combating risk and uncertainty, in the form of future weather conditions, price fluctuations etc. Timeliness may also have value. Still further, it is necessary to determine how much possible future incomes from the investment are worth now, by considering the life of the investment and alternative income opportunities; thus, future incomes must be discounted back to find their present values. Various interest rates for discounting may be used, depending on a farmers financial condition, with differing results as to the advisability of making investments.

Interest Rates

As Heady and Jensen[1/] point out the cost of having money tied up in

1/ E. O. Heady and H. Jensen, Farm Management Economics, Prentice - Hall Inc., New York, 1954

machinery is difficult to determine and no answer fits all conditions. The best general assessment is that the rate charged should vary with the amount of capital available. If the farmer borrows funds to buy machinery the actual interest rate which may vary from around 5 percent up to and approaching 50 percent is the appropriate charge to make. If he has funds over and above those used in the farm business the rate charged should be the rate he could earn on an outside loan or investment. The use of the market rate of interest is most applicable to the farm operator who is not limited on capital and who does not need to consider returns on alternative investments in additional fertilizer applications, more livestock, buildings or other farm improvements. For the farmer severely limited on funds, the interest rate is the "opportunity cost" or rate of return his money would yield when used for other investments on the farm. This rate is particularly appropriate for machines which require a high initial investment and where the service can be custom hired without loss of yield or quality. Practical difficulties arise, however, in determining this rate.

In certain instances, high market rates will be applicable to the farmer limited on funds; for instance if a certain piece of equipment, such as a mower, is indispensable to his operations, a high market rate may have to be paid to obtain the necessary funds. This will apply particularly during periods of depression when credit facilities are "tight."

Machinery Ownership Patterns

The most economic organization of men and machinery depends on how the machinery is owned as costs are conditioned by ownership patterns. There are five main patterns:

1) Self ownership
2) Joint ownership
3) Custom hiring
4) Combination of self ownership and custom hiring
5) Combination of self ownership and custom work off the farm.

Various combinations of the above patterns are possible.

Custom Hiring

Some factors to consider in deciding whether to own or custom hire machinery are:

1) Is there enough annual use to justify ownership?
2) Is the service available at the time desired?
3) Will the delay of an operation result in quality losses greater than the savings offered by custom service?
4) Pride of ownership or personal desires.
5) Independence associated with owning the equipment.
6) Availability of capital required for owning the equipment.

Frick and Weeks[1/] state that "in general, a farmer can afford to

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1/ G.E. Frick and S.B. Weeks, When to Hire and When to Own Farm Equipment on New England Dairy Farms, New Hampshire Agricultural Extension Service, Extension Circular 302, July, 1951.
The following formulas, which were derived from the work of Frick and Weeks, can be used to determine the break-even point, i.e. the number of annual hours of use required to justify ownership of the machine. At this point custom hiring charges and machinery ownership and operating costs are equal. At the Break Even Point:
Cost per hour of custom work = Average total cost per hour for owning and operating machinery (ATC).
Average total cost (ATC) = Average Variable Cost (AVC) + Average Fixed Cost (AFC).

1) $\frac{\text{Total Fixed Cost per year (TFC)}}{\text{Average Fixed Costs per hour (AFC)}}$ = Number of units i.e. Break Even Point in hours of use.
Thus, if the custom rate = \$10 per hour = ATC; AVC = \$2 per hour; and TFC, = \$400 per year; then
Break Even Point: hours of use per year = $\frac{TFC}{ATC - AVC} = \frac{400}{10-2} = \frac{50 \text{ hours}}{}$
2) Break Even Point (acres per year) = $\frac{\text{Break even point (hours per year)}}{\text{Performance rate (hours per acre)}}$
Thus, if performance rate is 2 hours per acre
Break Even Acreage = $\frac{50}{2}$ = 25 acres per year.

hire when total cost of custom work for a single piece of equipment is equal in value to the annual ownership, direct operating, and labor costs for using the equipment" i.e. custom hiring is justified when the cost of owning and operating the machinery is equal to or greater than the custom rate.

Contract Operation

Weeks and Frick[1/] consider that there are three types of farmers who may undertake custom work (a) those who wish to perform a sufficient

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1/ S. B. Weeks and G. R. Frick, How to Make Money Doing Custom Work, New Hampshire Agricultural Extension Service, Extension Circular 303, July, 1951.

In the case of (a) in the text the following formula may be used:

$$\text{Break even point (total hours of use per year on and off the farm)} = \frac{\text{Total Fixed Costs (TFC) per year}}{\text{Average total Costs (ATC) - Average Variable Cost (AVC) per hour.}}$$

1) Thus, if the rate charged to perform custom work is \$10 per hour = ATC; AVC = \$2 per hour; TFC = \$800 per year then

$$\text{Break even point} = \frac{\text{TFC}}{\text{ATC-AVC}} = \frac{800}{10-2} = \underline{100 \text{ hours per year}}$$

2) If performance rate = 1 hour per acre then

$$\text{Break Even (acreage)} = \text{Break Even (hours of use per year)} = \frac{100}{1} = 100 \text{ acres per year}$$

3) The price to charge per hour for custom work can be determined by the following formula:

$$\text{Price (Dollars per hour)} = \frac{\text{Total Fixed Costs (TFC) (\$ per year)}}{\dfrac{\text{Total Annual Acres of Work (Acres Per Year)}}{\text{Performance rate (hours per acre}}} + \text{Average variable Cost (AVC) (\$ per hour).}$$

Thus using the above figures in (1) and (2)

$$\text{Price (dollars per hour)} = \frac{800 \text{ (\$ per year)}}{\dfrac{100 \text{ (acres per year)}}{1 \text{ (hour per acre)}}} + \$2 \text{ per hour} = \$10 \text{ per hour}$$

volume of off farm work so that, combined with the work at home, it will justify ownership of the equipment (b) those who wish to cover all costs by outside work, thus ignoring work at home in ownership calculations and (c) those who wish to perform a large amount of custom work, as a source of additional income over and above that required to justify ownership of the machinery. However, if undertaking custom work involves postponing harvesting on the home farm, with the risk of reducing feeding values, the net result may well be a loss.

Joint Ownership

Joint ownership of machinery may be either through a cooperative with a definite membership, or by an agreement of two or more farmers. In view of the limited period available for many harvesting operations, it is essential that the order in which the work is to be done be worked out before the start of the season. This applies particularly to grass silage operations where the period for high quality production is limited and it is suggested that only two, or at the most, three partners be concerned in ownership of forage harvesters, blowers, etc.

CHAPTER III

THE SURVEY

The aim was to obtain data on performance rates and labor requirements for the newer forage harvesting equipment for grass silage making, but many operations using older machinery were also observed since it was suspected that organization of the operation was as important as capacity of machinery in obtaining high output (such proved to be the case). The sample was not random but was roughly stratified to obtain representative data for harvesting and storing first cutting alfalfa brome mixtures for silage on Southern Central Michigan dairy farms with specified herd sizes and employing specified forage harvesters and blowers. Of the 189 farmers contacted partial data were obtained from 86 and complete data from 71. Contacts were obtained from the Department of Agricultural Economics, from County Extension Agents and, to a considerable extent, by stopping at farms where operations were either in progress or looked as if they would be in the near future.[1/] No farmer refused to help and all seemed interested in the subject. Unfortunately, due to the difficulty of arranging travel schedules and to wet weather, it was not always possible to be at the farm during the relatively short period of actual harvesting operations.

No operations involving green crop loaders and stationary choppers were observed. This had been a popular method with the smaller herds as

1/ This method also seems to have been used by S. A. Engene "Sampling Procedures Used In Haymaking", Journal of Farm Economics, Vol. 29, December, 1947.

previous surveys had indicated.[1/] It was assumed that the owners of such small herds who remain in milk production will avail themselves of custom hiring of forage harvesters and blowers in the future. Such was the case for many of the small herds observed. In other instances such operators had been able to buy second hand forage harvesters and blowers.

The crop being harvested was usually first cutting alfalfa or alfalfa brome mixtures. A few observations were also made on harvesting and storing oats, sudan grass, corn, and sorghum silage. (Brief details of these operations are presented in Appendix Table 5.)

Most of the observations were made during the period early June to early July but, due to the wet season and conflicts with corn cultivating, many farmers were still harvesting first crop silage in mid July. By this time, the crop had long passed its optimum value.

Procedure

The performance data were obtained by observing the time requirements for the various stages of the operation by means of a stop watch on a "time and motion" basis. Loads were followed through from cutting to final blowing or unloading into the silo. In certain instances, the various stages of the operation were continually recorded and composite "runs" synthesized from the data.

1/ K. Vary, Hay Harvesting Methods and Costs, Michigan Agricultural Experiment Station, Special Bulletin 392, May, 1954; B. Bookhout and K. Vary, "Farmers Experience with Grass Silage," Michigan Quarterly Bulletin, Vol. 32, February, 1949.

An attempt was made to utilize the technique of "work sampling".[1/] Unfortunately, due to the difficulty of obtaining a vantage point from which to view the complete operation, it was only possible to operate this technique in cases where silage was being made in a field adjoining the building. In such cases it proved very effective. The results obtained were similar to those derived by the "stop watch" procedure.

Description of Farms

Variations in the type of housing, type of silo and ownership pattern of the equipment used occurred with variations in herd size. Horizontal silos occurred mainly on farms with larger herds, operating some system of loose housing. The stanchion barn system, more common with the smaller sized herds, relied more on the conventional upright silo, some of which dated back to 1920 and prior. The larger uprights of 300-500 ton capacity were mainly of very recent origin.

Custom hiring and sharing of equipment occurred for the most part on farms with the smaller sized herds (see Table 1).

Also relatively smaller proportions of the hay acreage tended to be harvested as chopped material on these farms. The farmers with medium

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1/ "Work Sampling" is a procedure for estimating the proportion of time spent by individuals or machines in a given category of activity by means of random observations of simultaneous operations in the process. Unit time requirements for the various components of a flow process in material handling can be determined from such observations with the aid of physical data on the quantities handled during the observation period. The proportion of idle time involved at the various stages of the operation is readily determined by this technique. c/f. D.G. Malcolm and L.L. Sammett, "Work Sampling - (1) Applications (2) Guides to Analysis and Accuracy Criteria", Giannini Foundation Papers No. 137, and 138. Journal of Industrial Engineering, Vol. 3 and 4, May and June, 1954.

TABLE 1

(1) [illegible] HERD SIZE, AND
(2) OWNERSHIP PATTERN OF EQUIPMENT [illegible]
ON 86 [illegible] DAIRY FARMS

HERD SIZE (Number of Cows)	(1) [illegible]				
	Upright	Upright and Bunker	Bunker	Trench	Total
< 10	1	-	-	-	1
11-20	-	-	-	-	-
21-30	1	1	3	-	5
31-40	1	2	[illegible]	1	7
41-50	1	-	2	1	4
51-60	3	-	1	-	4
61-70	-	1	1	-	2
> 70		2	-	-	
TOTAL	1[illegible]	6	10	2	28
	(1) [illegible] HOUSING				
< 10	-	-	-	-	-
11-20	7	-	-	1	8
21-30	1[illegible]	-	1	-	1[illegible]
31-40	16	1	1	-	1[illegible]
41-50	11	-	-	-	11
51-60	1	-	-	-	1
61-70	4	-	-	-	4
> 70	3	-	-	-	3
TOTAL	54	1	2	1	58

HERD SIZE (Number of Cows)	(2) OWNERSHIP PATTERN OF EQUIPMENT			
	Custom Hire	Share	Own	Total
< 10	-	-	-	-
11-20	1	1	6	8
21-30	2	3	13	18
31-40	5	-	20	25
41-50	-	2	13	15
51-60	-	-	5	5
61-70	1	-	5	6
> 70	-	-	8	8
TOTAL	[illegible]	6	71	86

TABLE 2

HIGH, LOW AND AVERAGE ACREAGES OF GRASS SILAGE
AND OTHER FORAGE CROPS BY SIZE OF HERD
86 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

HERD SIZE (Number of Cows)		FORAGE CROPS							
		Grass Silage		Corn Silage		Dry Hay			
						Baled		Chopped	
		Sample Size	Acreage	Sample Size	Acreage	Sample Size	Acreage	Sample Size	Acreage
1-10	Mean	1	8.0	-	-	1	22.0	-	-
11-20	High	-	15.0	-	10.0	-	14.0	-	53.0
	Low	-	5.0	-	5.0	-	46.0	-	32.0
	Mean	8	11.0	3	7.0	[illegible]	30.7	3	40.0
21-30	High	-	60.0	-	25.0	-	75.0	-	-
	Low	-	6.0	-	5.0	-	27.0	-	-
	Mean	18	20.4	8	14.1	8	49.2	1	15.0
31-40	High	-	75.0	-	40.0	-	100.0	-	65.0
	Low	-	5.0	-	6.0	-	25.0	-	45.0
	Mean	25	36.3	7	19.5	4	48.0	8	56.6
41-50	High	-	100.0	-	35.0	-	175.0	-	88.0
	Low	-	8.0	-	5.0	-	22.0	-	34.0
	Mean	15	31.4	12	15.3	11	85.5	5	[illegible]
51-60	High	-	60.0	-	35.0	-	-	-	-
	Low	-	15.0	-	15.0	-	-	-	-
	Mean	5	35.6	15	20.1	1	55.0	1	80.0
61-70	High	-	100.0	-	10.0	-	100.0	-	-
	Low	-	15.0	-	53.0	-	70.0	-	-
	Mean	5	37.0	4	26.1	4	86.2	-	-
> 70	High	-	150.0	-	[illegible]	-	-	-	-
	Low	-	60.0	-	20.0	-	-	-	-
	Mean	8	96.2	3	20.0	3	77.0	3	[illegible]

sized herds, generally owned their forage harvesters, and tended to conserve chopped hay, while the larger herd owners tended to bale their dry hay. Relatively smaller acreages of corn silage were grown on the farms with large herds (See Table 2).

Performance Rates

It should be borne in mind that the survey was not designed to compare the performance and capacity of different makes of machines performing under identical conditions but rather to compare the various systems and combinations of equipment used in forage harvesting. Although differences in performance rates were observed, these were due in many cases to the skill, method, and intensity[1/] with which the operation was conducted rather than to differences in the mechanical efficiency of the various forage harvesters. It would seem that certain makes and types of machines are more suitable to certain conditions than others. However, more testing by agricultural engineers under farm conditions would be necessary before definite conclusions could be obtained and recommendations made.

The performance rates and details of equipment of the operations studied are given in Tables 3 through 9. The rates are those obtained with the existing organization. They allow for minor delays but not for the major breakdowns or weather hold-ups which were particularly important in the 1957 season. All the data have been adjusted to a hauling distance

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1/ For an analysis of the importance and distinction between these factors, c/f M.E. Brunk and J. C. Thompson, "Maximising Worker Productivity Through Evaluation Of Its Components - An Hypothysis" Journal of Farm Economics, Vol. 33. No. 3, 1951. pp. 381

of 80 rods.

No allowance has been made in Table 3 for variations in the size of loads but these are, of course, reflected in Table 4 through 5. The loads ranged from 1.74 tons to [illegible] tons with an average of [illegible] tons. In the case of the wilted material no allowance has been made for the time for mowing and raking or windrowing, or for the actual period of wilting. This latter ranged from 6 hours down to a few minutes (which in effect was almost the equivalent of direct cutting) with an average time of wilting around 1.[illegible] hours. Mowing and raking time averaged 10 minutes per ton. Moisture or chemical analyses were not conducted so it was not possible to compare the weights of actual dry matter hauled by the two systems. Thus, the figures given are for weight of material as hauled, and many of the differences which occur on this basis may disappear, or be reversed in terms of tons of dry matter.

Overall average time to harvest and store a load was 35.9 minutes for direct-cut, and 42.6 minutes for wilted material (Table 5).

TABLE 5

AVERAGE TIME REQUIREMENTS PER LOAD FOR HARVESTING AND STORING GRASS SILAGE. DIRECT CUTTING AND WINDROWING COMPARED ON 71 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

METHOD	SAMPLE SIZE	OPERATION				Total Time
		Chopping	Travel 1/ from Field 2/	Position & Unload 1/	Travel 1/ from Silo 2/	
			Minutes			
DIRECT CUT	36	14.1	5.4	11.6	4.8	35.9
WINDROW	35	13.3 3/	5.3	1[illegible].7	[illegible]	42.6

1/ Waiting periods and minor delays included.

2/ Travel adjustment to 80 rods.

3/ Excludes mowing/windrowing time, - this averages 10 minutes per load plus wilting time.

Overall performance rates for the three types of storage were, 9.6 tons per hour for direct cut and 8.7 tons per hour for wilted material with an average, by all methods, of 9.1 tons per hour. The typical sized crew was 3 men and 2 wagons. (Table 4).

TABLE 4

AVERAGE PERFORMANCE RATES FOR [illegible] GRASS SILAGE, [illegible] OF MATERIAL AND TYPE OF SILO, ON 71 [illegible] 1957

ITEM	KIND OF MATERIAL						OVERALL AVERAGE
	DIRECT-CUT			WINDROW			
	Upright	Horizontal	Overall Average	Upright	Horizontal	Overall Average	
TONS PER HOUR	8.8	10.8	9.6	8.5	9.7	8.7	9.1
TONS PER MAN HOUR	3.25	3.70	3.41	2.[illegible]	2.[illegible]	2.57	3.0
MAN HOURS PER TON	.3[illegible]5	.2[illegible]	.[illegible]	.4[illegible]	.416	.429	.37[illegible]
AVERAGE CREW							
MEN	2.9	3.2	3.0	3.6	4.0	3.7	3.2
WAGON	2.2	2.0	2.1	2.3	2.3	2.3	2.[illegible]

Variations in rates between crews ranged from 7.[illegible] tons per hour with 2 men and 1 truck to 15.0 tons per hour with 4 men and 2 trucks for direct-cut material (Table 5); and from [illegible] tons per hour with 1 man and 1 wagon to 11.1 tons per hour with [illegible] men and 3 wagons for wilted material (Table 6).

To obtain a high performance rate the operation should be designed to keep the forage constantly on the move from field cutting or chopping until it is stored in the silo.[1] This rate of flow depends on the capacity

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1/ For a discussion on the flow process in material handling and of the need to avoid bottlenecks, c/f F.C. Winter, "An Approach to Efficiency Studies", Agricultural Engineering, Vol. 37, July, 1956.

TABLE 5

HIGH, LOW AND AVERAGE PERFORMANCE RATES FOR HARVESTING AND STORING DIRECT CUT GRASS SILAGE BY TYPE OF SILO AND ALTERNATIVE SYSTEMS ON 71 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

SYSTEM		TONS PER HOUR		TONS PER MAN HOUR		MAN HOURS PER TON	
		Upright	Horizontal	Upright	Horizontal	Upright	Horizontal
1 man 1 wagon	High	4.5	-	4.5	-	.22	-
	Low	3.0	-	3.0	-	.33	-
	Mean	(2) 1/ 3.8	-	(2) 3.8	-	(2) .28	-
2 men 2 wagons	High	11.4	12.0	5.7	6.0	.18	.17
	Low	6.3	8.5	3.1	4.2	.32	.23
	Mean	(5) 8.0	(3) 10.0	(5) 4.0	(3) 5.0	(5) .26	(3) .20
2 men 1 truck		-	(1) 7.6	-	(1) 3.8	-	(1) .26
3 men 2 wagons	High	11.6	12.0	3.9	4.0	.26	.25
	Low	5.2	7.4	1.7	2.5	.58	.40
	Mean	(6) 8.0	(6) 10.6	(6) 2.7	(6) 3.5	(6) .40	(6) .29
3 men 3 wagons	High	15.0	-	5.0	-	.20	-
	Low	12.0	-	4.0	-	.25	-
	Mean	(3) 13.5	-	(3) 4.5	-	(3) .22	-
4 men 2 wagons	High	8.4	-	2.1	-	.48	-
	Low	7.5	-	1.9	-	.53	-
	Mean	(2) 8.0	(1) 7.0	(2) 2.0	(1) 1.7	(2) .50	(1) .58
4 men 2 trucks		-	(1) 15.0	-	(1) 3.8	-	(1) .27
4 men 3 wagons	High	12.0	-	3.0	-	.33	-
	Low	7.0	-	1.7	-	.58	-
	Mean	(3) 10.0	(1) 13.8	(3) 2.5	(1) 3.5	(3) .42	(1) .29
5 men 2 wagons		-	(1) 14.0	-	(1) 2.8	-	(1) .36
5 men 3 wagons		(1) 9.3	-	(1) 1.9	-	(1) .53	-

1/ Sample size.

TABLE 6

HIGH, LOW, AND AVERAGE PERFORMANCE RATES FOR HARVESTING AND STORING WILTED GRASS SILAGE BY TYPE OF SILO AND [illegible] SYSTEMS ON 71 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

SYSTEM		TONS PER HOUR Upright	TONS PER HOUR Horizontal	TONS PER MAN HOUR Upright	TONS PER MAN HOUR Horizontal	MAN HOURS PER TON Upright	MAN HOURS PER TON Horizontal
1 man 1 wagon		(1) 1/ 4.8	-	(1) 4.8	-	(1) .21	-
2 men 2 wagons	High	10.9	-	5.5	-	.18	-
	Low	5.0	-	2.5	-	.4[illegible]	-
	Mean	(3) 7.2	-	(3) 3.6	-	(3) .[illegible]1	-
3 men 2 wagons	High	9.1	-	3.1	-	.33	-
	Low	4.[illegible]	-	1.[illegible]	-	.6[illegible]	-
	Mean	(5) 7.0	-	(5) 2.[illegible]	-	(5) .[illegible]6	-
3 men 3 wagons	High	11.[illegible]	-	3.7	-	.27	-
	Low	9.0	-	3.0	-	.33	-
	Mean	(6) 9.8	(1) 9.3	(6) 3.3	(1) 3.1	(6) .31	(1) .32
4 men 1 truck		-	(1) 11.0	-	(1) 2.7	-	(1) .36
4 men 1 wagon 1 truck		(1) 6.2	-	(1) 1.6	-	(1) .64	-
4 men 2 wagons	High	11.3	-	2.8	-	.36	-
	Low	4.[illegible]	-	1.2	-	.83	-
	Mean	(5) 8.9	(1) 9.4	(5) 2.2	(1) 2.4	(5) .50	(1) .43
4 men 3 wagons	High	8.8	-	2.2	-	.46	-
	Low	7.8	-	1.9	-	.51	-
	Mean	(2) 8.3	-	(2) 2.1	-	(2) .48	-
5 men 2 wagons		(1) 11.1	-	(1) 2.2	-	(1) .45	-
5 men 3 wagons	High	12.3	-	2.5	-	.41	-
	Low	9.0	-	1.8	-	.56	-
	Mean	(5) 10.7	(1) 9.0	(5) 2.1	(1) 1.8	(5) .47	(1) .56
5 men 2 trucks		(1) 9.5	-	(1) 1.9	-	(1) .52	-
6 men 3 wagons		(1) 9.6	-	(1) 1.6	-	(1) .62	-

1/ Sample size

of the chopper and blower. (Tables 7 and 8 show that these differ in most cases.) Men and wagons have to be fitted into the system with the object of reducing the breaks and holdups in this flow to a minimum.

A frequent cause of delay was the "plugging" of the blower elevator pipe, especially with over-wilted material. In the field, slugging of the chopper occurred from "badly laid" stands and from wads of material in the windrows. Age of machine was a contributing factor to delays in many instances.

Forage Harvesters

Variations in the potential performance of the different kinds of forage harvesters rates ranged from 7.3 tons per hour with a 4' P.T.O pick-up model to 15.0 tons per hour with 6' of P.T.O. rotary direct-cut model. The overall average was 12.0 tons per hour for direct-cut and 11.0 tons per hour for wilted material (Table 7). Most of the models observed were of the P.T.O. type. The wagons were normally drawn behind the chopper, and power provided by a 3 plow tractor. Some of the more recent higher capacity models required a 4 plow tractor. The smaller motor mounted choppers were powered by 2 plow tractors, but this reduction in the costs for power requirements of the tractor did not offset the additional costs arising from the power requirements for the motor and the higher initial costs of the chopper. Output was no greater with the motor mounted machines.

A major factor affecting output was the size and shape of the field. Considerable differences occurred when the chopper had to frequently run "empty" in turning at wide headlands etc. Sloping, uneven, surfaces to

TABLE 7

POTENTIAL 1/ HARVESTING RATES FOR CHOPPING GRASS SILAGE BY KIND OF MATERIAL, AND SIZE, TYPE, AND MAKE OF MACHINERY ON 71 SOUTHERN CENTRAL [illegible] DAIRY FARMS, 1957

ITEM	Mach. Width	Manufacturer	KIND OF MATERIAL: DIRECT CUT Size of Sample	DIRECT CUT Tons Per hr.	WILTED Size of Sample	WILTED Tons Per hr.
	feet					
CONVENTIONAL CHOPPER						
P.T.O.	6	Gehl	10	13.6	-	-
	"	Fox	3	1[illegible].1	-	-
	"	International	1	9.0	-	-
	"	Mean	14	1[illegible].5	-	-
	5	Case	-	-	9	1[illegible].7
	"	John Deere	1	10.[illegible]	1	7.[illegible]
	"	Fox	2	10.8	3	1[illegible].[illegible]
	"	Gehl	1	8.7	3	1[illegible].7
	"	International	-	-	5	11.1
	"	New Holland	1	11.[illegible]	2	8.[illegible]
	"	Papec	-	-	4	1[illegible].6
	"	Mean	5	10.[illegible]	27	11.2
	4	Allis-Chalmers	3	8.6	-	-
	"	Case	1	10.[illegible]	-	-
	"	John Deere	-	-	1	7.[illegible]
	"	Fox	-	-	3	10.[illegible]
	"	Papec	-	-	1	1[illegible].[illegible]
	"	Mean	4	9.0	5	9.6
Motor Mounted	4	Allis-Chalmers	2	6.8	-	-
	"	Case	1	8.6	-	-
	"	Ferguson	1	9.[illegible]	-	-
	"	Fox	-	-	1	11.6
	"	Gehl	-	-	1	10.7
	"	Papec	-	-	1	10.[illegible]
	"	Mean	4	8.0	3	1[illegible].[illegible]
ROTARY TYPE CHOPPER						
P.T.O.	5	Brady	2	13.1	-	-
	"	John Deere	3	13.9	-	-
	"	Lundell	4	15.[illegible]	-	-
		Mean	9	1[illegible].2	-	-
MEAN ALL METHODS			36	12.0	35	11.[illegible]

1/ Potential capacity with continuous operation not the observed rate.

the fields also reduced performance rates. It was often necessary to run the direct cut choppers in one direction only, when the crop was heavy and beaten down by weather.

Where automatic hitches were provided, these reduced the time required for changing wagons and, thus, resulted in a greater daily capacity - an important feature where time is a limiting factor. Many simple home made designs for hitches seemed as effective as some of the more complicated manufactured articles. Where trucks were used, the delay caused by hitching and unhitching was obviated. The trucks normally ran alongside the chopper although in one operation, using a direct cut rotary type chopper, the truck ran behind the chopper.

Yield per acre affected performance to some extent. The higher capacity machines were able to chop a load quicker in a heavier crop while the smaller machines seemed to do better in an average crop where the material seemed to come through at a rate at which it was better able to deal with it.

Ground speed had an effect on capacity and it was often difficult to synchronise a suitable gear and ground speed for the tractor to what seemed to be the best speed of operation for the chopper.

Hauling

The hauling distance did not seem to have as much affect on output as would be imagined. Most of the time is involved in hitching, unhitching, positioning around the silo and waiting either at the field or silo. Once the load is moving - even at the relative slow speeds of tractors -

actual distances, normally encountered on farms, do not affect capacity of the operation to any great extent. Even farmers hauling at distances up to two miles were able to maintain good performance rates. This is not surprising considering that normally much of this distance may be on a surfaced road. (A 400 yard haul across uneven fields may take longer than a mile haul along surfaced roads.) The correction of the figures to a hauling distance of 80 rods did not, therefore, result in any large differences in output from those actually observed.

A further point in connection with hauling is that no great differences occur between hauling wagons full and empty. In both cases surface conditions would seem to be a more limiting factor than weight of the load in determining speed of hauling.

Size of Load

The size of the load should be such as to keep the whole system in motion. Thus for short distances it is often far better to use relatively more wagons and smaller loads, while for longer hauls larger loads and relatively fewer wagons are often more economical. Dangers arise from overloading and it was observed, in several instances, that delays due to wagon breakdowns frequently occurred where large loads were hauled.

Unloading

Eighty percent of the operators used the false-end gate type of wagon for hauling (Table 10). Most of the winding mechanisms, either cable or chains, were operated by detachable electric motors, with a few powered from the motor mounted blowers. In the horizontal silos many of the chain type were operated by attaching the chains to the tractor used for packing. The hydraulic operation of the false-end gate, either from the tractor or from a jeep, - as was observed in one case, - was most efficient and enabled the load to be either emptied slowly for feeding into a blower or very rapidly for direct unloading.

Since rate of filling upright silos is conditioned mainly by the capacity of the blower, the method of unloading is not so important as with horizontals, (the operator who unloaded entirely by hand was able to keep the blower working steadily and achieved a rate of output well up to average). Opinions varied as to whether one or two men are needed at the blower. When additives, such as sodium meta-bisulfite, are being used a second man is often useful. This operation, however, can often be performed by a young boy or by means of some mechanical attachment. Generally the man hauling would assist with the unloading, leaving one man at the silo continuously; he cleans up around the blower when there are no loads to be handled.

It is important that the hauling units used should be of a similar type and size. Thus the case of one truck and one wagon did not lead to a steady flow or high output (Table 6). Similarly, a combination of two wagons where one was a false-end gate and the other a self unloading type resulted in idle man power. A man has to be kept at the silo to deal with the false-end gate wagon. Thus, when the self unloading wagon arrives two men stand idly watching it feed into the blower. As stated above, blower capacity limits performance and rate of emptying with the self unloader was no higher than with the other wagon. In view of the high initial cost of such wagons, it is not economical to purchase

TABLE [illegible]

POTENTIAL[1] PERFORMANCE RATES FOR FILLING SILOS BY KIND OF [illegible], [illegible] SILO ON 71 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 19[illegible]7

TYPE	Manufacturer	KIND OF MATERIAL			
		DIRECT CUT		WILTED	
		Size of Sample	Tons Per hr.	Size of Sample	Tons Per hr.
Upright Silo					
Blower Belt Driven	Allis-Chalmers	-	-.	8	16.[illegible]
	Case	2	19.5	7	1[illegible].[illegible]
	John Deere	1	15.4	-	-
	Fox	2	1[illegible].8	2	1[illegible].[illegible]
	Gehl	3	22.3	6	1[illegible].[illegible]
	International	6	17.6	1	18.[illegible]
	New Holland	1	1[illegible].2	-	-
	Papec	1	1[illegible].[illegible]	4	1[illegible].2
	Mean	15	18.1	28	14.[illegible]
P.T.O.	[illegible]	3	27.1	1	23.4
P.T.O. (Suction)	[illegible]	-	-	1	10.5
Motor Mounted	Allis-Chalmers	3	15.7	1	17.5
MEAN ALL BLOWERS		22	18.7	31	14.6
Horizontal Silo					
MEAN ALL METHODS		14	30.[illegible]	4	31.[illegible]

1/ Potentional capacity with continuous operation not the observed rate.

them for use with uprights unless a very high capacity blower is used and unless they have additional uses for daily chopping for dry lot feeding etc. There is possibly more justification for their use in horizontals where blower capacity is not a limiting factor but, here again, considerable utilisation is necessary to justify the initial investment.

Blowers

Potential performance rates for filling uprights with blowers ranged from 13.4 tons per hour to 27.1 tons per hour (mean 18.7) for direct-cut material and from 10.[illegible] tons per hour to 23.4 tons per hour (mean 14.6) for wilted material (Table 8). The majority of the blowers were belt driven; capacity was greater with the more recently developed P.T.O. models. Performance rates are affected, to some extent, by the height of the silo. Some consider that for the large 60 to 80 feet silos, elevators are necessary. Unfortunately no elevators were observed in operation, but the P.T.O. blowers observed had no difficulty in blowing material to these heights.

TABLE 9

KIND OF MECHANISM FOR UNLOADING WAGONS, BY SIZE OF SAMPLE
ON 71 SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

KIND OF MECHANISM		SIZE OF SAMPLE
False End Gates	- Cable or Chains	54
	- Hydraulic	3
Canvas Apron		2
P.T.O.	Chain Mechanism	5
P.T.O.	Self Unload - Bars and Beater (Gehl type)	2
Hand Unload		1
Tip Trucks		4

Potential rates of unloading into horizontals were greater than with uprights and averaged 30.0 tons per hour for direct-cut and 31.2 tons per hour for wilted material (Table 8). Actual rates, however, varied with the method of unloading. In the bunker type, difficulties often arose in hauling wagons up the slope to the top when filling was nearing completion. Generally, in such cases, the tractor used for packing had to assist the hauling tractor. The packing tractor was also frequently needed when dump trucks were used. When tipped, the load would often stick, and the truck would be unable to draw forward on the silo, without assistance from an additional source of power.

One operation was observed where filling of a small trench silo was undertaken by means of a blower. A more even distribution of the material was obtained by this means. The job was custom hired so that the blower, which was part of the custom hirer's equipment, would otherwise have been idle. Normally, investment in a blower specifically for this purpose would not be justified.

Investment Costs

On the farms studied, forage harvesting equipment varied considerably as regards to age and initial cost. Many farmers had been successful in obtaining reasonably efficient choppers and blowers from second hand sources. In the case of forage wagons many had successfully adapted unloading gear to existing bodies. Initial cost of equipment was considerably affected by trade-in values obtained on existing machinery. Most of the forage harvesters observed had been purchased within the last two or three seasons. The average age was 3.8 years and average cost $1795.

Costs ranged from $300 paid for a second hand Papec pick up machine purchased in 1951 to $3500 for a Case motor mounted direct-cut machine purchased in 1955. The oldest machine observed in operation was a 1947 Gehl motor mounted pick-up machine purchased for $2800. Many farmers were operating 6 foot direct-cut P.T.O. models purchased within the last few seasons for approximately $3000.

Blowers tended to be older than the choppers and many farmers had changed choppers but retained their existing blower. Average age was 4.4 years and average cost $598. Initial cost varied from $100 paid for a second hand International belt driven model purchased in 1950 to $1400 paid for an Allis-Chalmers motor mounted model purchased in 1956. Several farmers had invested in the recently introduced P.T.O. model blowers costing approximately $800.

As mentioned above, many wagons used were adaptations to existing bodies. Average investment was $394, with initial costs ranging from $100 for a wagon which had been in operation - with repairs - since 1930, to $1200 for the latest mechanically unloading models. All the operators using dump trucks had obtained them second hand - the cheapest being a 1937 model purchased for $200 in 1950. Costs for the others ranged around $2000. Naturally, there was also considerable variation in the age, power and cost of the non-specialized equipment - such as mowers, rakes, and tractors used in the operation.

Case Studies

The following are brief descriptions of four of the operations observed. They were not in all cases those operations obtaining the highest output, but are ones which illustrate certain important features. They stress the importance of organization, of the existing equipment, pattern, rather than of high output and capacity of machinery. Costs are based on the assumptions used in Chapter 5.

FARM A

This was a 600 acre farm with 100 milking cows in a stanchion barn system and a further 100 heifers and steers in open barns. One hundred seventy five acres of first cutting alfalfa and clover mixtures were used for daily chopping for dry lot feeding and for silage. About 900 tons of grass silage were put up in 4 upright silos - one 10' x 45', one 12' x 45', one 14' x 60' and a newly constructed 16' x 65'. It is planned to install a self unloader and auger feed bunks in this latest silo for feeding the heifers and steers. Five tons of green forage were chopped daily from June 15 to September 1 for feeding to the dairy cows; corn was chopped daily up to October 15. About 100 tons of corn silage were made and the second cutting of the 175 acres of alfalfa was baled as dry hay.

The team consisted of two men, two wagons and three tractors. One man chopped with a 6-foot direct-cut P.T.O. Fox industrial chopper purchased in 1954 for $3000, which was coupled to the wagon, and powered by an 1957 International 450 diesel tractor. The other man operated the blower. Initially a Case belt driven blower was used but during the season a Fox P.T.O. model was purchased for $825 and utilized for filling the 16' x 65'. One of the wagons was a 14' x 7' Gehl P.T.O. mechanical unloading wagon purchased in 1957 for $1200 and the other a conventional

14' x 7' false end gate type purchased in 1953 for $500 and operated by means of chains and an electric motor.

When observed, harvesting was taking place on a level, 40 acre field of alfalfa brome mixture, situated 200 yards from the buildings. The 12' x 45' was being filled by means of the Case blower powered by a 1950 Cockshutt 40. The farmer operated the chopper and collected and delivered loaded wagons to the buildings to within 30 yards of the silo. Release hitches were employed - consisting merely of a piece of rope attached to the pin. The full load was drawn to the blower by the brother, using a 1950 Oliver 88 for the purpose. When emptied, "Purina" Bulky-Less additive was spread on the floor and the wagon drawn away from the blower for collection by the chopper operator at the exchange area. When filling the 16' x 65' sodium meta-bisulphite was used instead of the "Purina".

Loads, especially with the Gehl wagon, were large and averaged four tons. The average time for chopping was 17 minutes which gave a potential capacity of 14.0 tons per hour. Unloading was easier with the Gehl wagon and average potential rate of blowing was 17.1 tons per hour. Average capacity from cutting to filling into the silo was 11.4 tons per hour with an output of 5.7 tons per man hour. This later was the highest rate observed and was made possible by the absence of idle time on the part of either man. When the P.T.O. blower was used, the farmer estimated its capacity at 30-40 tons per hour. Since unloading time was thereby considerably reduced, the man at the blower was able to collect and deliver wagons to and from the field and so increase output to the full extent of the chopper. This farmer is well satisfied with the results from feeding grass silage and dry lot feeding and plans to invest in another self unloading wagon next season.

Despite the high investment in machinery, estimated costs per ton of grass silage were only $1.21. This figure should be reduced next season when full advantage can be taken of the increased output possible with the new blower and additional self unloading wagon. Thus, this operation may be characterised as a high machinery investment, low labor cost combination, which with high capacity and large total output results in low unit costs.

FARM B

This was a 240 acre farm with 60 milking cows and 50 young stock in a loose housing setup. Twenty acres of first cutting alfalfa were ensiled in 14' x 43' upright for summer feeding. This was later filled with corn silage for winter feeding. Seventy acres of chopped dry hay were also harvested. The team consisted of three men (farmer and two sons), three wagons and three tractors with one man on the chopper one at the blower and one hauling. Most of the equipment had been purchased at reduced prices and consisted of a four foot International pick-up chopper purchased in 1954 for $800, an International belt driven blower purchased in 1954 for $500 and three homemade false end gate type wagons adopted from 1930 wagons at a total cost of $550.

The chopper, which had a wagon attached was powered by a 1954 International Super M and took an average of 18 minutes to chop a 3.5 ton load, - a potential capacity of 11.6 tons per hour. The man hauling, using a 1930 International F30 tractor collected the loaded wagon directly from the chopper. Thus, idle time was reduced to a minimum.

Hauling distance was 300 yards.

The blower -- powered by a 1950 International M -- was in continual operation since change over of wagons was very rapid. There was always a full load at the silo by the time the other wagon was emptied. Both sons then helped to clean up around the blower after towing the empty wagon from the blower, the full one was drawn in, unhitched and then the empty one rehitched and hauled to the chopper. Since one man was needed almost continually to unload into the blower, the system was arranged so that the two sons alternated the task of hauling with that of unloading. Potential blower capacity was 21.5 tons per hour. Output from windrow to silo was 11.2 tons per hour or 3.7 tons per man hour.

Estimated costs per ton for harvesting and storing were $1.10 excluding costs of mowing and raking. (The latter would amount to about $.25 per ton.)

This operation is characterized by a medium labor force and low investment costs due to wise buying at opportune times. It also obeys the rule to keep the material in motion and to have no idle time for men or machines in process. As a result low unit costs are achieved.

FARM C

This was a 200 acre farm with 47 milking cows in a loose housing system. Eighty-nine acres of grass and clover mixture are used for silage which is stored in a 30' x 100' bunker and used for winter feeding. Daily chopping of green forage for dry lot feeding is also practiced.

Equipment is shared on a 50-50 cost basis with a neighboring farmer who operates a similar system of farming and silage making. Four men

(two from each farm) operate two trucks and two tractors, with one man on the chopper, one man packing at the silo and two men hauling with the trucks. The chopper is a Lundell P.T.O. Flail type model purchased in 1957 for $1130 of which the farmer paid one-half. One truck was purchased in 1950 for $1000 and the other in 1947 for $750. The chopper was powered by a 1954 Farmall M with a truck following directly behind. Average time to chop a 3 ton load was ten minutes and thus potential capacity is 18 tons per hour. When observed, hauling distance was about 200 yards. Apart from one period when only one truck was in operation, (due to a broken transmission on the other) the chopper was able to keep in almost constant motion.

Unloading normally only took two minutes, but occasionally the 1939 Farmall H, used for packing, had to assist the truck over the material in the silo. Average output of the system from chopping in the field to storing in the silo, was 15 tons per hour. This was one of the highest rates observed. Output per man hour was 3.75 tons and estimated costs per ton $1.10.

As an indication of the typical weather conditions which farmers had to contend with in the 1957 season, of 17 possible working days between June 25 and July 15, operations were rained out for the entire day on two consecutive periods of two days. In the 2 days preceeding the former of these periods, work was only possible for $1\frac{1}{2}$ hours each day. Thus, in effect, harvesting was delayed for 6 working days. This may help to explain why this farmer, and many others, considered that the silage made this year was not up to usual standards. It also stresses the need for machinery to be in a good state of repair where large volumes of silage have to be made. On this farm the truck which caused frequent delays by breakdowns may be replaced by next season.

This operation, then, is characterized by high labor, low equipment costs coupled with high capacity and total output which enables unit costs to be kept to a very low figure. This is achieved mainly as a result of the sharing and pooling of labor and machinery by neighboring farmers and illustrates the benefits which result from the use of this system.

FARM D

This was a small, one-man farm of 130 acres with 13 dairy cows in a stanchion barn. Eight acres of alfalfa timothy were cut for silage and stored in 10' x 35' upright silo. Thirty-two acres of dry hay were baled. No corn silage was made.

Forage harvesting was a one man operation consisting of the farmer with one wagon and one tractor. This was used to haul the chopper and wagon and also power the blower. Equipment was all owned and consisted of a 4' Allis-Chalmers direct cut chopper purchased in 1956 for $1500, a Gehl belt driven blower purchased in 1954 for $300, and a false end gate wagon and electric motor purchased in 1954 for $200. The hay baler, also owned, was an International, purchased for $2300 in 1955.

The chopper was powered by a 1954 International Farmall M. The average time to chop a 3 ton load was 24 minutes and thus, potential capacity was 7.5 tons per hour. The 8 acre field was adjoining the buildings and the chopper and wagon were both hauled to the silo. After drawing the wagon into position at the blower the tractor had then to be connected up as a source of power for the blower. The reverse process had to be performed when emptying was complete. All this took 12 minutes on the average. Blowing time averaged 14 minutes i.e. a potential capacity of 12.8 tons per hour. Thus, the whole operation took 60 minutes, and resulted in an output of 3 tons per hour which was the lowest figure observed. However, in terms of output per man hour the figure of 3 tons per man hour was well up to average. Unit costs for the 50 tons were $6.94 per ton of which $6.20 were fixed costs for equipment.

Thus, this operation, although it may not be typical of all small scale operators, is characteristic of the high fixed costs which occur when only small tonnages are harvested. It would be considerably more economical for this farmer to custom hire the operation. Most custom operators have a minimum charge for filling these small 10' x 35' uprights and a typical rate charged by an efficient operator was $50 for the silo or $1.00 per ton. This included chopper, blower, 2 wagons and 2 men. The operation would be completed in half a day. Thus, the subjective value which the farmer placed on independence was certainly high. Since the "opportunity cost" of the machinery investment was probably very high, the results seem all the more uneconomical. They stress the need for the use of custom operators' services among small scale operators.

CHAPTER IV

REVIEW OF RELEVANT STUDIES BY OTHER DISCIPLINES

The performance data presented in the previous chapter are only part of the information - or "messages"[1/] - required by a farm operator in determining the optimum practices to employ to maximise profits when harvesting and storing grass silage.

Many other agricultural disciplines have been concerned with the various chemical, biological and mechanical aspects involved in the process of ensilage, and it is desirable, therefore, to briefly review some of the more important contributions made by these physical scientists. Use will be made of these data, in conjunction with that presented in Chapter 3, to develop the synthetic cost data and partial budgets to be presented in Chapter 5.

Characteristics and Chemical Composition of Grass Silage

Although ensilage tends to be regarded as one of the developments of modern agriculture, the process has been known since early Egyptian and Roman times. Developments occurred in Europe in the 17th and 18th centuries and by the end of the 19th century, the practice had become well established in the USA. Almost any vegetable material can be ensiled.

1/ For a presentation of a concept of the relationship between human behavior and the managerial process, and of the importance that information or "messages", from various sources, plays in the decision making process c/f K. Boulding, The Image, The University of Michigan Press, Ann Arbor, 1956.

The more common green forages used are corn, sorghum, small grains - especially oats, sudan grass, alfalfa and various legume grass mixtures. Corn silage has been the most popular in the USA with grass/clover mixtures more common in Europe. A great deal of research work has been undertaken into the various aspects of the process, with various crops, and the literature on the subject is vast and impressive - even though much of it is inconclusive.

This section is concerned with the work undertaken with alfalfa - grass silage.

The process of ensiling in its essential involves the storing of forage with the expulsion of air through pressures developed either by the mass of the material or by mechanical packing. This is followed by a series of reactions involving normal plant cell respiration which utilizes oxygen and in turn is succeeded by reactions caused by anaerobic bacteria. The type of bacterial action depends to a large extent on the type of material ensiled. The desirable type of action is that which results in the rapid formation of lactic and acetic acids from fermentation of carbohydrates. When an acidity of Ph 3.5 to 4.0 is reached the action of the putrefactive bacteria giving rise to butyric acid is checked. When all the oxygen entrapped with the air has been converted to carbon dioxide and water, anaerobic organisms continue the functions originated by the aerobic yeasts and molds. It is essential, therefore, to exclude as much air as possible, by efficient compaction, to reduce the activity of the yeasts and molds. Failure to effectively do this accounts for the wide differences that occur in nutritive losses between different storage systems and within different storage systems between different farms.

Much of the earlier empirical work was concerned with yields and nutritive values of silage as fed and only more recently has attention been given to changes and losses in feeding value which occur during processing and storage. Many reviews of the literature have been presented and those by Huffman,[1/] Bender and Brosshardt[2/] and Watson[3/] give good accounts of the work undertaken prior to 1939. (A table prepared by the latter summarizing nutrient losses as reported in various studies up to 1939 appears in the Appendix. Table 2.)

Comparative Feeding Values

Much of the work has been concerned with comparisons of losses between varying harvesting methods. The most comprehensive of such works was undertaken at Beltsville where preserving alfalfa as (1) field cured hay, (2) barn dried hay, (3) wilted silage and (4) dehydrated hay, all harvested at the same period, were compared in relation to labor and equipment requirements, yields, losses of dry matter and various nutrient and vitamin contents. The results of five years work are reported by

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1/ C. F. Huffman, "Roughage Quality and Quantity in Dairy Rations - A Review," Journal of Dairy Science, Vol. 22, November, 1939.

2/ C. B. Bender and D. K. Brosshardt, "Grass Silage - A critical review of the Literature," Journal of Dairy Science, Vol 22, August 1939.

3/ S. J. Watson and A. M. Smith, Grassland and Grassland Products Arnold, London, 1950

Shepherd et. al.[1/] A table derived by Hoglund[2/] from this work appears in Appendix, Table 3. It was found that wilted silage was leafiest, highest in protein, carotene, and total nutrients and lowest in crude fibre. Considering all operations, total equipment hours were the same for all methods.

It must be borne in mind that many of the differences in feeding value which occur with forages harvested by different methods are partly due to differences in the stage of maturity, and hence quality of the crop as harvested. Lutz and Walcott in studies in the Upper Peninsula of Michigan, an area subject to wet weather at harvest, reported 25 percent more (4 percent F.C.M.) milk produced from silage than from field cured hay and 12 percent more than from barn dried hay, when the forages were harvested at different stages of maturity. The Beltsville workers concluded that there was a definite relationship between length of time the cut forage is left in the field (subject to weather) and the loss of dry matter and feed constituents. "Hence using a harvesting method (such as silage making) which shortens the field curing process provides an effective means of increasing yield, leafiness, carotene content and quality."

The importance of the stage of maturity as affecting quality of

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1/ Shepherd et. al., Experiments in Harvesting and Preserving Alfalfa for Dairy Cattle Feed, USDA. Technical Bulletin 1079, February, 1954.

2/ C. R. Hoglund, The Economics of Alternative Forage Systems, Department of Agricultural Economics, A. E. No. 674, Michigan State University, April, 1957.

3/ W. B. Lutz and A. R. Wolcott, "Seasonal Adaptation of Three Methods of Curing and Storing Grass and Legume Forage as Requested in the Milk Production of Dairy Cows," Michigan Agricultural Experiment Station Quarterly Bulletin, No. 32, November, 1949.

forage harvested has been stressed by many writers; Hoglund et.al.[1] concern themselves with this point in relation to all forages. Logan[2] found little difference in chemical analysis and digestibility of two alfalfa silages harvested at bud and full bloom stage and concluded that the significantly greater milk yield, which resulted from feeding the former, must have been due to the higher TDN and protein content of the silage.

Losses in Feeding Value

The losses of nutrients with grass silage vary depending on the method of harvesting and storing. Losses may occur from (1) top spoilage -- this will be greater in horizontal silos, (2) seepage losses -- these will be directly proportional to the moisture content and pressure developed and, hence, greatest with upright silos using direct cut, (3) fermentation losses. Monroe[3] has estimated dry matter losses as 3 to 6 percent from top spoilage, 1 percent from seepage - where the original contains less than 70 percent moisture, and 5 to 10 percent from fermentation. Turk, et. al.[4] in a 5 year trial recorded

1/ C. R. Hoglund, et. al. "Forage Quality and Protein Feeding of Dairy Cows," Michigan Agricultural Experiment Station, Quarterly Bulletin, Vol. 38, February, 1956,

2/ V. S. Logan, "Effect on Milk Production of Legume Silage Harvested in Bud Stage versus Full Bloom Stage of Maturity of Alfalfa," Journal Dairy Science, Vol. 37, March, 1954.

3/ C. F. Monroe, et. al., "Losses of Nutrients in Hay and Meadow Crop Silage During Storage," Journal of Dairy Science, Vol. 29, April 1946.

4/ K. L. Turk, et. al., Effect of Curing Methods Upon the Feeding Value of Hay, Cornell Agricultural Experiment Station Bulletin 874, August, 1951.

actual losses of dry matter with wilted silage as 5.0 percent from top spoilage and 30.7 percent from all causes in 1947 and 4.4 from top and 33.4 percent from all causes in 1948. They estimated that with a good silo losses would only have been 21.6 percent and 20.1 percent in the two years.

According to McCalmont[1/] losses of dry matter in bunker silos usually range from 15 to 30 percent compared to 10 to 20 percent in upright silos.

Watson[2/] reports losses of dry matter of 15.9 percent for ordinary silage and 12.2 percent for molassed or acidified. His figures for composition and digestibility of protein by different storage methods are given in Appendix Table 4. From this it can be seen that less losses occur with upright silos than with trench and stack silos -- these figures are for unchopped material. Hoglund[3/] refers to dry matter losses, as reported by Shepherd, of 12 percent in conventional tower silos, 8 percent in gas tight tower silos, 21 percent in trench silos and 33 percent in stack silos, all at 70 percent moisture. Losses from tower silos were about double these levels at 85 percent moisture.

Much of the dry matter losses in the field occurs, because of difficulties in keeping wagons and field choppers correctly synchronised to avoid "blowing" of material when turning at headloads etc.

1/ J. R. McCalmont, Bunker Silos, USDA. Agricultural Information Bulletin No. 149, February, 1956

2/ S. J. Watson, op. cit.

3/ C. R. Hoglund, op. cit.

Moisture Content

Archibald et. al.[1/] consider that a good estimate of the quality of grass silage can be obtained by determining water content and Ph value. This point of moisture evaluation and control is stressed by all writers. Shepherd et. al.[2/] state that moisture content of the crop at time of ensiling is the most important factor in determining character of silage fermentation, the extent and character of losses through seepage and fermentation and quality of silage produced. Moisture content should be from 65 to 70 percent for wilted and will be 80 percent and above for direct-cut material. Good drainage is essential with all types of silo, since grass silage exerts more pressure than corn silage and a crop ensiled at 75 percent moisture in a 14' x 40' upright may exude 1600 gallons of liquid through seepage.

Wilting Versus Direct-Cut Material

The practice of wilting has long been advocated by authorities in the USA. Woodward and Shepherd[3/] reporting on trials at Beltsville stated that a reduction in moisture content improves the quality of silage as judged by odor and dry matter consumed without increasing losses of dry matter or protein. Wilting increases loss of carotene in

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1/ J. G. Archibald, et. al., "Further Observations on Composition of Grass Silage," Journal Dairy Science, Vol. 37, November 1954.

2/ J. B. Sheperd, et. al., "Ensiling Hay and Pasture Crops, "Grassland, USDA. Year Book of Agriculture, 1948.

3/ T. E. Woodward and J. B. Sheperd, "A Statistical Study of the Influence of Moisture and Acidity on the Palatability and Fermentation Losses of Ensiled Hay Crops," Journal of Dairy Science, Vol. 25, June, 1942.

the field. It was found that low moisture silage did not keep as well when exposed to the air as high moisture silages and, therefore, should be fed out more rapidly when the silo is opened. Greater lateral pressure was exerted by the high moisture silage. No additives were necessary with the wilted material and no differences in acidity were found between the high and low moisture silage. Murdoch et. al.[1/] reported that over heating occurred with wilted material owing to greater difficulties involved in excluding air.

Chopped and Unchopped Material

Gordon, et. al.[2/] reported trials at Beltsville showing that harvesting, silo filling and feeding of unchopped material was more tedious than chopped material. Total losses of dry matter were 28.0 percent for unchopped and 31.0 percent for chopped material. More air trapped in unchopped material was associated with higher Ph, butyric acid and ammoniacal nitrogen values and lower lactic acid values. The cows consumed more silage and dry matter, gained more live weight and produced significantly more milk when fed chopped silage. Results of trials by Murdoch et. al.[3/] confirmed the view that chopping or lacerating

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1/ J. Murdoch, et. al. "Ensiling of Lucerne with Addition of Formic and Glycolic Acids, Molasses and Barley Meal and with Wilting," Journal of British Grassland Society, Vol. 10, No. 2, 1955.

2/ C. H. Gordon, et. al., "Comparison of Chopped and Unchopped Silage Stored in Bunker Silos," Abstract paper to 51 AGM, Journal of Dairy Science, Vol. 39, June, 1956.

3/ J. Murdoch, et. al., "Effect of Chopping Lacerating and Wilting of Herbage on the Chemical Composition of Silage," and "Ensiling of Lucerene with Addition of Formic and Glycolic Acids, Molasses and Barley Meal and with Wilting," Journal of British Grassland Society, Vol. 10, No. 2, 1955.

improves the quality of silage and also that losses of nutrients are lower with wilted material. Murdoch[1] makes the point that the decrease in moisture content reduces the weight of material to be hauled, but as wilted material does not pack as well as more moist material it is unlikely that there will be a reduction in the number of loads to be hauled; up to a certain point, however, 65 to 70 percent moisture material packs very well. In a wet harvesting season, such as the recent one in Michigan, the actual weight of dry matter per load must have been very small in many cases.

Wilting would seem to be advisable, therefore, but advocates for the direct-cut method point out that the latter saves time, labor and the money involved in mowing, raking or windrowing.

A survey which seems to support direct-cut methods was conducted by Allis-Chalmers and reported on by Whisler and Frushour.[2] The authors conclude from the results observed on farms over a 10 year period (1942-1952) that "the simplest, most economical, most foolproof, way to make good grass silage under farm conditions appear to be to cut the crop direct and ensile without additives." They contend that more spoilage occurs through silage being too dry under the wilting method than being too wet, under the direct cut method, -- provided free drainage is available. The point is also made that there is less danger of picking up stones, pieces of metal and other foreign objects with the direct cut

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1/ J. C. Murdoch, "Recent Developments in Silage Making in Britain," Journal of Agricultural Engineering Research, Vol. 2, No. 2, 1957.

2/ P. A. Whisler and G. V. Frushour, "Engineers Advance Art of Making Grass Silage," Agricultural Engineering, Vol. 34, May, 1953

method. These findings in favor of direct cut material are in contrast to much of the experimental work, and the authors admit that such conditions may not apply to all farms. (The present writer would readily agree with this latter statement.)

In comparison between direct cut and wilted silage, it is important to bear in mind that additional initial storage space will be required by the direct cut method in order to store a given quantity of dry matter. This may not be so important with horizontal silos but can be very important where storage capacity is limited, as may occur with upright silos on farms with smaller sized herds.

This latter factor is particularly important where custom hiring is being used. The operator using his own equipment is able to refill when the silo has settled, and make maximum use of the storage facilities available. The custom operator, on the other hand, fills as quickly as possible and then moves on. Refilling is not possible with this system and hence greater initial storage capacity has to be provided. The cost of this has to be taken into account when considering any possible reductions in costs which the custom hiring system allows.

Additives

Considerable differences of opinion exist among research workers and farmers as to the advisability of using additives and as to the most suitable one to use. There seems fairly general agreement among the writers that if the material is wilted to a moisture content of 65 to 70 percent then it can be "put up" without preservatives. In Europe where most silage is made from unchopped material, mineral acids (AIV) and molasses have been popular. Here in the USA. phosphoric acid was used at one period. However, much material is now ensiled without additives.

Gordon, et. al.[1/] reported a series of experiments to determine the effect on grass silage of using (1) corn meal (2) beet pulp (3) kylage[2/] (4) recirculation seepage, as additives. The first two improved the quality but consumption of dry matter was less, the 'kylage' made no improvement and recirculation was impracticable because there was only slight improvement in silage quality and the necessary equipment was costly. They concluded that certain benefits would occur from their use with poor quality silage but with excellent quality the limited improvement would not be economically justifiable.

Reaves and Brubaker[3/] in experiments in Virginia tested the following additives for use with chopped alfalfa with over 80 percent moisture: - none, molasses, corn and cob meal, brewers dried grains, beet pulp sulphur dioxide and wilting.

The percentage moisture after 67 days (in order) was 79.2, 77.3, 76.1, 74.9, 75.5, 78.2, 62.5.

The seepage in pounds and the percentage of dry matter in the seepage was 12.7, 7.6; 16.4, 10.0; 0.7, 11.9; 0.4, 14.1; 0.0, 0.0; 32.6, 7.7; 0.0, 0,0; thus, beet pulp and wilting seem to be effective ways to reduce seepage losses.

Opinions as to effectiveness of the more recently introduced sodium

1/ C. H. Gordon, et. al., "Some Experiments in Preservation of High Moisture Hay Crop Silage," Journal of Dairy Science, Vol. 40, July, 1957.

2/ 'Kylage' is a patented preservative, mainly sodium nitrite and calcium formate in dry powder form.

3/ P. N. Reaves and R. E. Brubaker, "Effect of Various Preservatives on Seepage from High Moisture Silage," Abstract of paper to 51 A[illegible], Journal of Dairy Science, Vol. 39, June, 1956.

meta-bisultite differ considerably.

Noller and Lindquist[1/] report that "silages made with chemical or feed additives are usually more readily consumed than those made without a preservative." This is primarily due to the type of fermentation and its affect on the palatability of the silage."

They admit that reports on the palatability of bisulfite-treated silages vary, although it is indicated that these silages not only retain more of the nutrients in the original grass than silages made without preservatives but that it conserves the more digestible fraction of the forage. Data from a Purdue experiment indicate that consumption of dry matter and milk production were essentially equal when cows were fed a total ration of grass silage preserved with corn, molasses or bisulfite.

Murdoch[2/] reports trials in Britain which show that bisulfite can produce good quality silage with direct cut material but no better results than by wilting or using molasses. Jones, et. al.[3/] in tests in Oregon reported no significant differences in nutritive value between bisulfite and dried molasses beet pulp as a preservative for high moisture alfalfa and grass silage. Whisler[4/] reports that farmers "who compared non

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1/ C. H. Noller and M. S. Lindquist, "Feeding Value of Silages for Dairy Cattle," Symposium on Silage, Purdue University Extension Conference papers, Mimeo ID-17, April, 1957.

2/ J. C. Murdoch, "Recent Developments in Silage Making In Britain," Journal of Agricultural Engineering Research, Vol. 2, No. 2, 1957.

3/ I. R. Jones, et. al., "Effects of Using Bisulfite and Dried Molasses Beet Pulp as Preservative for High Moisture Silage," Abstract of paper to 51 AGM, Journal of Dairy Science, Vol 39, June, 1956.

4/ P. A. Whisler, Private Communication dated September 24, 1957.

treated with 'bisulfite' treated admit little or no difference in feeding value but feel that the extra cost of the additive is warranted merely to eliminate the odor which non-treated imparts to clothing and barns."

There was little agreement among the farmers in the present survey as to the effectiveness of bisulfite but most considered it was worth something to reduce the odor and most continued to use it once they had started.

Use of Plastic Covers

Considerable interest has recently been aroused by the use of plastic material either as a covering for horizontal or upright silos or to enclose stack silos. These latter may be used either as temporary or permanent measures.

Larrabee and Sprague[1/] reported satisfactory results with this material when used in a series of experiments with "snow fence" surface silos. Air was effectively excluded and when opened good quality silage acceptable to stock was produced. Damage by punctures is proportional to the size of the opening. Any "flapping" from wind acts as a pump action to force air into the container. It would seem from the above, and the writer's observations, that such stacks should be fed out as soon as possible, once opened, as surface spoilage seems very high and rapid. The method would be appropriate for small stacks as an emergency measure but not as a regular system for silage storage. Several farmers in the survey reported satisfactory results when using plastic

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1/ W. S. Larrabee and M. H. Sprague, "Preservation of Forage Nutrients in Silage in Gas Tight Enclosures of Polyvinyl Chloride Plastic," Journal of Dairy Science, Vol. 40, July, 1957.

as covers for bunkers. Clear plastic is not suitable and a dark color must be used. Two grades are available, a thinner "one use" type and a thicker type suitable for several occasions - care will be necessary in storing this latter to avoid tears etc. (A 20' x 100' x 6 mm. will cost about $60.)

Gordon and McCalmont 1/ reported somewhat similar findings to the above from three years work with plastic seals at Beltsville, and stressed the need to avoid even minute leaks of air into the stacks.

Feeding System Wastages

Losses of feeding value due to wastage and spoilage depend upon the method of feeding. Foreman, et. al. 2/ in studies at Iowa reported the following results from trials on soilage versus silage, and self feed versus bulk feed.

Mean daily milk yield (lbs)	
Soilage	44.5
Silage	41.3
Self Feed	30.2
Bunk Feed	34.9

Wastages occur with self feeding systems. Walker - Love 3/

1/ C. H. Gordon and J. R. McCalmont, "Improvement of Forage Preservation in Bunkers and Stacks through the use of Temporary Seals," Abstract of paper to 52 AGM, Journal of Dairy Science, Vol. 40, June, 1957.

2/ C. F. Foreman, et. al. "Comparison of soilage (chopped fresh alfalfa) and alfalfa silage for lactating cows," Abstract paper presented to 52 AGM, Journal of Dairy Science, Vol. 40, June, 1957.

3/ J. Walker-Love, Observations on Self Feeding Roughage to Dairy Cows in Loose Housing, Unpublished M. S. Thesis, Department of Dairy Science, Michigan State University, 1954.

in a Michigan study with a self feed bunker system estimated that only 52.4 percent of the quantity ensiled could be accounted for as actually fed.

Summary on Feeding Value Losses and Wastages

The above is merely a brief review of the voluminous writings on the subject of nutrient losses and feeding values of grass silage. It should be sufficient, however, to show that much of the work is inconclusive with the basic questions of the best harvesting and storage methods to employ to produce high quality silage, under varying farm conditions, still unanswered. In general, losses of nutrients in the harvesting and storing process are greater with direct cut material and horizontal silos and wastages greater with self feed systems. Little differences in the reduction of nutrient losses occur from the use of the various additives. Sodium meta bisulfite does seem to have a beneficial effect -- if only to remove the offensive odor of grass silage. Care is needed when using plastic covers as silo seals.

It should also be remembered that many of the findings are based on work with glass-jar laboratory type silos or outdoor silos considerably smaller than the large uprights and horizontals which, will be needed in the larger herds of the future. In these pressures and chemical reactions may be considerably different from those encountered under laboratory and experimental farm conditions.

Forage Harvesting Machinery

There are various makes, types, and sizes of forage harvesters, blowers and wagons each having its own merits and capacity under given conditions.

Each manufacturer is striving constantly to make his machine turn out either more product per unit of input or a better quality product. In consequence there may be very little difference in efficiences between different makes of machines, - or, if there are, those who buy them do not know it and generally believe that they are buying the most efficient machine.

Forage Harvesters

Essentially the forage harvester either picks up green forage from the windrow or cuts it direct, chops it by means of some cutting or lacerating mechanism and elevates it by means of a blower directly into a wagon or truck running behind or alongside the chopper. These then empty the chopped material either directly into the horizontal type silage or by means of a blower or elevator into upright silos.

According to De Long[1/] the first field ensilage harvester was introduced in 1913. This early model was horse drawn and obtained its power from the ground wheels. Models with improved sources of power were developed later and various combinations of PTO and motor mounted tractor drawn harvesters are now in operation. There is also a self propelled model on the market. Most of the early models were designed to harvest corn silage. When originally used for grass silage, the crop was first wilted and then chopped from the windrows. During recent years direct cut machines have been introduced and are popular with many farmers.

1/ H. H. DeLong, Field Ensilage Harvester Operation and Costs, South Dakota Agricultural Experiment Station, Circular 90, September, 1951.

The forage harvesters has few unique mechanical developments, the machine being a combination of the gathering points, gathering chains, and sickle of the corn binder together with the cutting mechanism of the standard silo filler.

The basic principle of the cutting mechanism of the forage harvester has changed little since early days. The two conventional types are (1) the "flywheel" type with knives parallel to the plane of rotation (2) the rotary cylinder or "lawn mower type" with the knives cutting edge perpendicular to the plane of rotation. More recently, a further type (3) which lacerates, instead of cutting, the forage has been introduced. This operates on a rotary principle with a series of beaters or knives and is an outgrowth of a type of stalk shedder. A type (4) developed recently in England (some of which are in operation in the USA.) also lacerates the material by means of cutter knives attached to a plate revolving in a horizontal plane.

A feature of most choppers is that they can be used for chopping, (1) grass, corn, sorghum, oats and other small grains for silage; (2) dry hay, and (3) straw and corn stalks and cobs for bedding. This multi-use is made possible by the use of three detachable "heads" ("Corn," "Pick up Reel" and "Direct Cut") which can be purchased separately; this lowers the unit costs to be borne by any single crop, or use, since the main "body" of the machine is the largest item of investment costs.

Although forage harvesters are initially relatively expensive they do replace much of the arduous labor involved with the older methods of silage making, unfortunately still practiced in many parts of the world,

besides replacing such previously needed machines as green crop loaders, ensilage cutters, corn binders, etc. As Cunningham and Fife[1] remark "Probably no other major machine introduced into dairy farming during recent years has resulted in such a large saving in labor as has the field chopper." This point has also been stressed by Duffee,[2] Davidson, et. al.,[3] Whisler[4] and many others. However, if the labor saved cannot be used to advantage somewhere else on the farm or marketed then it should be ignored in any analysis of the costs and savings resulting from the use of forage harvesters.

The rotary flail type choppers are the least expensive but tend to be more limited in their use. Although "Corn Heads" have been developed for use with these latter models they do not seem to be so successful for corn silage as those used with the non-rotary models.

The greater capacity and output, within a given period attainable with a forage harvester does enable more grass and legumes to be harvested at the correct stage of growth to obtain the maximum nutrient content.

By harvesting quickly and early, the second cut is given a longer growing period and thus the total supply of nutrients produced per acre in a season is greater than it would otherwise be.

1/ L. C. Cunningham and L. S. Fife, op. cit.

2/ F. W. Duffee, "New Developments in Forage Harvesting," Agricultural Engineering, Vol. 24, June, 1943.

3/ J. B. Davidson, et. al., "Labor Duty in Harvesting of Ensilage," Agricultural Engineering, Vol. 24, September, 1943.

4/ P. Whisler, "The Field Forage Harvester" Agricultural Engineering, Vol. 28, November, 1947.

Power Requirements

Power requirements for forage harvesters vary with type and size. Blevins and Hansen[1] point out that each time the forage undergoes a change in direction a certain amount of power is required to produce the change. Power is required (1) by the feed mechanism, (2) to cut the forage, (3) to accelerate forage, (4) to move air, (5) to overcome the friction of forage against stationary parts of machine (6) to overcome mechanical friction of moving parts. They concluded from a study of these components that the power required to chop forage depends primarily upon the type of forage and rate of chopping and, therefore, cannot be altered by the designer to any great extent. They consider that the ideal design for a forage harvester would be one in which the material is cut and discharged instantly from the cutting unit allowing no time for frictional drag or excessive velocity increases.

This ideal is met to some extent by some of the rotary flail type choppers where the design eliminates much of the friction against the fan and cutting housing which occurs with conventional models. Bockhop and Barnes[2] consider this type has a higher capacity than the conventional harvester because of its relatively simple design. In analysing the power requirements for this type or machine they concluded that it can be powered by 2 or 3 plow tractors at a relatively low capacity but that to maintain

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1/ F. S. Blevins and J. Hansen, "Analysis Forage Harvester Design" Agricultural Engineering, Vol 37, January, 1956.

2/ C. W. Bockhop and K. K. Barnes, "Power Distribution and Requirements of a Flail type Forage Harvester," Agricultural Engineering, Vol. 37, July, 1955.

a high capacity a 3 or 4 plow tractor will be required. A 4 plow tractor is essential for some of the more recently introduced higher capacity conventional models.

Some doubts have arisen with the use of the flail type models because of differences between lacerated and chopped material. Cowan, Barnes and Allen 1/ conducted field and laboratory experiments with the two types of silage to determine what, if any, were the main differences. In a trench silo, a 2-year study showed no difference between the silage in carotene, crude protein, dry matter and Ph. In the laboratory study shredded was found to have a lower Ph, higher carotene and higher level of acetic and butyric acids than chopped. However, because of the differences in compaction which occur in the laboratory and the field silos these differences, which would seem to favor shredding, were masked, and thus little differences due to machine treatment could be found in the field scale silo.

Hauling Units

Relatively little research work has been undertaken into the various methods of unloading wagons or trucks.

Tests by Bayer 2/ and co-workers at Iowa, designed to compare the efficiency of the false endgate and canvas apron, showed there was little

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1/ A. M. Cowan, K. K. Barnes and R. S. Allen, "An Evaluation of Shredded Legume-Grass Silage," Agricultural Engineering, Vol. 38, August, 1957.

2/ E. J. Bayer, "Results of Tests on Mechanical Loading Devices for Chopped Forages," Agricultural Engineering, Vol 30, May, 1949.

difference in power requirements or performance with the two methods. Further tests with 10 different combinations of unloading equipment and wagons showed no significant differences in unloading times or capacity with any of the combinations. Rate of unloading is controlled by the capacity of the blower rather than the method of unloading.

Blowers

Blowers may be powered by (1) belt drive, (2) mounted motors, and more recently (3) tractor PTO's. According to Raney and Liljedall[1/] the power requirements of most currently produced forage blowers are excessive for the useful work done and mechanical efficiences are in the order of only ten percent. The reason for this low efficiency is similar to that with forage harvesters, namely the friction between forage material and machine housing.

The feed system from the collecting tray to the fan may be either auger or belt type. In many cases spilling occurs at the collecting plate and improvements in size and design of the collecting tray may be desirable.

The latest PTO type blowers are capable of very high capacity rates and tests have indicated rates of filling of up to 36 tons of alfalfa silage per hour.[2/] Filling of upright silos can also be undertaken by elevators and these are being used to an increasing extent with the larger silos.

1/ J. P. Raney and J. B. Liljedall, "Impeller Blade Shape Affects Forage Blower Performance," Agricultural Engineering, Vol. 38, October, 1957.

2/ Agricultural Reports, File 20.60, August, 1957.

Previous Studies on Grass Silage Harvesting

Previous studies on forage harvesting have been undertaken in Michigan by Bookhout and Vary [1/] and many of the findings of the present survey, as regards methods of harvesting and storing grass silage have already been reported upon by them. However, as was seen in the last chapter performance rates are now somewhat higher. On the basis of performance rates and cost data applicable in 1950 Bookhout estimated that at least 75 hours annual use were needed to justify the purchase of a small chopper ($1750) and 125 hours for a large chopper ($2800).

Summaries of the performance rates derived from these, and other studies, are presented in Appendix Table 1. Observations of silage operations in Michigan have also been reported on by Fuller.[2/]

1/ B. R. Bookhout and K. Vary, "Costs and Methods of Harvesting Grass Silage," Michigan Agricultural Experiment Station Quarterly Bulletin, Vol. 32, May, 1950. B. R. Bookhout, "Can You Afford a Field Chopper," Michigan AES. Quarterly Bulletin, Vol. 33, August, 1950. K. L. Vary and B. R. Bookhout, "Farmers Experience with Grass Silage," Michigan AES. Quarterly Bulletin, Vol. 32, May, 1950, K. L. Vary, "Hay Harvesting Methods and Costs", Michigan Agricultural Experiment Station Special Bulletin 392, May, 1954.

2/ E. I. Fuller, op. cit.

CHAPTER V

PARTIAL BUDGETS AND SYNTHETIC COST DATA

The performance data provided from the survey results in Chapter 3 may be useful to a farmer, but the broader problem facing him is what combination of forage crops and harvesting machinery will enable him to maximize profit. This involves cutting forage at the correct state of maturity, reducing field and storage losses to a minimum and at the same time avoiding excessive labor and machinery costs. It also involves producing combinations of crops which yield a large quantity of feed nutrients per acre.

Because conditions vary from farm to farm, no one forage harvesting pattern is best for all situations. Combining of men and machines into economical patterns is as important as the capacity of the individual machines.

Several approaches to the problem have been made in recent studies.[1/] Among these is the construction of partial budgets and cost data for varying patterns of crop production and harvesting systems, and of various combinations of men and machinery within a given system.

In this chapter, synthetic cost data and partial budgets for varying harvesting systems with varying combinations of men and equipment will be

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1/ R. G. Kline and W. W. McPherson, An Economic Analysis of Forage Harvesting Possibilities, Department of Agricultural Economics, North Carolina State College, A. E. Information Series No. 55, February 1957; L. C. Cunningham and L. S. Fife, An Analysis of Forage Harvesting Patterns on New York Dairy Farms, Cornell Agricultural Experiment Station Bulletin 917, October, 1955.

developed.

Limitations to the Approach

A limitation to this approach is its implicit use of a static theoretical framework. Static economics assumes single valued expectations in a timeless and changeless enviroment which is not found in agricultural production. In this study, the position and shape of the cost curves for the varying combinations are derived for a given range of technologies with no consideration of risk and uncertainty in the operations. However, construction of optimum organization under the assumptions of static theory, permits some worthwhile comparisons between alternative systems.

A major weakness in all approaches lies in our imperfect knowledge of physical production functions and of price relationships. The standards of performance, assumed prices and other data presented in this study alleviates this limitation to some extent and makes possible comparisons which are not confounded by these two variable elements. They also permit the testing of the influence of the particular variable when other variables are held constant.

A weakness to using standard rates of performance is that even in a very large survey,- which the one undertaken here was not - only a relatively small proportion of all the possible combinations of men and equipment and performance rates are observed. It is also possible that farmers have not put these resources together in optimum conditions.

Partial budgeting provides a method by which an approximate solution can be reached when alternatives are limited to combinations of a relatively few important variables and when other variables are held constant. The location and shape of the synthetic cost curves for different farms can be derived for only a few types of situations and the selection of important conditions and variables to be tested is critical to the usefulness of the analysis in solving management problems.

Assumptions

The following assumptions are made in this study; they are based on (1) typical data from the survey, (2) data from relevant related studies,[1/] and (3) discussions with members of the Department of Agricultural Economics:

1. Distance of hauling from field to silo averages 80 rods.

2. Average weight per load for grass silage is 3 tons.

1/ K. Vary, Hay Harvesting - Methods and Costs, Department of Agricultural Economics, Michigan Agricultural Experiment Station Special Bulletin 392, May 1954; R. G. Kline and W. W. McPherson, An Economic Analysis of Forage Harvesting Possibilities, Department of Agricul-Economics, North Carolina State College, A. E. Information Series No. 55, February 1957; L. C. Cunningham and L. S. Fife, An Analysis of Forage Harvesting Patterns on New York Dairy Farms, Cornell Agricul-Experiment Station Bulletin 917, October, 1955; G. E. Frick, S. B. Weeks and J. F. Fellows, Production Efficiency on New England Dairy Farms, New Hampshire, Agricultural Experiment Station Bulletin 407, May, 1954; R. E. Marx and J. W. Birkhead, New Harvesting Methods and Costs, U.S.D.A. Circular 868, June 1951; J. Ulvilden and C. H. Benrud Farm Labor, Power and Machinery Performance in East Central South Dakota, Department of Agricultural Economics, South Dakota Agricultural Experiment Station, Circular 131, May, 1956; H. H. De Long, Field Ensilage Harvester Operation and Cost, South Dakota Agricultural Experiment Station, Circular 90, September 1951; E. M. Elwood, Rates for Custom Work in Michigan 1954 and 1955, Michigan State University, Cooperative Extension Folder, F-101; A.Epp. Cost of Operating Machinery on Nebraska Farms, Nebraska Agricultural Experiment Station Bulletin 413, September 1952.

3. For wilted silage picked up from windrows costs of mowing and raking or windrowing are not included. An estimated cost for mowing and windrowing would be 25 cents a ton.

4. Direct costs - Annual fixed costs of forage harvesting machinery, to cover depreciation, interest, taxes, housing and repairs are based on the following rates on the initial investment:

Forage chopper (conventional)	17.0 percent
Forage chopper (rotary)	17.0 percent
Blower, Belt, PTO or motor mounted	17.0 percent
Wagons and unloading equipment	14.0 percent
Trucks	14.0 percent
Upright silos	5.0 percent
Horizontal silos	10.0 percent

These figures are considered average rates over the life of the machines. They would be too high were the machines 10 years old but as stated in Chapter 3, average age of choppers was 3.8 years and for blowers 4.4 years. The rates, therefore, would appear to be appropriate. Many wagons are adaptations to existing equipment which may be 10 years old or more. However, since repairs due to overloading etc. were frequent with this type of equipment, the rate used is considered appropriate for operations similar to those in the survey.

5. Variable Costs:
<u>Power Costs:</u> 2-3 Plow tractors $1.00 per hour
4 Plow tractors $1.25 per hour

These figures cover depreciation, interest, taxes, housing repairs, oils, grease and fuel.

Difficulties arise in pricing tractor hours since during operations one or more of the tractors may be idle at various periods, e.g. the tractor powering the blower may be switched off between loads, a hauling tractor may be idle during unloading etc. The above figures, however, are considered typical for the system observed.

Labor Costs: - $1.25 per hour

This "price" to apply to all hired labor, a charge for the operator, and any adult family labor.

The Wagley-Johnson estimate 1/ of the <u>annual</u> marginal value productivity of labor on Ingham County dairy farms, on Miami-Conover soil in 1952, of 67 cents per day would not be appropriate for this study, since during peak periods of labor demand, the marginal value productivity of labor will be higher than for the year as a whole. Other reasons for adopting the figure of $1.25 per hour are (1) the casual labor rates are higher at such peak periods, (2) that the costs are supposed to reflect future price conditions rather than historical conditions. It seems reasonable to presume that both the price of casual labor and the marginal value productivity of labor may be higher in the future. Fuller 2/ has considered ways in which this latter possibility may be accomplished.

o. Total harvesting costs are the combined costs of machinery, power and labor costs. Average total costs are total costs divided by output (tons) and are the sum of average fixed and average variable cost. Average total costs per ton are derived by dividing annual fixed costs by total annual tonnage and adding to this the average variable cost per ton -- derived by

1/ G. E. Schuh, op. cit.

2/ E. I. Fuller, op. cit.

dividing operating cost per hour for labor and power by the capacity in tons per hour.

$$\text{Average Fixed Costs (AFC in \$ per ton)} = \frac{\text{Total Annual Fixed Cost \$}}{\text{Total Output (tons)}}$$

$$\text{Average Variable Costs (AVC in \$ per ton)} = \frac{\dfrac{\text{Machine Operating Charges} + \text{Labor Charges (\$ per hour)}}{}}{\text{Output per hour (tons per hour)}}$$

Synthetic Cost Curves

Synthesized average total costs schedules for varying quantities of output, are presented in Tables 10 and 11. Great care is necessary in using these, as their nature depends on the assumptions for performance rates and investments costs. Modifications have to be made before applying them to any given farm conditon. The particular cost schedules presented here are mainly for illustrative purposes.

The performance rates and investment costs for the combinations of men and machinery given in Table 11 may be considered typical figures for medium, and large sized dairy farms in South-Central Michigan where grass silage has been made with forage harvesters and blowers, for more than one season. The figures are based on the survey data presented in Chapter 3. It is considered that the rates used have application to similar farms in other areas. The average performance rate for all methods of harvesting and storing was 9.1 tons per hour, with a typical size crew of 3 men, 2 wagons and 3 tractors.

Limitations of Cost Curves

A fundamental weakness of such schedules and cost curves, as normally presented, is that the method used to determine average total costs assumes that the output per hour for the given combination of labor and power with the fixed amount and type of machinery is constant over the whole range of total output. Thus, marginal and average variable costs will be constant and equal. Graphically, as in Figure 1, Average Variable Cost $(AVC)_{(1)}$ = Marginal Cost $(MC)_{(1)}$ for any output OY. Average total cost is then given by $ATC_{(1)}$.

However, quality considerations have to be taken into account in conserving grass silage. As indicated in the previous chapter nutrient content, decreases with advances in the stage of maturity of forage crops. This decrease is more rapid with grasses than legumes and hence, a slightly longer period is available in which to harvest the latter. However, in both cases decreases occur and hence, in terms of the cost of feed nutrients, rather than of more bulk of green material, marginal costs will not be constant but will tend to increase; i.e., the marginal cost curve will tend to rise.

A factor causing further increases in marginal cost is that as total output, with any given system, increases, minor delay from machinery breakdowns etc. tend to increase. This decreases rates below the constant figure assumed for the cost data. Other decreases may occur from such reasons, as the difficulties which occur with hauling loads over horizontal silo when filling is near completion etc. Variations in performance rates also occur within any given period of the total operating time; thus rates are often slower at the end of the day, or early in the day when some dew is still on the forage, or before or after meal breaks etc.

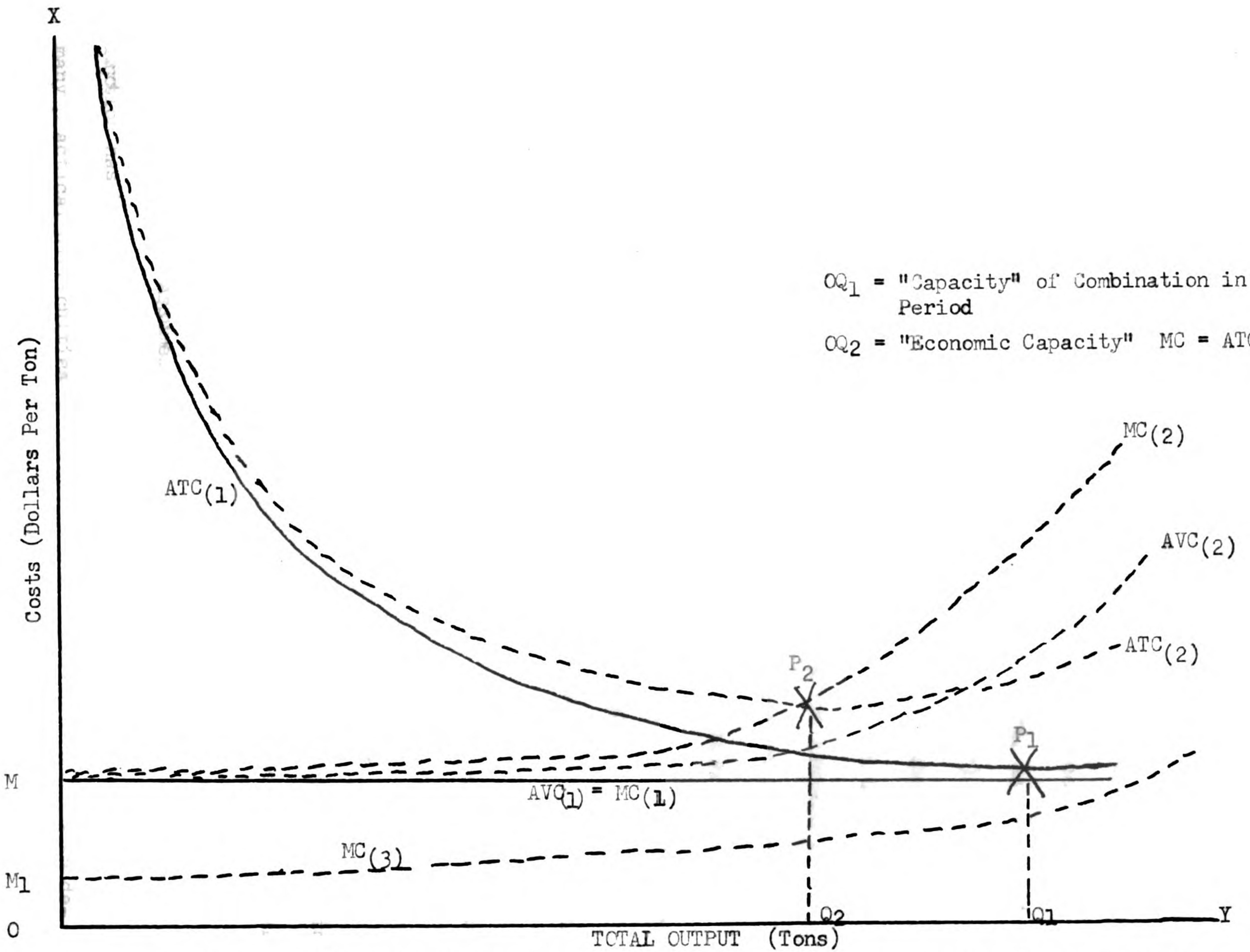
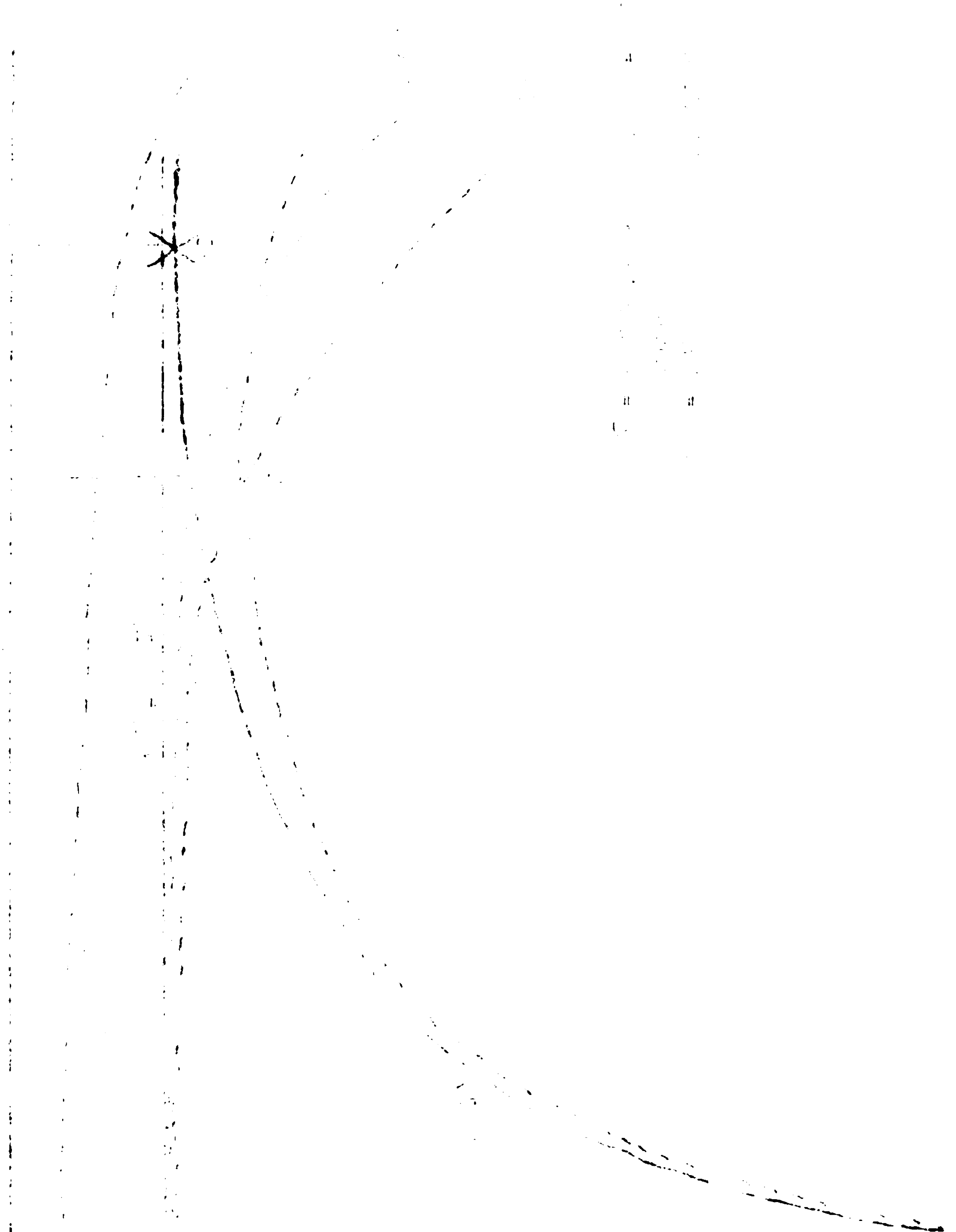


FIGURE 1: Marginal (MC) and Average Total Cost (ATC) Curves for Harvesting Varying Outputs of Grass Silage Under A Given Hypothetical System



Under actual conditions marginal and average variable costs are not constant and equal; thus, in Figure 1 they may more correctly be represented as $AVC_{(2)}$ and $MC_{(2)}$. Average total cost would then be $ATC_{(2)}$. If it is assumed that, in the long run, all the fixed assets in the system have been correctly priced, ie, all earnings correctly capitalized, then on the basis of the theory of the firm, as developed within a static framework, the marginal value product (MVP) of the harvesting services produced by the system will interest the marginal cost curve at the point P_2, where the marginal and average total costs are equal. This is also at the lowest point on the average total cost curve and is the long run equilibrium level of output for the system, ie, it is the maximum profit point on the production function and the output OQ_2 is, thus, the true "economic capacity" of the system.

The shape of the MVP for forage harvesting systems has not been determined,,but in view of the rapid decrease in nutrient content which occurs, it is probable that it falls sharply in the region of the maximum profit point OQ_2. An alternative way would be to consider that the marginal cost rises sharply in this region. In either case the point of intersection would be at the same level of output.

A similar "economic capacity" (OQ_3) could be determined from marginal cost curve $MC_{(3)}$; in this case, the average total cost curve has not been drawn.

This analysis assumes that more than one point on the production function has been determined for each farm. To do this would involve many practical difficulties of recording the complete operation in detail, chemical analyses, and feeding trials etc.

In this study a best estimate of only one point on the production function is obtained for each farm and the marginal cost for a system determined from such single point estimates for a number of farms. Thus, the survey data is severely limited since it was not obtained and presented in a manner which enables the true marginal costs of the systems to be determined. The best estimate of the marginal cost is assumed to be $MC_{(1)}$ but since the average total cost curve $ATC_{(1)}$ is a rectangular hyperbola, asymptotic to this marginal cost curve (MC_1), intersection of the two curves, and the determination of economic capacity of the system, is impossible. Therefore, estimates referred to as "capacity limits" have to be made of the economic capacity, by arbitrarily fixing levels of output, such as OQ_1 in Figure 1, at which it is assumed that the marginal value product (MVP) of the system is equal to the marginal cost and also equal to average total cost. (Such "capacities" are often converted to "working days" on the basis of constant performance rates.)

As drawn in Figure 1, OQ_1 will always tend to be at a greater level of output than OQ_2. However, with $MC_{(3)}$ where it is assumed that MC_1 has been placed at too high a level, the "economic capacity" OQ_3 could be at a greater level of output than OQ_1 - the estimated capacity.

Analyses using "imperfect" data from single point estimates are too frequently undertaken.

Figure 2 shows two sets of cost curves for two hypothetical methods of harvesting determined in this manner. Method $A_{(1)}$ may be considered as utilising existing machinery, with a relatively low output with marginal cost $MC_{(1)}$ and average total cost $ATC_{(1)}$. System $B_{(2)}$ represents a method with newer more expensive machinery capable of higher output. With this, marginal costs $MC_{(2)}$, will be lower than $MC_{(1)}$, due to higher performance rates, and the average total cost $ATC_{(2)}$ higher than $ATC_{(1)}$ for low levels of output, because of the relatively higher fixed costs incurred at these levels.

At first glance it would appear that a farmer faced with the choice between these two methods for harvesting would choose method A for outputs up to output OQ_1; - the point where the two average total cost curves intersect. However, if we assume that the farmer already owns, and is operating method A, it would not be profitable to change to the higher investment, greater output method B, until output OQ_2 has been reached. At this point the marginal cost $MC_{(1)}$ of method A is equal to the average total cost of method B. This principle will apply whether constant marginal costs as in Figure 2, or increasing or 'true' marginal costs $MC_{(2)}$ in Figure 1 are being considered. The reason for this is that when new machinery is purchased all factors are variable and all costs become variable costs; i.e. the average total cost becomes the marginal cost. Thus, for outputs $OQ_2 - OQ_1$ the marginal cost under method B is give by P_1P_2. Since this is higher than the marginal cost $MC_{(1)}$ of method A it will not be profitable for the farmer to change methods until output OQ_2. Beyond this point $MC_{(1)}$ will be higher than $ATC_{(2)}$ and $MC_{(2)}$. This principle accounts for the reason why many farmers continue to operate existing equipment, rather than purchase new higher capacity machinery, when only small additions to existing total outputs are contemplated. Thus, in general a shift to a newer method implies an increase in output.

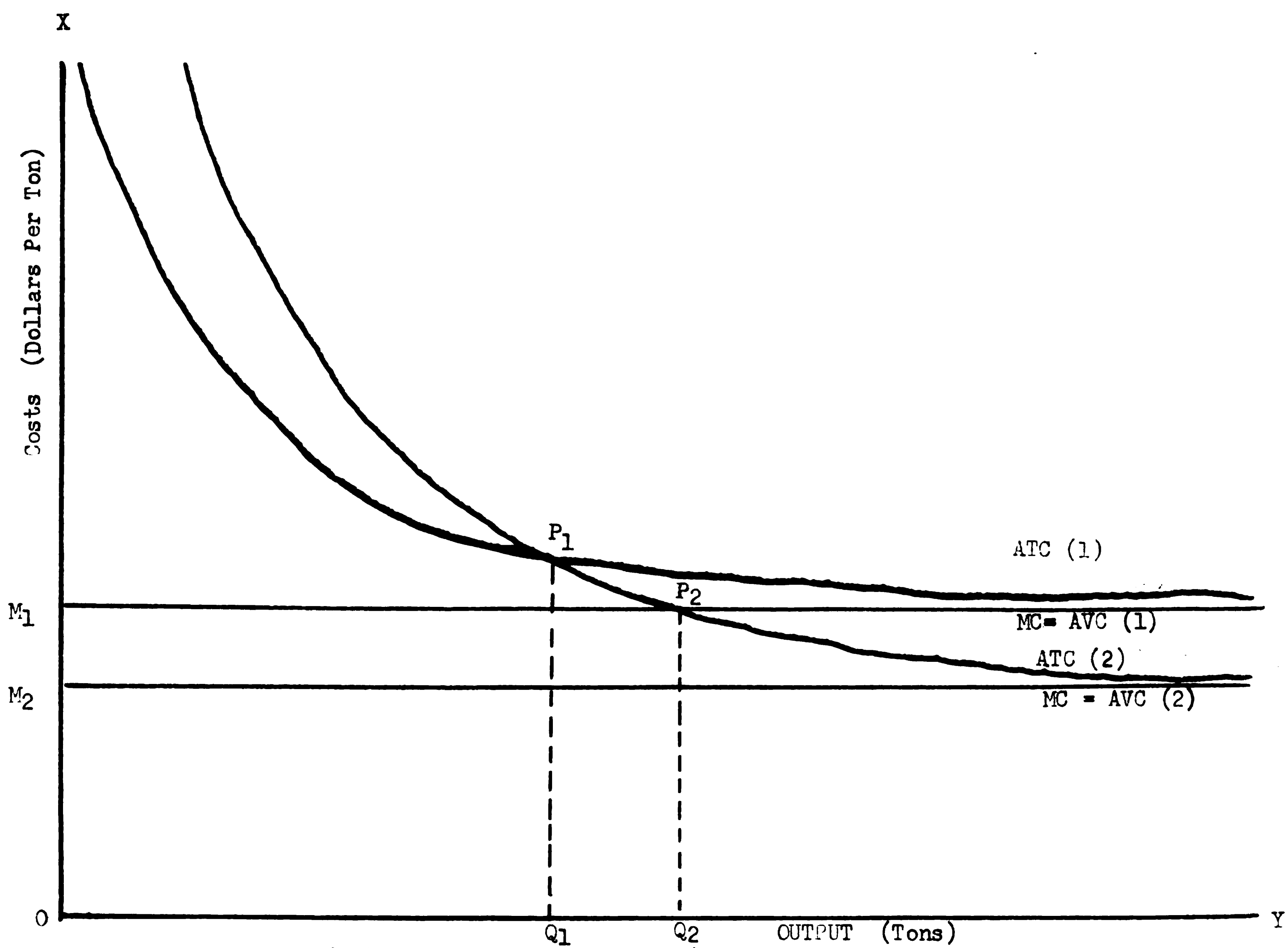


FIGURE 2: Marginal (MC) and Average Total Cost (ATC) Curves for Harvesting Grass Silage By Two Hypothetical Alternative Systems.

Cost Curves for Alternative Harvesting Methods

In Tables 10 and 11 the total "capacity of the combinations is assumed to be that attainable in a period of ten working days of 8 hours each. Ten days are chosen as this is approximately the period available during early June when high quality silage can be made and as such is an estimate of the "true economic capacity" of each system. Delays due to wet weather may result in the output within the period being reduced, or the quality of the silage reduced, if the 10 working days have to be extended over a longer period. Capacity will also be reduced when only 6 hour working days are possible. This is often the maximum time available on the smaller dairy farms where chores have to be done. The farms envisioned in Table 11 are large scale operations where breaks for chores may not occur since a separate field team could be used.

The cost curves developed in Figures 3 and 4 are analagous to those in Figure 2 but due to the high level of fixed costs, relative to variable costs, intersection points between cost curves for different machinery patterns do not occur within meaningful levels of output. In Figure 3 point P between methods 3 and 5 (where the same chopper and blower is used with different combinations of men and wagons for filling an upright silo with wilted material), shows that up to an output of approximately 270 tons, combination III gives the lower average total cost. If the farmer were already operating with 4 men and 2 wagons it would be profitable for him to continue with that system up to the output where the marginal cost curve of system III intersected the average total cost curve of method IV, before dis-

TABLE 19

ESTIMATED MARGINAL AND AVERAGE TOTAL COSTS PER TON FOR HARVESTING VARYING OUTPUTS OF GRASS SILAGE BY ALTERNATIVE SYSTEMS, AT PERFORMANCE RATES OBSERVED ON SOUTH-CENTRAL IOWA DAIRY FARMS, 1957

SYSTEM 1/	Capacity Per Hour (tons)	Marginal Cost Per Ton Dollars	Average Total Cost for Harvesting Tons: 50	100	150	200	250	300	400	500	600	700	800	900	1,000
			Dollars Per Ton												
Windrowed to Upright Silo :															
Own Equipment															
I. 5M 3W 3T	11	0.93	12.93	6.93	4.93	3.93	3.33	2.93	2.43	2.13	1.93	1.79	1.68	1.59x 2/	1.5[illegible]
II. 5M 2W 3T	7	0.96	11.97	6.47	4.63	3.72	3.17	2.80	2.35	2.07	1.88x	1.76	1.66	1.58	1.52
III. 4M 2W 3T	9	0.89	11.89	6.39	4.55	3.64	3.09	2.72	2.27	1.99	1.80	1.68x	1.59	1.50	1.44
IV. 3M 3W 3T	10	0.68	11.68	6.68	4.68	3.68	3.08	2.68	2.18	1.88	1.68	1.54	1.43x	1.34	1.28
Custom Hire															
V. 3M 3W 3T	10	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Direct-Cut to Horizontal Silo :															
Own Equipment															
VI. 3M 2W 3T	11	0.61	9.61	5.11	3.61	2.86	2.41	2.11	1.73	1.51	1.36	1.25	1.17	1.11x	1.06

M = Men. W = Wagon. T = Tractors.

1/ Assumptions : Combination I, II, III, IV : Initial Cost : Chopper 2,000 (dollars), Blower 600 (dollars), Wagon 400 (dollars), each.

Combination VI : Initial Cost : Chopper 2,000 (dollars), Wagons 400 (dollars), each.

Combination V : Custom Hire Charge 15 (dollars) per hour for 1 Chopper, 1 Blower, 1 Wagon, 1 Tractor, 1 Man. [illegible]

2/ x Capacity in [illegible] period.

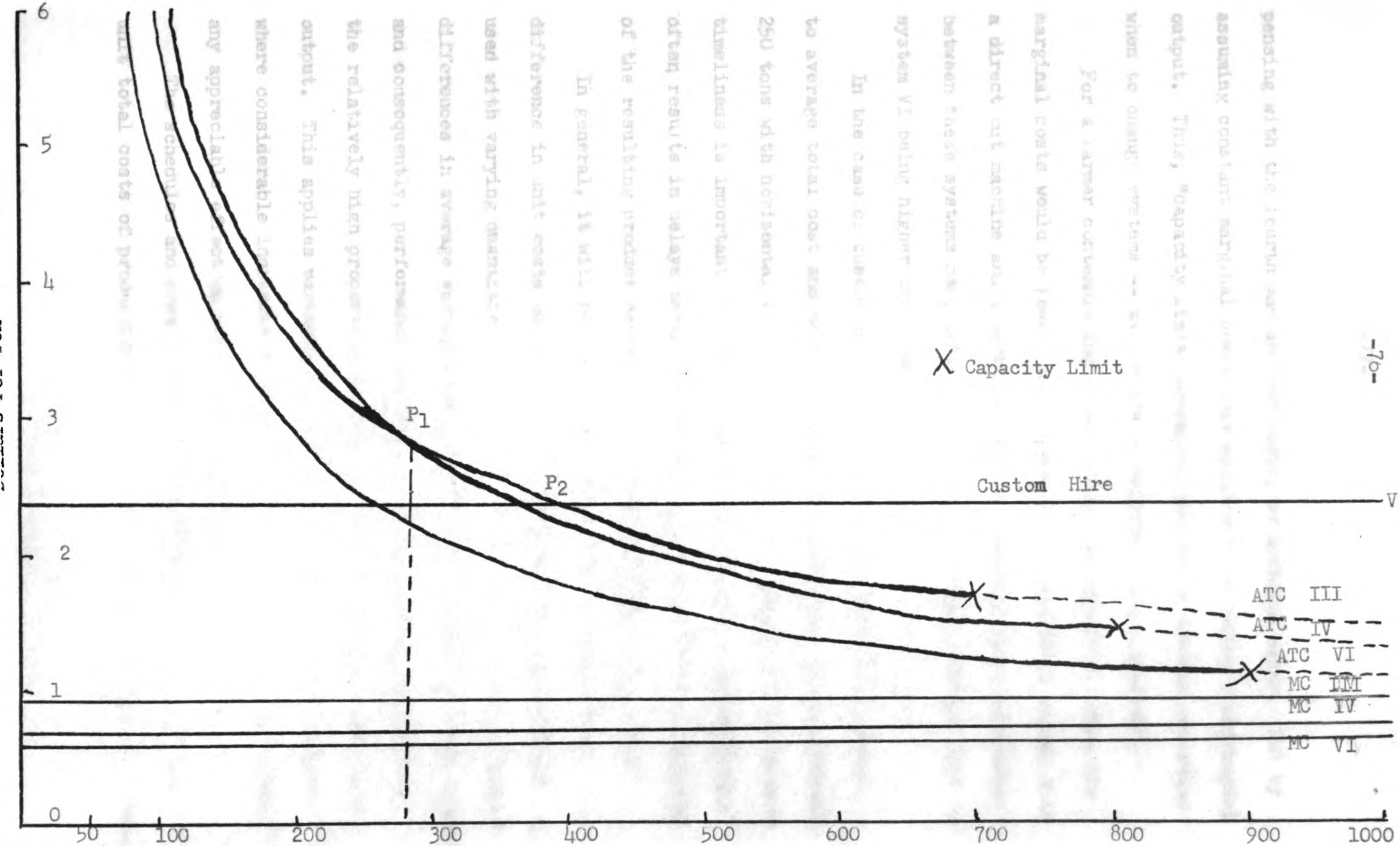
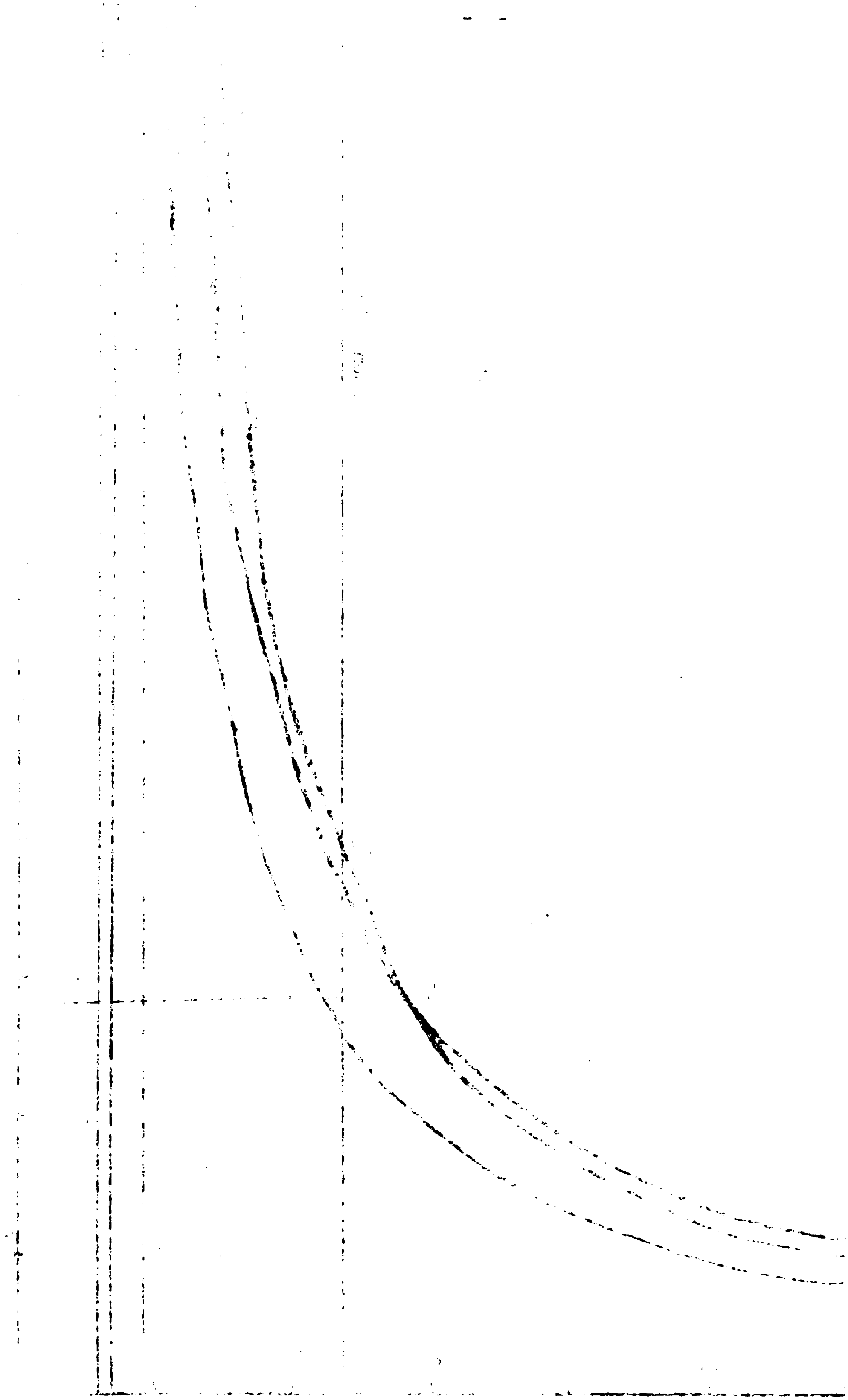


FIGURE 3: Estimated Marginal and Average Total Costs Per Ton For Harvesting Grass Silage By Varying Systems, Based on Performance Rates on South-Central Michigan Dairy Farms, 1957.



pensing with the fourth man and purchasing an addition wagon. But by assuming constant marginal costs this point will be beyond a meaningful output. Thus, "capacity limit" estimates have to be used to determine when to change systems -- as the X's in Figures 3 and 4 indicate.

For a farmer contemplating silage making for the first time, the marginal costs would be lowest for system VI, - 3 men and 2 wagons with a direct cut machine and a horizontal silo. Feeding value differences between these systems may, however, result in the real marginal cost for system VI being higher than that for III or IV.

In the case of custom hiring (System V), marginal cost is equal to average total cost and this is lowest for outputs up to approximately 250 tons with horizontal silos and 370 tons with upright silos. However, timeliness is important in determining quality and since custom hiring often results in delays before operations commence, the reduced quality of the resulting product may more than offset the lower unit costs.

In general, it will be seen from Table 10 and 11 that little difference in unit costs occur when the same harvesting equipment is used with varying quantities of power, labor and hauling units. Although differences in average variable costs occur as the amount of labor, power, and consequently, performance rates alter these are largely masked by the relatively high proportion of fixed costs which occur at any given output. This applies particularly at the low levels of total output where considerable increases in performance rates have to occur before any appreciable effect on unit costs is observed.

The schedules and cost curves illustrate the point that for low unit total costs of production to occur a high output and use of machinery must take place. This use may be in any of the forms previously mentioned - i.e. daily chopping of forage for dry lot feeding, a high acreage of grass, corn, oats, sorghum, etc. for silage or the use of chopped straw and corn stalks for bedding. Similar results may be obtained through custom operating, or sharing equipment with neighbors.

Though performance rates used in Table 11 appear rather high, they are capable of being attained within the near future with machinery of high capacity -- and high cost -- now being developed to an increasing extent. The machinery envisioned is a high capacity chopper requiring a 4 plow tractor for power operating, a PTO blower, and 3 self unloading wagons. These latter would enable the blower to operate to full capacity since, emptying from a chute at the side they could be driven up directly to the end of the blower's collecting tray. The delay caused with rear unloaders of having to clean up, then lift the tray clear, backing wagons into position, etc. are all obviated and the spilling of chopped material which may occur with this fast rate of filling can be kept under control by the blower operator as the wagon is unloading.

The high investment cost of the machinery will necessitate high total output -- as can be seen from the cost schedule for combination I -- if unit costs are to be kept to a reasonably low figure. The advantage which the sharing of such expensive machinery allows can be seen in combination II, when the same equipment and crew as combination I are used but where, by sharing the initial investment on a 50-50 basis, the annual fixed cost is reduced by 50 percent. However, capacity is also reduced.

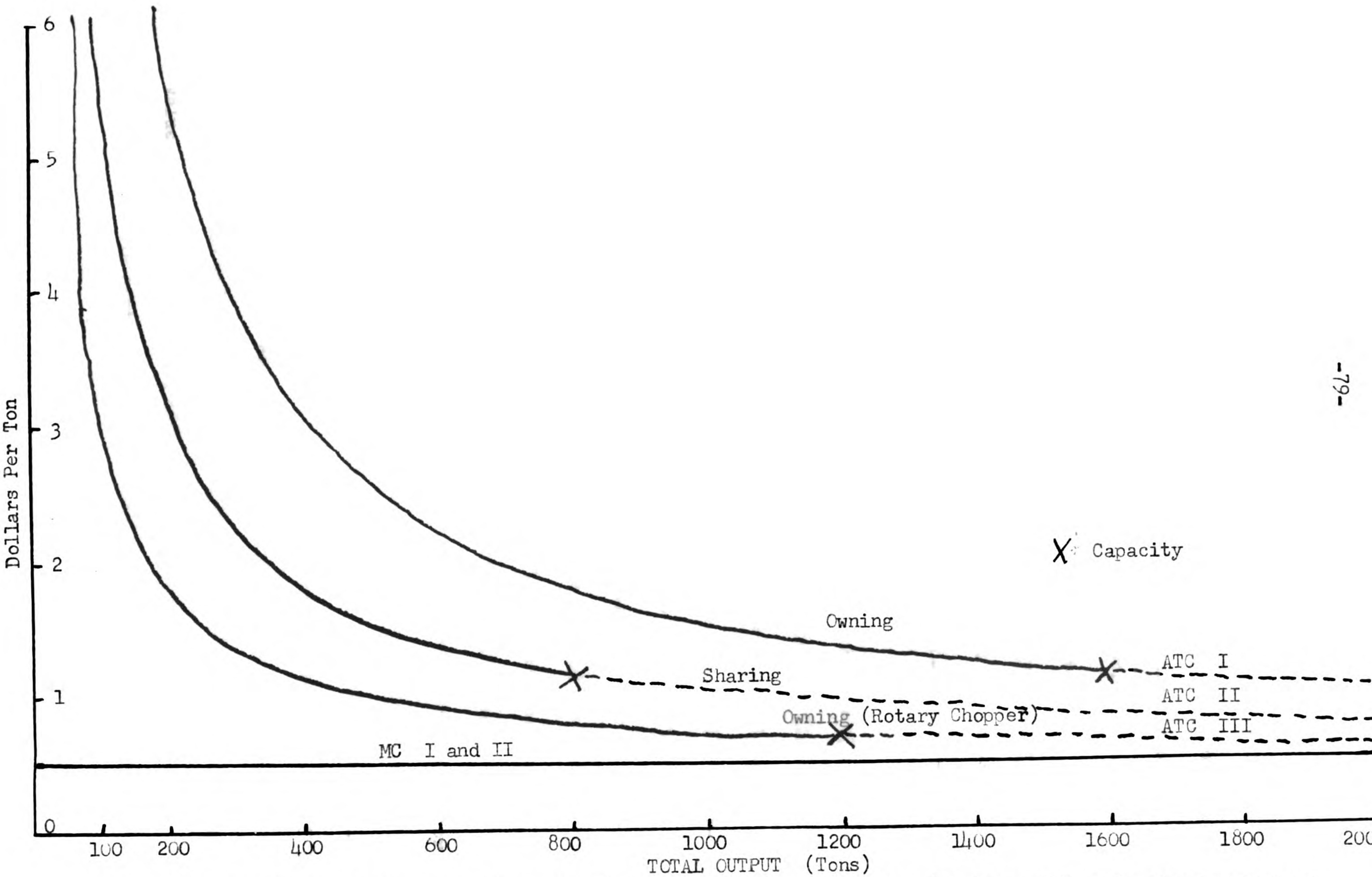
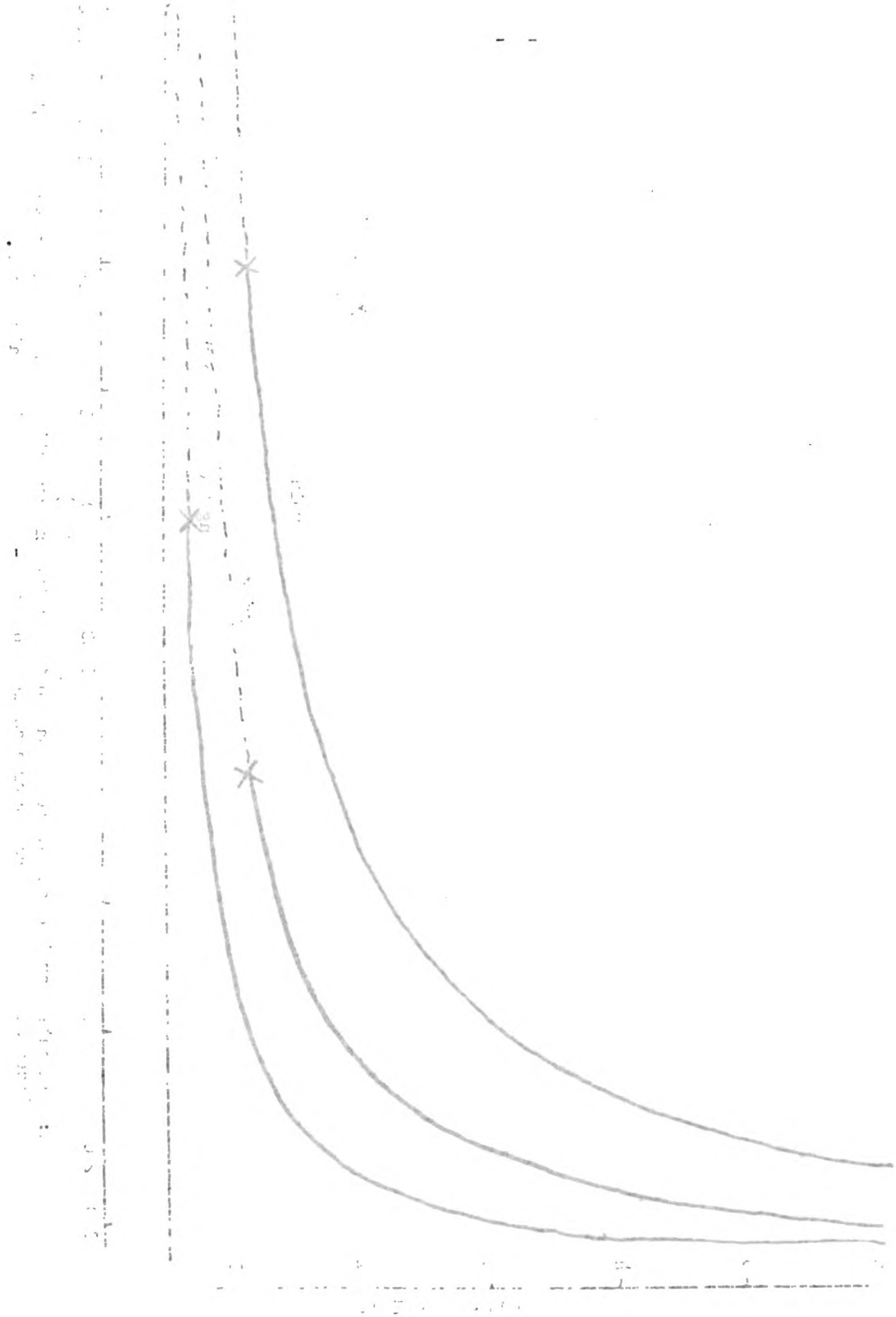


FIGURE 4: Estimated Marginal and Average Total Costs Per Ton for Harvesting Grass Silage By Varying Systems Based On Possible Future Performance Rates on South-Central Michigan Dairy Farms.



Combination IV shows the slight reduction in unit costs which occur when a horizontal silo is used instead of an upright. The tractor needed for packing could be in continual use since the self unloading wagons would be powered by the hauling tractor. In some cases, 2 tractors may be necessary in silos of this size.

Combination III shows the results of using a rotary flail type chopper. This type has a lower initial investment cost and is more suitable for use with horizontal silos. Difficulties have occurred, however, with feeding lacerated material from bunkers.

The average total cost curves together with capacity levels for combinations I, II and III are given in Figure 4. Thus, at 1200 tons a farmer operating system III would have to change to system I, since 1200 tons is the assumed level at which the marginal cost of III intersects the average total cost (= marginal cost) of the new system I.

When observing these cost curves it is essential to bear in mind; (1) that in their construction marginal costs are assumed equal to average variable costs whereas in fact as output increases marginal costs probably increase, (2) that the cost curves do not necessarily compare identical products or identical production functions. Thus, for any given output, the silage which results from using combination III, although lower in average total cost than that from II or I may be considerably lower in feeding value. In terms of cost of feed nutrients III may well be higher than II or I and the subjective value which the farmer may place on reducing the risk involved in producing a high feeding value silage may more than offset the lower unit costs of III.

Thus, synthetic cost curves as developed in this chapter have

[illegible]

[illegible]

[illegible] 1/	[illegible] Per Ton (tons)	[illegible] Cost Per Ton Dollars	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,[illegible]	[illegible]
			Do[illegible]										
Direct Cut-[illegible] to [illegible] Silo : [illegible] Equipment [illegible] 2/	[illegible]	[illegible]	[illegible]	[illegible].77	[illegible]	[illegible].1	[illegible]	[illegible]	1.70	1.[illegible]	[illegible]	1.1[illegible] × 4/	1.[illegible]
[illegible] Equipment [illegible] 2/	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.7	1.[illegible]	1.[illegible]	1.1[illegible] ×	1.[illegible]	[illegible]	.[illegible]1	.7[illegible]
[illegible] Chopper to [illegible] Silo : [illegible] Equipment III [illegible] 3/	1[illegible]	[illegible]	[illegible]	1.8[illegible]	1.[illegible]	1.1[illegible]	1.[illegible]1	[illegible]	[illegible]	.7[illegible]	[illegible] ×	[illegible]	[illegible]
Direct Cut-[illegible] to [illegible] Silo : [illegible] Equipment [illegible] 2/	2[illegible]	[illegible]	[illegible].7[illegible]	[illegible].1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.[illegible]	1.[illegible]1	1.[illegible]	1.[illegible] ×	[illegible]

[illegible] = [illegible]en. [illegible] = [illegible]. [illegible] = Tractors.

1/ [illegible]umptions : I : Initial Cost : Chopper [illegible] (dollars), [illegible] (dollars), [illegible] [illegible] 1,[illegible] (dollars) each, ([illegible]).

II : Initial Cost : Chopper 1,[illegible] (dollars), [illegible] (dollars), [illegible] [illegible] 500 (dollars) each, ([illegible]).

III : Initial Cost : Chopper 1,[illegible] (dollars), [illegible] [illegible] (dollars), each, ([illegible]).

IV : Initial Cost : Chopper [illegible] (dollars), [illegible] 1,[illegible] (dollars), each, ([illegible]).

2/ Tractor Charges : Two at 1.[illegible] (dollars) per hour, [illegible] 1.[illegible] per hour.

3/ Tractor Charges : Three at 1.[illegible] (dollars) per hour.

4/ × [illegible] – [illegible] to [illegible] [illegible].

limited application in demonstrating some of the obvious points referred to, such as high use for low unit cost etc., but are useless for determining the "true economic capacity" for a system unless the true marginal costs of the services provided by the system are available.

Partial Budgets

The previous analysis has been concerned only with estimated costs of harvesting grass silage, however, it is not possible to consider harvesting systems for a single forage crop in isolation from the rest of the farm. To obtain low unit cost, use of machinery for other forage crops besides grass silage is necessary. This may necessitate changes in cropping and feeding systems, and possibly in the livestock enterprises - with consequent changes in net farm income, etc.

As previously pointed out, harvesting and storage methods affect silage quality. Thus, least cost combinations for various systems have only limited meaning without reference to the feeding value of the product. This is not easy to determine in advance, as chemical analyses are often misleading, and the real quality can only be determined from its effect on milk production. This is difficult to determine as many other factors besides silage quality affect milk production.

The "capacity" of a combination to harvest the required amount during a given period - when quality is highest - is most important. Thus, in previous studies[1/] the low investment cost combination of green crop loader and ensilage cutter has been shown to give lowest unit costs for

1/ R. G. Kline and W. W. McPherson, op. cit.

all levels of output up to approximately 1000 tons, but "capacity" is so low that only very small amounts could be harvested in the available period.

Similarly the cost curves developed above have shown that the direct-cut rotary type chopper used in conjunction with a horizontal silo gives the lowest unit costs in terms of tons harvested but, as pointed out, this does not necessarily mean least cost in terms of feed nutrients or milk production potential. Ross and Fellows[1/] in their budgets considered that by eliminating weather losses, grass silage increased milk receipts by 16.5 percent. However, differences between qualities of silage may lead to even greater increases than this, as some of the data in Chapter 4 indicated.

Evaluation Problems

A major difficulty, in considering quality differences between forages, is determining a method of evaluating the original product. As Hadley and Suter[2/] observe, the value of any commodity is always considerably influenced by the time, place, and form in which it is held. Pasture has a time and place disadvantage because it cannot be stored or moved. Hay and silage both have a place disadvantage because they are difficult to move. All roughages have some form disadvantages

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1/ V. E. Ross and I. F. Fellows, An Economic Evaluation of the Barn-Finishing Method of Harvesting Hay, Connecticut Agricultural Experiment Station Bulletin 227, April, 1951.

2/ N. S. Hadley and R. C. Suter, "What is Silage Worth," Symposium on Silage, Department of Agricultural Economics EC-148, Purdue University, April, 1957.

because their use is limited to livestock farming.

Johnson and Hardin 1/ have presented an analysis of the problem and concluded that an acre of harvested forage should be valued at (1) not less than the highest net value realizable by disposal-salvage value, (2) not more than the cost of acquiring by the most economical means available additional forage units or their equivalent- acquisition cost, (3) the value through use - the marginal value product - if this falls between the limits of (1) and (2) above. They concluded, - on the basis of the Wagley study 2/ - that the MVP of an acre of forage was $14.00, Assuming that values then and in 1957 are approximately the same, an estimate, based on this latter figure, of $7.00 per ton was determined as an appropriate value to place on one ton of wilted grass silage stored in an upright silo. Assuming 400 pounds TDN per ton of wilted silage 3/ then the unit value of TDN in silage would be 1.75 cents per pound.

As indicated in the previous chapter, variations in the TDN and protein content of grass silage occur depending on the stage of maturity at harvesting. In general, protein content is higher the earlier the harvest, but total dry matter, and possibly TDN content, increases with stage of maturity.

Typical dry matter losses, for different harvesting and storing

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1/ G. L. Johnson and L. S. Hardin, Economics of Forage Evaluation, North Central Regional Publication No. 48, Published as Purdue Agricultural Experiment Station, Bulletin 623, April, 1955.

2/ R. V. Wagley, op. cit.

3/ Based on figures appearing in Tables by F. B. Morrison, Feeds and Feeding - Abridged, Eighth Edition, Morrison Publishing Company, Ithaca, 1950.

methods may be as follows:

	Wilted Material (Percent)	Direct-Cut Material (Percent)
Upright Silos	12	25
Horizontal	- 1/	30

Thus for every 100 tons of wilted grass silage stored in an upright silo the following additional quantities and acreages would be required by the direct-cut methods:

	Wilted Material	Direct-Cut Material	
	Upright Silo	Upright Silo	Horizontal
Tons	100	113	118
Acres (8tons per average)	12.5	14.1	14.75

The main purpose of the presentation is to demonstrate that harvesting and storage costs are not the only considerations involved in decisions concerned with silage conservation.

Construction of Budgets

Partial budgets, for harvesting and storing varying quantities of grass silage for five different sized dairy herds, are presented below. The assumptions on costs and performance rates are based on those presented in the early part of this chapter and in Chapter 3. The assumptions concerning losses of nutrients with the different harvesting and storing systems have been utilized as follows: - four alternative methods of harvesting and storing grass silage are budgeted for each herd size. The ones presented are considered to be the more likely of the many

1/ Although instances were observed, in the survey, of the use of wilted material with bunker silos, the practice is not generally recommended because of the difficulty involved in effectively "packing" the wilted material.

alternatives possible on each farm. In each case, harvesting wilted material, stored in an upright silo - Method A - is budgeted first. This method, results in least loss of nutrients (but highest costs for harvesting and storing), and is, therefore, taken as the norm from which the other methods are evaluated. It is assumed that the total amount of silage required on each farm is that obtainable with Method A. The figures given for Methods B through D are the equivalent amounts and additional acreages (assuming 8 tons of wilted silage per acre) that would be required, after allowance has been made for the increased losses of dry matter that occur with these other methods. Total fixed costs for harvesting these additional amounts will not change, but total variable, and hence total costs, will increase. Storage costs will also increase. Item 7 in each set of budgets shows the difference in total costs for harvesting and storing between Method A and the alternatives. Item 8 takes account of dry matter losses and shows the value of the additional land required to produce the additional amounts of silage, when an acre of land is valued at $30[1/] - (based on $16 for land charges and $14 as the MVP of an acre of forage). Item 9 shows the net effect of comparing Method A with the alternatives.

It will be seen that, in many instances, reductions in harvesting and storing costs are more than offset by the value of the additional land requirements. Very often the net differences are relatively small and hence, inconclusive as to the best method to adopt.

1/ This is approximately the same figure as that for current conditions on Southern Michigan farms as determined by C. R. Hoglund and R. L. Cook, Higher Profits from Fertilizer and Improved Practices, Michigan Agricultural Experiment Station, Agricultural Economics 545, October, 1956.

Feeding costs have also to be taken into account and where these are low, as in self feeding systems, they may offset any other cost and value differences. If we assume a price for labor during the winter period of 80 cents an hour, then over 240 days, a possible reduction, with self feed methods of only 30 minutes labor per day would amount to $96.

The Farms

Hypothetical farms have been used as a basis for evaluating the alternative harvesting and storing methods. With the exception of the 250 cow herd, similar operations were observed on the survey and, in effect, each set of budgets is a composite presentation of practices on several actual farms. More meaningful alternatives can be considered by doing this since limitations often occur on actual farms which prevent some alternatives, which may have wide applicability, from being feasible. Only brief details of the hypothetical farms are presented below as it is hoped that the budgets, all constructed in the manner described, are self explanatory.

Farm A

The results of considering some of the alternatives facing a farmer with a small herd of 15 cows who wishes to feed 80 lbs. grass silage per day during a 100 day summer period and to refill the silo in the fall with corn silage are considered in Table 12. Storage for the required 60 tons could be provided either by a 10' x 35' upright or by a 20' x 40' trench silo.

It is assumed that the machinery is purchased second hand at auctions etc. and that the team is made up of 3 men, 2 wagons and 3

TABLE 12

ESTIMATED TOTAL "COSTS" OF HARVESTING AND STORING THE EQUIVALENT OF 60 TONS OF WILTED GRASS SILAGE IN UPRIGHT SILOS BY ALTERNATIVE METHODS ON SOUTH-CENTRAL MICHIGAN DAIRY FARMS

ITEM	METHOD A	B	C	D
Machinery Ownership	Self-Owning	Self-Owning	Custom Hire	Custom Hire
Type of Material	Wilted	Direct Cut	Wilted	Direct-Cut
Type of Silo	Upright	Trench	Upright	Trench
Tons Required	60	70.8	60	70.8
Additional Acreage Above A	-	1.35	-	1.35
Capacity Tons Per Hour	7(1)	8(1)	10(1)	11(1)
Costs	Dollars	Dollars	Dollars	Dollars
1. Total Fixed Costs	162.50(2)	137.00(3)	78.00(4)	83.69(4)
2. Total Variable Costs	57.84	59.74	27.00	28.96
3. Mowing and Windrowing Costs	15.00	-	15.00	-
4. Total Harvesting Costs	235.34	196.74	120.00	112.65
5. Storage Costs	17.50	2.95	17.50	2.95
6. Total Harvesting and Storage Costs	252.84	199.69	137.50	115.60
7. Comparative Total Cost to Method A	-	-53.15	-115.34	-137.24
8. Estimated Value of Additional Land Requirements	-	+40.50	-	+40.50
9. Net Costs (8 - 7)	-	-12.65	-115.34	-96.74

(1) Crew: 3 Men, 2 Wagons, 3 Tractors.
(2) Initial Cost: (Second Hand) Chopper $1200, Blower $300, Wagons $250 Each, (10'x35') Silo.
(3) Initial Cost: (Second Hand) Chopper $1200, - - Wagons $250 Each, (20'x40'x4') Silo.
(4) Custom Rate: $13 per hour - High Capacity Equipment - Farmer Provides 2 Men, 2 Tractors.

tractors. The fixed costs are based on a machinery use for 60 tons of grass and 60 tons of corn silage. If the 60 tons of dried hay, required for winter feeding, were also chopped, fixed costs would be reduced by $54.50. This is not sufficient, however, to bring total harvesting costs with owned equipment below those for custom hiring. On the basis of the budgets, custom hiring wilted material to an upright, (Method C) is the most profitable with a net decrease of $115.34 over Method A. The results would be even more in favor of custom hiring if the machinery had been purchased new. Reductions in feeding costs, possible with the trench silo, could easily offset the small difference between Methods C and D and, hence, the trench silo would be preferable.

Farm B

The case of a farm with a 35 cow herd, producing 200 tons grass silage, 100 tons corn silage and 80 tons dry hay, is considered in Table 13. Storage for the grass silage could be either in a 16' x 40' upright, estimated cost $1800, or a 20' x 60' bunker silo, estimated cost $600. It is assumed that the chopper and blower are used for the dry hay as well as for the grass and corn silage. Custom hiring wilted material to an upright -- Method C -- results in a decrease in net costs of $56.48 compared to A. However it is doubtful if this is sufficient to compensate for the possible inconvenience and loss of independence which occurs with custom hiring. Less loss of independence occurs when machinery is shared, as in Method D. This is the most profitable and results in a net decrease in costs of $64.28 over Method A and would, therefore, be the most appropriate method.

TABLE 13

ESTIMATED TOTAL "COSTS" OF HARVESTING AND STORING THE EQUIVALENT OF 200 TONS OF WILTED GRASS SILAGE IN UPRIGHT SILOS BY ALTERNATIVE METHODS ON SOUTH-CENTRAL MICHIGAN DAIRY FARMS

ITEM	METHOD A	METHOD B	METHOD C	METHOD D
Machinery Ownership	Self-Owning	Self-Owning	Custom Hire	Sharing
Type of Material	Wilted	Direct-Cut	Wilted	Direct-Cut
Type of Silo	Upright	Bunker	Upright	Bunker
Tons Required	200	236	200	236
Additional Acres Above A	-	4.5	-	4.5
Capacity Tons Per Hour	8(1)	9(1)	10(1)	9(1)
Costs	Dollars	Dollars	Dollars	Dollars
1. Total Fixed Costs	237.73(2)	198.85(3)	260.00(4)	99.42(5)
2. Total Variable Costs	168.75	176.98	90.00	176.98
3. Mowing and Windrowing Costs	50.00	-	50.00	-
4. Total Harvesting Costs	456.48	375.83	400.00	276.40
5. Total Storage Costs	90.00	70.80	90.00	70.80
6. Total Harvesting and Storage Costs	546.48	446.63	490.00	347.20
7. Comparative Total Cost to Method A	-	- 99.85	-56.48	-199.28
8. Estimated Value of Additional Land Requirement	-	+135.00	-	+135.00
9. Net Costs (8 - 7)	-	+ 35.15	-56.48	- 64.28

(1) Crew: 3 Men, 2 Wagons, 3 Tractors.
(2) Initial Cost: P.T.O. Chopper $2500, Blower $500, Wagons $400 each, Silo (16'x40') $1800.
(3) Initial Cost: P.T.O. Chopper $2500, - - Wagons $400 each, Silo (20'x60'x8') $600.
(4) Custom Hire: $130 per hour, Farmer to provide 2 men, 2 tractors.
(5) Assumes Equipment of Method B Shared on 50-50 basis, both farms having similar systems, 200 tons grass, 100 tons corn and 80 acres baled hay.

Farm C

The case of a farmer with a herd of 50 dairy cows who wishes to feed 60 pounds grass silage per day for a 260 day period is considered in Table 14. Storage for the required 400 tons could be either in a 20' x 50' upright or a 30' x 80' horizontal. It is assumed that the dry hay will be baled and that the chopper is used only for the grass silage. It is assumed, as reported in Chapter 5, that no differences in feeding value or nutrient losses occurs between lacerated and chopped material. On the basis of the budgets, Method D is the most profitable with a reduction of $96.92 over A. However, farmers have experienced difficulty in feeding lacerated material from bunkers and, thus, feeding costs with this method may well be higher offsetting any other cost decreases. Self feed auger bunks for use with the upright may be justified, especially if the operator is able to place a high opportunity cost on his own or his workers' labor. A saving of 30 mins labor per day (worth $96 per year) in feeding may be possible with Method C. If the farmer wished to change his system from Method A to a newer, higher capacity system of 4 men, 3 wagons and 3 tractors with a new $3000 chopper and $800 PTO blower, output would increase to 15 tons per hour. Total costs for harvesting and storing the 400 tons would increase from $1112 to $1267, but "capacity" of the system would increase from 800 tons to 1200 tons. Thus, if a large increase in cow numbers and silage requirements was contemplated, the farmer would retain his existing equipment for harvesting up to 800 tons, but beyond that level would change to the newer system. The marginal cost for the old system was $.657 per ton and it is assumed that somewhere in the region of 800 tons this equals the average

TABLE 14

ESTIMATED TOTAL "COSTS" OF HARVESTING AND STORING THE EQUIVALENT OF 400 TONS OF WILTED GRASS SILAGE IN UPRIGHT SILOS BY ALTERNATIVE METHODS ON SOUTH-CENTRAL MICHIGAN DAIRY FARMS

ITEM	METHODS A	B	C	D
Machinery Ownership	Self-Owning	Self-Owning	Self-Owning	Self-Owning
Type of Material	Wilted	Direct-Cut	Direct-Cut	Lacerated (Rotary Chop)
Type of Silo	Upright	Upright	Bunker	Bunker
Tons Required	400	452	472	472
Additional Acreage Above A	-	6.5	9.0	9.0
Capacity Tons Per Hour	10(1)	12(1)	12(1)	12(1)
Costs	Dollars	Dollars	Dollars	Dollars
1. Total Fixed Costs	600.00(2)	600.00(2)	498.00(3)	338.00(4)
2. Total Variable Costs	272.00	254.20	265.48	265.48
3. Mowing and Windrowing Costs	100.00	-	-	-
4. Total Harvesting Cost	972.00	854.20	763.48	603.48
5. Storage Costs	140.00	158.20	141.60	141.60
6. Total Harvesting and Storage Costs	1112.00	1012.40	905.08	745.08
7. Comparative Total Cost to Method A	-	-99.60	-206.92	-366.92
8. Estimated Value of Additional Land Requirement	-	+195.00	+270.00	+270.00
9. Net Costs (8 - 7)	-	+ 95.40	+ 63.08	- 96.92

(1) Crew: 3 Men, 3 Wagons, 3 Tractors
(2) Initial Cost: P.T.O. Chopper $2500, Blower $600, Wagons $400 each, Silo (20'x50') $2800.
(3) Initial Cost: P.T.O. Chopper $2500, - - Wagons $400 each, Silo (30'x80'x8') $1200.
(4) Initial Cost: P.T.O. Chopper $1000, - - Wagons $400 each, Silo (30'x80'0 $1200.

total cost of the new system. In buying a new system, ATC = MC, as all factors are variable. The marginal cost for the new system, once the investment is fixed, would be $.533 per ton.

Farm D

What may become the typical dairy herd of the future - namely 80 cows - is considered in Table 15. It is assumed that 700 tons grass silage, 200 tons corn silage and 180 tons dry hay are produced. The latter is baled. Storage could be provided in either two 16' x 65' uprights or two 30' x 65' bunker silos. The team is 4 men, 4 tractors and 3 wagons. In Method A these latter are assumed to cost $500 each. However, in the other methods it is assumed that daily chopping of green forage takes place and that one wagon, used for this purpose, is a mechanical unloading type costing $1000. The use of the chopper for daily cutting reduces the fixed costs to be borne by the silage operation.

It is possible that some of the grass or corn silage would be replaced by oat silage. However, this would not affect unit costs of grass silage unless the oat silage was an additional supply. Similarly sudan grass may replace, or supplement, grass for daily chopping during July. In Method D it is assumed that the rotary flail type chopper would be used for the grass silage and daily chopping. On the basis of the budgets, lacerated material in a bunker would be the most economical, with a decrease of $75.11 over Method A. However, as mentioned above, difficulties in feeding lacerated material occur and, hence, Method A would be preferable -- especially since mechanical feed bunkers could be justified on herds of this size.

TABLE 15

ESTIMATED TOTAL "COSTS" OF HARVESTING AND STORING THE EQUIVALENT OF 700 TONS OF WILTED GRASS SILAGE IN UPRIGHT SILOS BY ALTERNATIVE METHODS ON SOUTH-CENTRAL MICHIGAN DAIRY FARMS.

ITEM	METHOD A	B	C	D
Machinery Ownership	Self-Owning	Self-Owning	Self-Owning	Self-Owning
Type of Material	Wilted	Direct-Cut	Direct-Cut	Lacerated Rotary Chop
Type of Silo	Upright	Upright	Bunker	Bunker
Tons Required	700	791	826	826
Additional Acreage Over A	-	11.375	15.75	15.75
Capacity Tons Per Hour	10(1)	10(1)	12(1)	12(1)
Cost	Dollars	Dollars	Dollars	Dollars
1. Total Fixed Costs	665.97(2)	625.51(3)	519.70(4)	292.92(5)
2. Total Variable Costs	630.00	711.90	619.47	619.47
3. Mowing and Windrowing Costs	175.00	-	-	-
4. Total Harvesting Costs	1470.97	1337.41	1139.17	912.39
5. Storing Costs	225.00	254.25	235.99	235.97
6. Total Harvesting and Storing Costs	1695.97	1591.66	1375.16	1148.36
7. Comparative Total Cost to Method A	-	-104.31	-320.81	-547.61
8. Estimated Value of Additional Land Requirements	-	+341.25	+472.50	+472.50
9. Net Costs (8 - 7)	-	+236.94	+151.69	- 75.11

(1) Crew: 4 Men, 3 Wagons, 4 Tractors.
(2) Initial Cost: P.T.O. Chopper $3000, Blower $800, 3 Wagons $500 each Silos-2-(10'x65') $4500.
(3) Initial Cost: Chopper $3000, Blower $800, Wagons two at $500 one at $1000, Silos-2-(30'x65'x8') $2000.
(4) Assumes self unloading wagon used to haul 8 tons chopped forage daily for 100 days
Initial Costs: PTO. Chopper $3000, Two Wagons $500 each, One at $1000.
(5) Initial Costs: PTO. Chopper $1000, Two Wagons $500 each, One at $1000.

Farm E

The large scale operator of the future is considered in Table 16. Two hundred and fifty cows would be housed in a loose housing set-up with dry lot feeding. Two thousand tons of grass silage would be made in addition to 500 tons of baled dry hay and 1000 tons corn silage. In Method A the chopper would be a high capacity, motor mounted model, capable of dealing with 4 windrows at a time. Storage would be provided by 4 upright silos 20' x 60' with mechanical self feed bunks. These would be used for all the year round feeding. The silo would be filled with first cutting grass clover mixtures for summer feeding and then refilled with second cutting and corn for the winter. They would be grouped together and filling would take place by means of a collecting pit into which the trucks -- preferred to wagons because of the distance involved -- would dump the chopped material. This would then be fed through a PTO type blower into a system of piping, enabling any of the four silos to be filled. Estimated costs for concrete silos and pit would be $14,000. (If steel glass-lined type silos were used, investment costs would be considerably higher.) In view of the high investment costs and the possible high interest charges a rate of 10 percent on initial costs is assumed for both upright and horizontal silos. Five men, two tractors and three dump trucks are assumed to be needed. A caterpillar type tractor would be preferable for packing in the horizontals.

In Method D, the bunkers (two 40' x 150' x 8') would be partly fed out during the summer by means of front end loaders into feed bunks. Self feeding would not be practicable with herds of this size.

TABLE 16

ESTIMATED TOTAL "COSTS" OF HARVESTING AND STORING THE EQUIVALENT OF 2000 TONS OF WILTED GRASS SILAGE IN UPRIGHT SILOS BY ALTERNATIVE METHODS ON SOUTH-CENTRAL MICHIGAN DAIRY FARMS.

ITEM	METHOD A	METHOD B	METHOD C	METHOD D
Machinery Ownership	Self-Owning	Self-Owning	Self-Owning	Self-Owning
Type of Material	Wilted	Direct-Cut	Direct-Cut	Lacerated Rotary Chop
Type of Silo	Upright	Upright	Bunker	Bunker
Tons Required	2000	2260	2360	2360
Additional Acres Above A	-	35.0	45.0	45.0
Capacity Tons Per Hour	20(1)	20(1)	20(1)	20(1)
Costs	Dollars	Dollars	Dollars	Dollars
1. Total Fixed Costs	815.76(2)	815.76(2)	726.00(3)	447.20(4)
2. Total Variable Cost	875.00	988.75	1032.50	1032.50
3. Mowing and Windrowing Costs	500.00	-	-	-
4. Total Harvesting Cost	2190.76	1804.51	1758.50	1479.70
5. Storage Costs	924.00	1044.12	708.00	708.00
6. Total Harvesting and Storage Costs	3114.76	2848.63	2466.50	2187.70
7. Comparative Total Costs to Method A	-	-266.13	-648.26	-927.06
8. Estimated Value of Additional Land Requirement	-	+1050.00	+1350.00	+1350.00
9. Net Costs (8 - 7)	-	+783.87	+701.74	+422.94

(1) Crew: 5 Men, 2 Tractors, 3 Trucks

(2) Initial Costs: Motor Mounted Chopper $4000, Blower $800, 3 Trucks $2000 Each, (1/4 to silage); 4-20'x60' Uprights $3000 each; Unloading Pit $2000.

(3) Initial Costs: Chopper $4000, 3 Trucks $2000 each, Bunker Silo Two-(40'x150'x8') $6000.

(4) Initial Costs: Rotary Chopper $1000, 3 Trucks $2000 Each, Bunker Silo Two-(40'x150'x8') $6000.

In Methods B and C, an 8 foot direct cut, motor mounted, chopper is used. This is also utilized for daily chopping of green forage, which occurs with both methods. Possibly a self unloading wagon instead of a truck would be used to feed the chopped forage into the bunks.

On the basis of the budgets, wilted material and upright silos are considered the most appropriate system for herds of this size. Since the mechanical feed bunks will be in continual use, unit feeding costs should be at a level comparable with the front end loader and bunker silos method.

The system of upright silos lends itself more readily to increases in herd size, since the space requirements for additional uprights are not so great as for horizontal silos.

Discussion and Recommendations

The partial budgets presented above emphasize that harvesting and storage costs are not the only considerations involved in silage making. Many failures and disappointing results would seem to arise from the fact that some farmers do not appreciate the elementary facts involved, - i.e. that nutrient content can never be higher than that of the material as cut and ensiled, and that storage and harvesting methods can affect considerably the feeding value of the end product.

The following recommendations are made from a consideration of (1) the survey results (2) the synthetic cost data and (3) the partial budgets. In view of the many subjective evaluations involved in harvesting, storing and feeding silage, many of these recommendations may not be generally acceptable. However, they are considered to be appropriate for farms similar to those observed on the survey.

15 Cow Herd

Herds of this size may not remain in milk production for very much longer. In the interim, until they either increase to a more economical size or cease milk production, the use of custom hiring is recommended. Trench silos offer the cheapest storage facilities and direct cut material would be preferable for use with these. Wilted material would be preferable if existing uprights are used. These latter, however, are often in need of repair on these small farms. The difficulties which arise with refilling uprights when using custom operators have been discussed previously.

35 Cow Herd

These herds will also probably increase in size but, in the meantime, forage harvesting can best be conducted by a system of sharing equipment with a neighbor. Obviously the greater the number that share the equipment the lower unit costs will be, but in view of the limited period available for high quality silage production, only two partners are considered feasible. With the tonnages normally required, both should be able to harvest their silage in the available period of 10 days in early June. Similarly with the corn silage and dry hay.

Bunkers are considered more suitable if self feeding is to be practiced, but where uprights are already in existance these could be used since the difference in storage costs could easily be offset by the greater losses and wastages which occurs with self feed bunkers.

Storage facilities are often limited, especially with upright silos. In such cases wilting enables a greater quantity of dry matter to be stored, with given storage facilities.

50 Cow Herd

With these herds sharing of equipment could be justified. However, where daily chopping occurs the owning of direct cut equipment would provide a more economical method.

Bunkers may still provide the least cost storage if self feeding is practiced, but due to decreased losses and wastage, uprights would be preferable, -- especially where cattle are housed in stanchion barns on a "rationing system" of feeding.

Custom operating for neighbors could be undertaken, thereby reducing unit costs for machinery use on the home farm. However, these latter reductions may be counterbalanced by possible quality losses if harvesting of the home farm crop is neglected in favor of the neighbors' operations.

80 and 100 Cow Herds

Although the 100 cow herd may be considered as two 50 cow units, its increased size makes the use of uprights and mechanical self feed bunks more feasible. Owning of equipment is assumed. In some cases there may be justification to use windrowing for the silage and to have a direct cut rotary models for daily chopping. Wilted material and the use of upright silos with mechanical self feed bunks would be considered the most appropriate system for both herd sizes.

250 Cow Herd

The system which seems most appropriate for the large herds is the one discussed above in which a motor mounted pick up machine is used with a group of upright silos which are filled by means of a collecting pit, a blower and adjustable piping. The silos are emptied automatically into self feed bunks which are used for all the year round feeding. All equipment would be owned by the farmer.

Applications To Beef Production

Although the analysis has been more concerned with grass silage as a feed for milk production, many of the findings and recommendations could apply equally as well to the beef producer. He is also faced with the problem of obtaining a high quality feed at an economic level of cost for harvesting, storing, and feeding. Thus, the systems advocated for the varying sized dairy herds have applications to beef herds. This is particularly the case with the larger herds, and many systems with large upright silos and mechanical self feeders are already in operation.

Further Needed Research

The above brief discussion may tend to leave the reader with the impression that the recommendations as to the most economical way to harvest and store grass silage are inconclusive. If this is so, then they would seem to be in line with many of the inconclusive studies which have been conducted by the physical scientists. Until some method of evaluating the many subjective, and even the objective, factors involved in the process is developed the various economic analyses, and recommendations based on them, will have only limited application to farm conditions. As yet, there would seem to be no "best" and "cheapest" way to make grass silage. The importance of observing the basic principles involved in the process has been stressed, but even when this is done results are often disappointing. Conversely good results are often achieved when many of the established rules are broken.

In many instances farmers in the survey reported that they could not account for differing results obtained when similar methods were used over several seasons. This has led to a decline in the popularity of grass silage in some instances, and accounts, to some extent, for the reason why it is neglected by many who continue to rely on corn silage and dry hay, as the basis of their roughage feeding.

Milk and beef production in the future will have to be undertaken on a low cost basis. Grass silage is a potential low cost source of high quality feed. It is desirable, therefore, that more interdisciplinary research work involving cooperation and joint endeavor, from all the agricultural sciences be conducted into the many economic, and technical factors involved in grass silage conservation. In particular, further technical work is needed on the feed losses involved in storing and feeding by alternative methods, as well as more data on nutritive losses with direct cut versus wilted, and lacerated versus chopped material. Agricultural economists should undertake exact measurement studies into the labor and machinery requirements <u>at all</u>

<u>stages</u> of the harvesting and storing operations. In brief, data are required to enable the true marginal cost of harvesting, storing, and feeding varying quantities of grass silage by alternative systems, to be derived. The optimum point on the relevant production function could then be determined for each system and more definite recommendations made which should enable the farmer to maximise profit.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Grass silage is suggested as a potential high feeding value, low cost, forage for dairy and beef cows. Machinery is available to enable large quantities of it to be harvested and stored in the limited period available for high quality production in early June.

2. Data on grass silage harvesting and storing operations were obtained by means of observations on a "time and motion" study basis on a roughly stratified sample of 71 South-Central Michigan dairy farms using specified forage harvesters and blowers in specified combinations of machinery, labor and power.

   Performance rates varied with size and type of machine, size of crew and storing methods. Overall average performance rates for harvesting and storing green material from field to storage were 9.1 tons per hour with an average of 9.6 tons per hour for direct cut and 8.6 tons per hour for wilted material. The typical outfit consisted of 3 men, 2 wagons and 3 tractors. Average potential capacity for forage harvesters of all sizes and makes was 12.0 tons per hour for direct cut and 11.0 tons for wilted material. Average potential blower capacity for all types was 18.7 tons per hour for direct cut and 14.6 tons per hour for wilted material with rates for PTO models of 27.1 and 23.4 tons per hour respectively. In all cases the potential performance rates for forage harvesters and blowers, given the associated equipment, on the operations observed, were below the manufacturer's claims for the various machines. Initial costs of equipment varied considerably as much had either been purchased second hand or by trade-ins on existing equipment. Case studies of four farms, representative of certain distinctive features of the varying harvesting system, were presented.

3. The importance of the various cost concepts and the difficulties involved in pricing fixed assets are discussed, together with a consideration of the economic factors involved in the varying machinery ownership patterns.

4. The work of the physical scientists on the losses of nutrients occurring with different harvesting and storing methods is reviewed. Reference is made to the use of additives and plastic covers as means of controlling nutritive losses. Many of the findings conflict and are inconclusive. In general, harvesting and storing losses are greater with direct cut material, horizontal silos, and feeding wastage greater with self feeding systems. Little difference was observed between the use of various additives. Care is needed with plastic covers to obtain good results.

5. The mechanical features of the various items of machinery; - forage harvesters, blowers, and wagons are discussed and reference made to the enquiries of the agricultural engineers into their efficiency. Blowers in general are considered relatively inefficient, but higher performance rates are attainable with the PTO models. Power requirements to overcome the friction between the material and machine housing are high with conventional model forage harvesters. These requirements are reduced in some rotary flail type models. Since rate of unloading into upright

silos is controlled by blower capacity, little differences occur between the various methods of unloading wagons. Hydraulically operated false end gate wagons are most effective. High use is needed to justify investment in the relatively expensive mechanically unloading wagons.

6. The data from the survey and the review of work by the physical scientists are used to develop synthetic cost data and partial budgets for harvesting and storing varying quantities of grass silage for different herd sizes, under varying assumptions. The need for high use of machinery to lower unit costs is demonstrated by the development of synthetic cost curves. In their construction, the assumption made in this, and similar studies, that marginal costs are constant for all levels of output prevents "true" economic optima, and machine capacity (where MVP = MFC), from being determined. Instead "guesstimates" of this point -- referred to as "capacity limits" -- are made for each system, beyond which "it is thought to be uneconomical to operate." The partial budgets demonstrate that the value of the additional land required to replace any additional dry matter losses, between different systems, may offset any reductions in harvesting and storing costs. Feeding costs have also to be considered.

7. Recommendations as to the most effective way to harvest and store grass silage for varying sized herds are given. In general, these include the use of custom hiring services and the use of trench silos for small herds, sharing of equipment and self feed bunker silos for medium sized herds and ownership of motor mounted forage

harvesters, with large upright silos having mechanical feed bunks for the larger herds.

8. The need for more interdisciplinary research into the various economic, and technical aspects of grass silage conservation under varying harvesting storing and feeding systems is stressed. In particular, agricultural economists should undertake exact measurement studies into the labor and machinery requirements at all stages of the operation, and the technicians should provide further data on nutrient losses and feed wastages with the various systems. This is needed in order that the "true" marginal cost of the alternative harvesting and storing systems can be derived and, hence, the optimum outputs to maximize profits determined. At present there cannot be said to be any real "best" system. This study has (it is hoped) provided some of the basic data which will be needed to solve this larger problem, and pointed to the need for further data which will lend itself to marginal analyses.

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APPENDIX TABLE 1

PERFORMANCE RATES FOR HARVESTING AND STORING GRASS SILAGE USING FORAGE HARVESTERS, AS RECORDED IN PREVIOUS SURVEYS

AUTHOR	LOCATION OF SURVEY	YEAR OF STUDY	AVERAGE SILO CREW		PERFORMANCE RATES: CHOPPING	HAULING	UNLOADING (BLOWING)	COMPLETE OPERATION
					Tons per Hour			
Duffee 1/	Wisconsin	1942	?		6.8	-	12.5	-
Day 2/	Missouri	1948 to 1950	2 Men 2 Wagons	(Eng)	7.4	Wagon 6.4	6.7	-
				(PTO)	7.3	Truck 7.0		
Turner 3/	Scotland	1956	3 Men 2 Wagons "Silorator" Lacerated silage		8.0	-	-	3.3
Marx & Birkhead 4/	Pennsylvania	1947	4 Men 2 Wagons		12.[illegible]	-	1[illegible].	Range [illegible] to 1[illegible]. Average 10.[illegible]
Kline & McPheron 5/	North Carolina	1954	5 Men 3 Wagons		-	P.T.O. Chopper		2.6
			3 Men 2 Wagons			P.T.O. Chopper		1.[illegible]
			5 Men 2 Wagons			Motor Mounted Chopper		4.[illegible]
			5 Men 3 Wagons			Motor Mounted Chopper		7.[illegible]
			4 Men 3 Wagons			Motor Mounted Chopper		4.[illegible]
			3 Men 3 Wagons			Motor Mounted Chopper		3.1
Vary 6/	Michigan	1949 to 1953	3 Men 2 Wagons		-	Average Rate (Small Chopper		3.3
						Average Rate (Large Chopper		[illegible]
						Efficient Rate (Small Chopper		3.[illegible]
						Efficient Rate (Large Chopper		[illegible].4

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6/ [illegible] Vary, op. cit.

APPENDIX TABLE 2

LOSSES OF NUTRIENTS IN THE ENSILAGE PROCESS BASED ON INFORMATION IN THE LITERATURE UP TO 1939[1/]

FORAGE	DRY MATTER		STARCH EQUIVALENT		DIGEST. CRUDE PROTEIN		DIGEST. TRUE PROTEIN	
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
<u>Grassland Herbage</u>								
No Additives	78	21.1	21	36.0	36	29.5	34	70.8
Sugar Added	20	13.7	15	22.7	15	7.3	14	58.2
Acids Added	40	14.5	25	25.6	25	8.0	25	47.8
<u>Legume and Grass Legume Mixtures</u>								
No Additives	49	16.8	8	35.8	4	23.6	7	57.9
Sugar Added	8	9.1	5	23.2	4	19.0	1	57.0
Acids Added	32	9.9	7	17.[illegible]	6	14.8	5	25.2

1/ Watson, S.J., <u>Silage</u>, Crosby Lockwood London, 1939.

APPENDIX TABLE 3

LOSSES OF TOTAL DIGESTIBLE NUTRIENTS FROM FORAGE DURING HARVESTING AND STORAGE AND PER CENT OF TDN PRESERVED FOR FEEDING[1]

METHOD OF HARVEST AND STORAGE	FIELD LOSS	STORAGE LOSS	PRESERVED FOR FEEDING
	Per Cent	Per Cent	Per Cent
Field Cured Hay :			
Rained on	38.3	3.8	57.9
Not rained on	21.6	3.9	74.5
Barn Dried Hay :			
No heat	16.8	7.2	76.0
Heat	18.	2.5	79.5
Wilted Silage :	6.6	10.9	82.5
Dehydrated Hay :	6.1	7.3	86.6

1/ Derived from tables by Shepherd et. al. Experiments in Harvesting and Preserving Alfalfa for Dairy Cattle Feed. USDA. Technical Bulletin 1079, 1954.

APPENDIX TABLE 4

COMPOSITION AND DIGESTIBILITY OF NITROGEN FRACTIONS OF GRASS SILAGE BY METHOD OF STORAGE[1]

	STACK		TOWER		PIT OR TRENCH	
	Per Cent of Dry Matter	Digestibility Per Cent	Per Cent of Dry Matter	Digestibility Per Cent	Per Cent of Dry Matter	Digestibility Per Cent
Crude Protein	15.9	40	16.1	68	17.9	64
True Protein	10.4	23	9.4	47	9.1	36

1/ Watson, S.J. Grassland and Grassland Products. Arnold London, 1951.

APPENDIX TABLE 5

PERFORMANCE RATES FOR HARVESTING AND STORING FORAGE CROPS, OTHER THAN GRASSES LEGUMES, FOR SILAGE ON SOUTHERN CENTRAL MICHIGAN DAIRY FARMS, 1957

Crop	Item: Chopper Make Size and Model	Item: Silo Type and Size	Item: Size of Crew (M = Men, W = Wagon, T = Tractor)	Operation: Chop Tons Per Hour	Operation: Unload Tons Per Hour	Complete Operation: Tons Per Hour	Complete Operation: Tons Per Man Hour	Complete Operation: Man Hours Per Ton
Oats								
Farm 162	Allis-Chalmers 4' Direct P.T.O.	Upright 16' x 50'	2M 2W 3T	6.0	6.0 1/	4.0	2.0	.500
Farm 1[illegible]	Papec 4' Direct P.T.O.	Upright 20' x 50'	4M 3W 3T	9.0	12.0 2/	8.5	2.1	.47[illegible]
Farm 87	Fox 6' Direct P.T.O.	Bunker 2[illegible]' x 9[illegible]'	3M 2W 2T + 1 Jeep	1[illegible].0	40.0 3/	8.8	[illegible].9	.3[illegible]0
Corn								
Farm 87	Fox	Bunker 24' x 90'	3M 2W 2T + 1 Jeep	1[illegible].0	40.0 3/	8.4	2.8	.3[illegible]6
Farm 69	Fox	Upright 10' x 40'	2M 2W 4T 4/	8.0	13.0	6.7	3.3	.2[illegible]
Sorghum								
Farm 151	New Holland 800 P.T.O.	Upright 20' x 50'	4M [illegible] 4T	15.5	20.0	12.0 5/	3.0	.33[illegible]
Sudan Grass								
Farm 53	Allis-Chalmers 4' Direct P.T.O.	Upright 14' x 45'	2M 2W 3T	?	?	9.0 6/	4.5	.[illegible]

1/ Continual breakdowns with wagon unloading mechanism.
2/ Two inexperienced men operating blower (Tools). Frequent "plugging".
3/ False end gate wagons operated hydraulically from tractor for oats and from jeep for corn. [illegible] by jeep, lazy driver.
4/ False end gate wagons operated by chain attached to additional tractor.
5/ Three makes of 4 plow tractors used as power unit for New Holland 800 chopper with little effect on performance rates. Frequent delays due to breakdown with [illegible] ton Dolly - [illegible] that time.
6/ Based on farmer's [illegible].