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Economic Comparisons of Hay Harvesting, Storing and Feeding Systems for Beef Cow Herds

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by

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Introduction

Beef cow numbers have nearly doubled in Minnesota during the past ten years. On January 1, 1968, there were 518,000 beef cows in Minnesota; in 1958 the number of beef cows in the state was only 270,000.

The largest item of expense for the cow-calf enterprise in Minnesota is the cost of winter feed. This may account for nearly one-half of the total costs of feeder calf production on a per cow basis. Approximately 2.5 tons of hay are required to winter a beef cow and her replacement at recommended levels of nutrition. Large full-time beef cow herds thus require substantial volumes of forage to be harvested for winter feed. The expenses and problems of harvesting and storing enough winter feed for a large size beef cow herd, during a relatively short growing season, are probably the greatest obstacles faced by Minnesota beef cow-calf operators, particularly in the northern part of the state.

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This report presents an economic analysis and comparison of the costs and resource requirements for six different systems of harvesting, storing, and feeding hay suitable for beef cow enterprises. The costs of the systems are compared at various volumes of hay handled to determine the least cost systems for the various levels of production. The information should provide some guides for the selection of hay harvesting and handling systems for beef cow enterprises in particular and with modification for other livestock enterprises. Systems for harvesting and handling other roughages, such as corn silage, were not studied.

I. Alternative Forage Harvesting and Handling Systems

Hay for beef cows is normally handled in one of, at least, three basic forms. These are long loose hay, baled hay, and chopped hay which may be either dry hay or of higher moisture content as haylage or silage.

The form in which hay is harvested determines the methods by which it may be handled, stored, and fed. Therefore, it is necessary to analyze the complete system of harvesting, storing, and feeding for each alternative when selecting a forage handling system for the beef cow herd or other forage consuming livestock.

Six systems of handling hay for the beef cow herd are compared in detail in this report. Two systems of handling hay in each of the three forms -- baled, loose, and haylage -- are compared. The systems analyzed are described below.

System No. 1 - Conventionally Baled Hay

The first system of hay harvesting, storing, and feeding analyzed is conventionally baled hay. A conventional baler drops the bales on the ground, a mechanical bale loader elevates them to a wagon where they are stacked by hand. The bales are then stacked by hand in an open hay shed or barn using an elevator where necessary. In the winter, the bales are removed from storage by hand and hauled on a wagon to the field where they are fed on the ground. This system of hay harvesting and handling is referred to as System No. 1 in this publication.

System No. 2 - Mechanized Bale Handling

This system of handling baled hay is somewhat more mechanized than System No. 1. It includes a mechanical bale accumulator towed behind the baler which leaves bunches of approximately eight bales on the ground. These bunches of bales are picked up and loaded onto a wagon with a special tractor mounted fork, which either squeezes the bales together or hooks them with small hooks. This fork may be used to unload the wagon and stack the bales inside an open hay shed. Also, it can be used to remove the hay from storage for feeding. Hay may be carried with the fork or a wagon may be used to haul it to the field for feeding.

System No. 3 - Loose Hay Fed Mechanically

With System No. 3 a tractor mounted sweep and stacker and a portable stacking frame are used to make stacks of loose hay weighing approximately

four to ten tons each. A mechanical stack mover is used to haul these stacks from the hay field to the feeding area anytime after harvest. The hay is distributed for feeding with a grapple fork attachment on the loader-stacker that was used for harvesting.

System No. 4 - Loose Hay, Self Fed

This system is identical to System No. 3 except the hay is self-fed from the stacks. An electric wire around the stack or across the face of several side by side stacks which are fenced on the other three sides controls the rate of feeding and elimates waste and trampling of the stacks.

System No. 5 - Haylage Stored in a Bunker Silo

Wilted, partially dry hay (50-60% moisture) is chopped and stored in a horizontal bunker type silo. The haylage may be removed from the silo with a tractor mounted scoop and dumped directly into portable feed bunks or put into a self-unloading wagon for distribution into feed bunks in the feeding area.

System No. 6 - Haylage Stored in a Cement Stave Silo

The last system analyzed is haylage stored in upright cement stave silos. The haylage is removed from the silo with a mechanical silo unloader and placed in a self-unloading wagon for distribution into feed bunks.

These six systems of forage harvesting and handling will be analyzed in some detail in the following sections of the report. They represent only a few

of the methods and combinations of methods of harvesting, storing, and feeding possible. For instance, hay could also be harvested with a baler with a bale thrower attached; haylage could be fed by hand or with an auger feeder, etc. However, the six systems described represent most of the more common methods of harvesting and handling hay for beef cow herds and, thus, should reasonably represent the alternatives. The next section of this report compares the estimated investment and annual costs for each of these six systems.

II. Estimated Investments and Annual Costs for Various Systems

To select the most economical system of hay harvesting and handling it is necessary to estimate and compare the investments and the expected annual ownership and operating costs required by each system. Such estimates and comparisons for the six representative systems described in the previous section were made using the results of various available research reports and bulletins, as well as the observations of approximately two dozen beef cow-calf operators interviewed in northern Minnesota.

The investments required and the annual costs of harvesting and handling hay on a per ton basis vary as the volume of hay harvested and fed varies. The cost differences between the various systems also change somewhat as the volume of hay handled changes. However, for ease of comparison the costs and investments for the six systems are compared in this section at only one volume (250 tons fed). The changes in costs which occur when the volume of hay handled changes are discussed in a later section of this report.

The data presented in the tables are estimates of the costs per ton of hay equivalent (85% dry matter hay) fed and the total investments involved in harvesting, storing, and feeding the 250 tons of hay per year. (More than 250 tons of hay must be harvested to have 250 tons to feed because of storage losses.) These costs are indicative of those incurred for harvesting, storing, and feeding hay for a 100 cow beef herd with a normal number of replacements when fairly typical sets of medium capacity harvesting and handling equipment are utilized. The cost estimates and other data presented in this report are indicative of those for a legume-grass hay mixture yielding approximately three tons per acre.

Harvest

Estimated investments in harvesting machinery range from $7,925 for loose hay -- Systems 3 and 4 -- to $12,550 for haylage -- Systems 5 and 6 -- (see table 1). These totals include tractors, wagons, loaders, and elevators which all have other uses. Therefore, they should not be charged completely against hay harvesting and handling for the beef cow herd if they are used a significant portion of the time for other enterprises. In fact, if this equipment would be on the farm whether or not the hay enterprise was there, the fixed costs and investments for these items could be ignored when selecting a hay harvesting and handling system. For comparison we assumed that these multi-use items are used almost entirely for hay harvesting and handling, which may be the situation on many full-time beef cow farms. Therefore, the full invest-

ment and annual ownership or fixed costs for these items is included in the totals for the hay harvesting and handling systems. The investment costs listed in table 1 are for new machinery except tractor investment costs which are for ten-year-old tractors. For a comparison of total investments in harvesting and handling machinery and storage structures for the various systems see appendix table IV.

Since the investment costs for machinery and power vary among systems, the annual fixed costs of owning the power and machinery also varies among systems. Fixed costs are those incurred by ownership of machinery regardless of how much the machinery is used. These costs include interest on the average investment in machinery, insurance, shelter, property taxes where appropriate, and depreciation, which in some cases may vary with amount of use. Annual use may sometimes reduce machine life to less than normal. Table 2 presents the total annual fixed costs of owning the sets of machinery listed in table 1.

The depreciation costs in table 2 are based on a 15-year life of the machinery assuming that the machinery will be either obsolete or worn out at that time. However, certain items of machinery will wear out sooner if more than 250 tons of hay equivalent are harvested and handled per year and in these instances will be depreciated out over a shorter life. Likewise, it is probable that a shorter depreciation period or faster rate of depreciation may be used for income tax and financial accounting purposes.

Table 1. Estimated investments in harvesting machinery for various systems

Item	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay	System No. 4- loose hay	System No. 5- haylage- bunker silo	System No. 6- haylage- upright silo
Blower	---	---	---	---	---	$ 1,000
Mower (7 foot)	$ 550	$ 550	$ 550	$ 550	$ 550	550
Rake	600	600	600	600	600	600
Bale loader	400	---	---	---	---	---
Wagon (2)	800	800	---	---	---	---
Elevator	600	---	---	---	---	---
Baler	2,400	2,400	---	---	---	---
Accumulator	---	1,200	---	---	---	---
Fork-bale pickup	---	500	---	---	---	---
Loader	---	1,000	---	---	1,000	---
Buck-stacker	---	---	1,600	1,600	---	---
Stack frame	---	---	400	400	---	---
Stack mover	---	---	2,000	2,000	---	---
Field chopper	---	---	---	---	2,500	2,500
Self-unloading wagon (2)	---	---	---	---	3,200	3,200
Tractor 30 hp [1/]	1,100	1,100	1,100	1,100	(2) 2,200	(2) 2,200
Tractor 40 hp	---	---	1,675	1,675	---	---
Tractor 45 hp	2,200	2,200	---	---	---	---
Tractor 55 hp	---	---	---	---	2,500	2,500
Total investment	$8,650	$10,350	$7,925	$7,925	$12,550	$12,550

1/ Used ten-year-old tractors.

Table 2. Annual fixed costs for harvesting machinery [1/]

	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay	System No. 4- loose hay	System No. 5- haylage- bunker silo	System No. 6- haylage- upright silo
Total fixed costs	$942.38	$1,129.38	$862.38	$862.38	$1,371.38	$1,371.38

[1] Annual fixed costs = depreciation + interest + shelter and insurance.

Depreciation = (new cost - 10% salvage value) ÷ 15 years or by years to wear out if less than 15.

Interest = 4% of new investment (or 8% of average investment)

Shelter and insurance = 1% of original cost

Any property taxes paid on machinery should be included in annual ownership costs. However, no property taxes are paid on farm machinery under current Minnesota law.

The total costs of harvesting hay include both the fixed costs of owning the machinery and operating costs which vary with the volume of hay handled. These variable operating costs for each system include such items as labor, repairs, gas and oil, twine, etc. (table 3).

The variable operating costs in table 3 include labor costs charged at $1.50 per hour. The labor utilized for harvesting may be wholly or partially the operator and his family, and may be worth substantially more or less than $1.50 per hour, depending upon the value of alternative uses for the labor. The effects of higher and lower costs of labor are discussed in a later section of this report.

Table 3. Variable operating costs of harvesting

Item	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay	System No. 4- loose hay	System No. 5- haylage- bunker silo	System No. 6- haylage- upright silo
Costs per ton harvested:						
Repairs [1]	$ .69	$ .87	$ .74	$ .74	$ .73	$ .73
Gas, oil, lubrication [2]	.38	.37	.36	.36	.39	.39
Twine [3]	.60	.60	---	---	---	---
Labor @ $1.50/hr.	2.54	1.48	1.64	1.64	1.29	1.17
Total variable cost per ton harvested	$4.21	$3.32	$2.74	$2.74	$2.41	$2.29
Total variable cost per ton fed [4]	$4.38	$3.45	$3.13	$3.13	$2.77	$2.48

1/ Repair costs per ton harvested were calculated as follows:

Repair cost/T harvested for mowers = [(new cost of machine x 120%) ÷ 2,250 hours life of machine] x hours use per year ÷ tons harvested per year.

Plus repair cost/T harvested for tractors = [65% x (new cost of machine x 120%) ÷ 6,000 hours life remaining] x hours use for hay harvest/year ÷ tons harvested per year.

Plus repair cost/T harvested for others = [new cost of machine x 80% ÷ 2,250 hours life] x hours use per year ÷ tons harvested per year.

TOTAL repair costs per ton harvested

Reference: Costs of Owning and Operating Farm Machinery, by Wendell Bowers, Agricultural Engineering 867, University of Illinois, January 1966.

2/ Gas, oil, lube costs per T harvested = (cost of gas, oil, lube, per hrs. of tractor use) x tractor hrs or (gallons gas used/hr. x $.18/gal.) x (1+15%) x tractor hrs.

gas used/hr. estimated at:

1.7 gal. for 30 hp. tractor
2.2 gal. for 40 hp. tractor
2.5 gal. for 45 hp. tractor
3.0 gal. for 55 hp. tractor

3/ Twine cost = 1.5¢/bale x 40 bales/Ton

4/ Variable operating costs per ton fed = variable operating costs per ton harvested x tons harvested per ton fed

Tons harvested/ton fed = $\left(\frac{1}{1 - \%\text{ storage loss}}\right)$

Total harvesting costs per ton of hay equivalent fed include annual fixed costs and the variable operating costs (see table 4). For an accurate dollar and cents comparison, the data in table 4 account for the losses of dry matter due to weathering and mechanical handling associated with each system. Note that these harvesting losses may vary considerably and may be substantially greater under unfavorable conditions particularly for the baled or the loose hay systems.

The baled hay systems, Nos. 1 and 2, had the highest harvesting costs after deductions for differences in harvest losses. The costs for the loose hay and the haylage systems were nearly the same. These differences in cost are based on a total 250 tons of hay equivalent fed per year; as the volume of hay harvested and fed changes these differences will be altered.

Storage

Investments for storage structures vary considerably; hence the cost of storage varies with each system. Storage costs include the annual fixed costs of ownership, maintenance costs for the structures and the value of storage losses (see table 5).

Table 4. Total harvesting costs per ton of hay equivalent fed for the alternative systems, 250 tons fed

Item	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay	System No. 4- loose hay	System No. 5- haylage- bunker silo	System No. 6- haylage- upright silo
Fixed costs [1]	$3.81	$4.52	$3.45	$3.45	$5.49	$5.49
Variable costs	4.38	3.45	3.13	3.13	2.77	2.48
Total harvesting costs	$8.19	$7.97	$6.58	$6.58	$8.26	$7.97
% harvest losses [2]	23	23	20	20	10	10
Value of excess harvest losses [3]	1.90	1.90	1.65	1.65	.07	---
Total harvesting costs including excess harvesting losses	10.09	9.87	8.23	8.23	8.33	7.97

[1] Ownership costs per ton fed = total ownership cost ÷ tons fed or (250 in this case).

[2] Estimated losses of dry matter due to handling and weather exposure expressed as a percent of total potential yield in the field. Varies with maturity of hay at cutting, adjustment of harvest machines, and weather conditions. Estimates are for average to good conditions and may be considerably higher under unfavorable conditions. References:

-Hoglund, C. R., An Appraisal of Comparative Losses in Alfalfa and Corn Silage Crops When Harvested at Different Moisture Levels and Stored in Gas-Tight and Conventional Tower Silos: An Appraisal of Research Results, Agricultural Economics 947, Michigan State University, March 20, 1964.

-Rieck, R. E., Forage Grades, Characteristics, Feeding Value and Economic Value, Applied Research Needs Subcommittee Report, North Central Farm Management Extension Committee, March 1968.

3/ Harvest losses are incurred in harvesting on a per ton fed basis. Excess harvest losses are the losses per ton fed above those for the system with the least amount of loss, which was System No. 6. The excess harvest losses are valued at $10 per ton ($18 per ton value of harvested hay minus an $8 per ton harvesting cost).

$$\text{Value of excess harvest losses/Ton fed} = \left[\begin{array}{l}\text{Value of total harvest}\\ \text{losses per ton fed}\end{array}\right] - \left[\begin{array}{l}\text{Value of total harvest losses}\\ \text{per ton fed for System No. 6}\end{array}\right]$$

$$\text{Value of total harvest losses/Ton fed} = \left[\left(\frac{1}{1.0\text{-}\% \text{ harvest loss}} - 1\right) \div \left(1\text{-}\% \begin{array}{l}\text{storage}\\ \text{loss}\end{array}\right)\right] \times \$10$$

$$\text{or} \quad \left(\begin{array}{l}\text{tons lost per}\\ \text{ton harvested}\end{array} \times \begin{array}{l}\text{Tons harvested}\\ \text{per tons fed}\end{array}\right) \times \$10$$

Table 5 illustrates that the storage costs for loose hay and baled hay are considerably lower than the storage costs for haylage. However, storage losses may vary considerably from these estimates, especially for loose stacked hay and haylage because of the care with which stacks are made or silos are filled, the amount of rainfall on the stacks, etc. Areas with more than approximately 24 inches of rainfall annually may have considerably larger storage losses in loose hay than the estimates used here. Baled hay stacked outside may have considerable variation in losses, also.

Table 5. Storage investments, losses, and costs, 250 tons fed

Item	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay	System No. 4- loose hay	System No. 5- haylage- bunker silo	System No. 6- haylage- upright silo
Type of storage structure	open hay shed	open hay shed	none	none	bunker silo	cement stave silo
Investment in storage structure	$3,255.00	$3,255.00	---	---	$4,022.50	$6,200.00
Investment in storage structure/ton fed[1/]	13.02	13.02	---	---	16.09	24.80
Annual cost for storage structure/ton fed[2/]	1.43	1.43	---	---	2.04	2.73
% storage losses[3/]	4	4	12.5	12.5	13	8
Value of storage losses per ton fed[4/]	.40	.40	1.43	1.43	1.49	.87
Total storage cost per ton of hay equiv. fed	1.83	1.83	1.43	1.43	3.53	3.60

1/ Investment per ton fed when 250 tons of hay equivalent are fed per year. Investment data based on Van Arsdall, R. N., Guides for Use in Planning Beef Feeding Systems, AE-3971, University of Illinois, December 1963, and Wendling, L. T., J. A. True, H. E. Stover and F. N. Reece, Planning Feed Handling Systems, C-322, Extension Service, Kansas State University, March 1965.

2/ Annual cost for storage structure per ton fed for systems 1, 2, 6 = 11% of original investment per ton fed.

= Depreciation (5%) + interest (4%) + maintenance (1%) + taxes and insurance (1%)

Annual cost for storage structure per ton fed for system 5 = 12.7% of original investment per ton fed.

= Depreciation (6.7%) + interest (4%) + maintenance (1%) + taxes and insurance (1%)

Depreciation based on a 20-year life for hay sheds and cement stave silos and a 15-year life for the bunker silo with wood walls and cement floor.

3/ Estimated percent dry matter losses in storage. Reference: Hoglund, C. R., op. cit. Note: No research data on specific losses in loose stacks was located, therefore, the estimate utilized is a rough one at best.

4/ Storage losses are valued at $10 per ton to cover the value of the lost forage after costs of harvesting and providing storage space for the lost quantity have been deducted. The calculation of harvesting and storage costs on a per ton fed basis include the costs incurred in harvesting and providing storage space for the hay which is lost in storage.

$$\text{Value of storage losses per ton fed} = \frac{1}{1 - \%\ \text{storage loss}} - 1 \times \$10$$

Storage costs per ton for baled hay and loose hay do not change appreciably as volume of hay stored changes, however, storage costs per ton for haylage do tend to be reduced as the amount stored increases. These differences are analyzed in a later section of this report.

Feeding

Feeding is the third and final phase of the hay harvesting and handling system. The investments in equipment and the amount of labor required to remove the hay from storage and to feed it to the cattle depends upon the form in which the hay was harvested, the type of storage used, and the method of feeding selected.

The estimated investments and annual fixed costs associated with owning the feeding equipment and the estimated labor and power requirements for removing hay from storage and feeding it are presented in table 6 for each system.

Table 6. Estimated investment and annual fixed costs of owning feeding equipment plus labor and power requirements for feeding 250 tons

Feeding equipment	Resource requirements and costs per ton fed					
	System No. 1- baled hay	System No. 2- baled, bale fork	System No. 3- loose hay, grapple fork	System No. 4- loose hay, self fed	System No. 5- haylage- bunker silo	System No. 6- haylage- stave silo- wagon
Grapple fork	---	---	$.40	$.40	---	---
Silo unloader	---	---	---	---	---	$6.60
Feed bunk	---	---	---	---	$1.20	1.20
Fence charger	---	---	---	$.20	---	---
Wire, posts, etc.	---	---	---	$.10	---	---
Total investment per ton fed [1]	---	---	$.40	$.70	$1.20	$7.80
Annual fixed costs of owning feeding equipment/ton fed [2]	---	---	$.05	$.12	$ .18	$ .95
Labor-Hrs./ton fed [3]	1.1	.8	.4	.2	.3	.3
Tractor Hrs./ton fed	1.1	.8	.4	.1	.3	.1
Electricity - hp-hrs/ ton fed	---	---	---	---	---	2.5

[1] Total investment per ton fed for equipment used for feeding only. Investments for equipment such as tractors and wagons used for both feeding and harvesting have been included in table 1 for harvesting equipment and are omitted here.

[2] Annual fixed costs of owning the feeding equipment per ton fed include:
For grapple fork and silo unloader:
Depreciation (6.7%) + interest (4%) + shelter, taxes, and insurance (1%)
For feed bunks:
Depreciation (10%) + interest (4%) + taxes and insurance (1%)
For fence chargers, wires and posts:
Depreciation (20%) + interest (4%) + taxes and insurance (1%)
Annual fixed costs of owning equipment used in harvesting were charged to harvesting in table 2.

3/ Labor requirements based on Van Arsdall, op. cit., and estimates from farmers interviewed. System No. 6 includes 1/3 of silo unloader operating time. If the operator has no other work to do while the unloader is operating, then the full operational time should be charged to labor. (In this case add approximately .4 hours per ton to labor requirements for System No. 6.)

In System No. 1 baled hay is removed from storage and fed by hand with a wagon used as transport. In System No. 2 bales are removed and fed with the use of a tractor loader and bale fork. The two methods for feeding loose hay are with a grapple fork in System No. 3 or self-feeding in System No. 4. In System No. 5 haylage is removed from the bunker silo with a tractor-loader and distributed with a self-unloading wagon. Haylage stored in an upright stave silo (System No. 6) may be removed with a silo unloader and fed with a self-unloading wagon.

The estimated costs of feeding per ton of hay equivalent (85% D.M.) fed are enumerated for the various systems in table 7. These costs are those incurred when approximately 250 tons of hay are fed per year.

Differences in feeding losses -- waste -- were not ascertained and were not included in the costs of feeding. However, if such differences exist they should be accounted for to provide a more complete cost comparison.

The costs of feeding in table 7 understate the actual costs because the annual fixed costs of owning the multi-purpose equipment were charged fully to harvesting rather than being pro-rated between harvesting and feeding as

Table 7. Cost of feeding per ton of hay fed, 250 tons fed

Item	System No. 1- baled hay	System No. 2- baled, bale fork	System No. 3- loose hay, grapple fork	System No. 4- loose hay, self-fed	System No. 5- haylage- bunker silo wagon	System No. 6- haylage- stave silo wagon
Labor @$1.50/hr. [1]	$1.65	$1.20	$ .60	$ .30	$ .45	$ .45
Gas, oil, lube [2]	.37	.27	.18	.05	.10	.03
Equipment, fixed cost [3]	---	---	.05	.12	.18	.95
Repairs [4]	.47	.66	.40	.10	.37	.48
Electricity @$.02 per hp. - hr.	---	---	---	---	---	.05
Batteries, misc.	---	---	---	.02	---	---
Total feeding cost per ton fed [1]	$2.49	$2.13	$1.23	$ .59	$1.10	$1.96

[1] Add $.60 per ton to costs for System No. 6 if the full operational time of the silo unloader is charged to labor.

[2] See table 3, footnote No. 2.

[3] Includes only the fixed costs of owning the equipment used exclusively for feeding as listed in table 6.

[4] Repairs for specialized feeding equipment such as feed bunkers and silo unloaders are assumed to be 5% of original investment per year. Repairs for other machinery are calculated as in footnote 1, table 3.

they should be in a strict cost accounting. However, total costs for the whole systems of harvesting, storage, and feeding will not be affected by this division of fixed costs.

Labor requirements and costs for feeding are affected by the volume of hay fed as is discussed in a later section.

Total Harvesting, Storing, and Feeding Costs

An economic comparison of alternative forage handling systems should emphasize the total costs of harvesting, storing, and feeding for each system, particularly since the selection of the harvested form determines and limits the methods of storage and feeding.

This report has presented the cost estimates for harvesting, storing, and feeding for six alternative systems. Table 8 brings together the individual costs and compares the total costs of harvesting, storing, and feeding for the six hay handling systems analyzed.

The estimated costs for the loose stacked hay, Systems 3 and 4, were lower than those for the baled hay or haylage systems when 250 tons of hay equivalent are fed per year. The total costs for the haylage systems were slightly lower than those for the baled hay systems. The haylage systems had lower harvesting costs but higher storage costs than those for the baled hay systems.

The costs presented in table 8 represent only the situation in which enough hay is harvested and stored to feed 250 tons of dry hay equivalent per year; a complete set of medium capacity equipment for harvesting and feeding is owned and the tractors, wagons, etc., are used only for the forage handling systems; and the value or cost of labor is $1.50 per hour. The cost relationships among the various hay handling systems will change with the volume of hay handled, the size and amount of machinery used, and with the cost of labor.

Table 8. Total harvesting, storing, and feeding costs per ton fed,[1/] 250 tons fed

Item	System No. 1- baled hay	System No. 2- baled accumu- lator	System No. 3- loose hay grapple fork	System No. 4- loose hay self-fed	System No. 5- haylage- bunker silo	System No. 6- haylage- stave silo
Harvesting costs	$10.09	$ 9.87	$ 8.23	$ 8.23	$ 8.33	$ 7.97
Storage costs	1.83	1.83	1.43	1.43	3.53	3.60
Feeding costs	2.49	2.13	1.23	.59	1.10	1.96
Total costs	$14.41	$13.83	$10.89	$10.25	$12.96	$13.53

[1/] Estimated total costs per ton of hay equivalent fed when 250 tons are fed per year under the assumptions outlined previously in this section.

The next two sections analyze the effects of varying volumes of hay handled, the selection and size of machinery, and the cost of labor.

III. Comparison of Systems and Machinery Selection at Varying Levels of Production

Costs per ton of hay handled at various volumes depend on the size of machinery used. Therefore, the first part of this section analyzes the harvesting costs for different sized sets of machinery and for combinations of custom harvesting and owned machinery for each system to determine the least cost or most economical set of machinery for each level of production.

Storage and feeding costs also vary with the volume stored and fed. These costs were determined and added to the harvesting costs for least cost sets of machinery at each volume to derive the total harvesting, storing, and feeding costs for each system at the varying volumes of hay fed. These total costs for the systems are compared to demonstrate the cost relationships between the systems of hay handling at various levels of production.

Machinery Selection and Harvesting Costs of Varying Levels of Production

To approximate the optimum or lowest cost sets of machinery for harvesting of various volumes of hay, three possible combinations or sets of machinery were compared for each system. The three combinations were: custom harvesting with a minimum amount of owned equipment (designated as set A), a medium capacity set of owned equipment as described in the previous section and in table 1 (set B), and a set of large capacity machinery (set C).

The total harvesting costs for each of these three sets of machinery in each system were compared at various levels of production ranging from 62.5 to 1,000 tons of dry hay equivalent fed per year. (These volumes of hay fed correspond roughly to that required to feed from a 25 to a 400 cow beef herd.) The harvesting costs for the least cost set of machinery for each volume in each system were then included in the total costs per ton fed for comparison of the various systems of hay handling at varying volumes of hay harvested, stored, and fed.

The relevant investments and costs for the three alternative machinery sets compared for System No. 1 are presented in tables 9 and 10. Table 9 lists the harvesting equipment and investments for the 3 sets of machinery compared for System No. 1 while table 10 shows the fixed costs, variable costs, and total costs of harvesting at varying volumes of hay fed.

Table 9. Estimated investments for three sets of harvesting machinery - System No. 1

Item	Set A	Set B	Set C
Mower (7 foot)	---	$ 550	---
Mower (9 foot)	---	---	$ 650
Rake	---	600	600
Baler (medium)	---	2,400	---
Baler (large)	---	---	3,200
Bale loader	$ 400	400	400
Wagon	400	(2) 800	(2) 800
Elevator	600	600	600
Tractor 30 hp. 10-years old	1,100	1,100	(2) 2,200
Tractor 45 hp. 10-years old	---	2,200	2,200
Total investment	$2,500	$8,650	$10,650

As indicated in table 10 the custom harvesting alternative (set A) is the least expensive at the 62.5 and 125 tons fed levels, the medium capacity machinery (set B) became the lowest cost set from 250 through 500 tons of hay fed, while the larger machinery (set C) was optimal for 750 and 1,000 tons fed. The harvesting costs associated with these least cost machinery alternatives at each level will be used in calculating the total harvesting, storage, and feeding costs at various volumes of hay fed for the system.

Table 10. Estimated fixed, variable, and total costs of harvesting for 3 sets of machinery at varying levels of production - System No. 1

Item	Tons fed					
	62.5	125	250	500	750	1,000
A. Annual fixed costs per ton fed:						
Set A	$ 4.40	$ 2.20	$ 1.10	---	---	---
Set B	---	7.61	3.81	$ 1.92	$ 1.32	---
Set C	---	9.37	4.69	2.34	1.61	$ 1.26
Machinery Set	Set A		Set B		Set C	
B. Variable costs per ton: (for all volumes fed)						
Custom hire						
mowing @ $1.10/ac.	$ .95		---		---	
raking @ $1.10/ac.	.95		---		---	
baling @ $.11/bale	4.40		---		---	
Repairs [1]	.18		$ .69		$ .63	
Twine [2]	---		.60		.60	
Gas, oil, lube [3]	.11		.38		.32	
Labor @ $1.50/hr.	1.50		2.54		2.34	
Total variable cost per ton harvested	$ 8.09		$ 4.21		$ 3.89	
Total variable cost per ton fed [4]	$ 8.41		$ 4.38		$ 4.04	

	Tons fed					
	62.5	125	250	500	750	1,000
C. Total harvesting costs per ton fed [5]						
Set A	$12.81	$10.61	$ 9.51	---	---	---
Set B	---	11.99	8.19	$ 6.30	$ 5.70	---
Set C	---	13.41	8.73	6.38	5.65	$ 5.30

[1] See footnote 1, table 3.

[2] See footnote 3, table 3.

[3] See footnote 2, table 3.

[4] See footnote 4, table 3.

[5] Total harvesting costs per ton fed = fixed costs/ton fed + variable costs/ton fed.

The procedure outlined above for determining the optimum or least cost machinery sets for System No. 1 was also carried out for the other five systems analyzed. The results of this procedure are presented in appendix tables I, II and III.

Storage Costs at Varying Volumes of Hay Fed

Storage costs per ton fed for the baled hay and loose hay systems (Systems 1-4) were assumed to remain constant over the volumes studied. The loose hay systems utilize small stacks of uniform size which will not change when the volume of hay harvested increases and, therefore, the percentage of storage loss should not change as the volume of hay handled changes. Baled hay storage sheds were assumed to be similar in cost per square foot for the various volumes studied, hence, storage costs for baled hay were also assumed to remain constant. Storage costs were estimated at $1.83 per ton fed for Systems 1 and 2, and at $1.43 per ton for Systems 3 and 4 (see table 5).

Substantial cost economies for haylage storage occur as volume increases. Table 11 presents the estimated losses, investments, and costs at various volumes of hay fed for haylage stored in bunker silos (System 5) and in concrete stave upright silos (System 6).

Table 11. Storage investments, losses, and costs - Systems 5 and 6 [1/]

Item	Tons fed					
	62.5	125	250	500	700	1,000
System 5						
Storage losses [2/]	15%	14%	13%	12%	11%	10%
Value of storage losses per ton fed [3/]	$ 1.76	$ 1.63	$ 1.49	$ 1.36	$ 1.24	$ 1.11
Investment in storage structure per ton fed [4/]	21.17	18.60	16.09	14.77	13.48	12.22
Annual cost for storage structure per ton fed [5/]	2.69	2.36	2.04	1.88	1.71	1.55
Total storage costs per ton fed [6/]	4.43	3.99	3.53	3.24	2.95	2.66
System 6						
Storage losses [2/]	10%	9%	8%	7%	7%	7%
Value of storage losses per ton fed [3/]	$ 1.11	$ .99	$ .87	$ .75	$ .75	$ .75
Investment in storage structure per ton fed [7/]	43.40	31.60	24.80	20.00	20.00	20.00
Annual cost for storage structure per ton fed [5/]	4.77	3.48	2.73	2.20	2.20	2.20
Total storage costs per ton fed [6/]	5.88	4.47	3.60	2.95	2.95	2.95

1/ All costs are per ton of hay equivalent (85% dry matter) fed.

2/ See footnote 3, table 5.

3/ See footnote 4, table 5.

4/ Bunker silo -- wood walls, concrete floor.

5/ See footnote 2, table 5.

6/ Total storage costs = value of storage losses + annual cost for storage structure.

7/ Concrete stave silos:

Tons fed	Silo size	Tons fed	Silo size
62.5	14 x 45	500	30 x 70
125	18 x 50	750	(2) 28 x 60
250	22 x 60	1,000	(2) 30 x 70

Feeding Costs at Varying Volumes of Hay Fed

The costs of feeding a ton of hay are reduced as unit labor requirements are reduced when the volume of hay fed increases and as the fixed costs of owning specialized feeding equipment are spread over larger volumes of hay. The estimated investment in specialized feeding equipment, labor requirements, and cost of feeding per ton of hay fed at various volumes are presented for each system in table 12.

Total Costs for Alternative Hay Handling Systems at Varying Volumes

The effects of the volume of hay harvested and fed upon the relative costs of the six alternative hay handling systems can be determined by putting together the harvesting, storing, and feeding costs developed in the preceding parts of this section. Table 13 compares the total cost of harvesting, storing, and feeding at volumes ranging from 62.5 to 1,000 tons of hay equivalent fed for the six systems.

System 4 -- loose hay, self-fed -- is the least cost alternative at all volumes up to 1,000 tons under the assumptions made in this study. The least cost alternative at 1,000 tons fed per year was System 5 -- haylage. Loose hay fed with a grapple fork -- System 3 -- was the next lowest cost alternative at all levels of production up to 750 tons fed per year at which point both System 5 and 6 -- haylage -- became cheaper. System 5 -- haylage in the bunker silo -- was slightly lower in cost than System 6 -- haylage stored in an upright stave silo --

Table 12. Investment in feeding equipment, labor requirement, and cost of feeding per ton of hay fed at varying volumes.

Item	Tons fed					
	62.5	125	250	500	750	1,000
Investment in feeding equipment: [1]						
System No. 1	---	---	---	---	---	---
System No. 2	---	---	---	---	---	---
System No. 3	$ 1.60	$ .80	$ .40	$ .20	$ .13	$ .10
System No. 4	2.50	1.30	.70	.40	.30	.25
System No. 5	1.20	1.20	1.20	1.20	1.20	1.20
System No. 6	22.00	12.40	7.80	5.40	4.00	3.30
Labor requirements: [2]						
System No. 1	1.3 hrs.	1.2	1.1	1.1	1.1	1.1
System No. 2	1.0	.9	.8	.8	.8	.8
System No. 3	.6	.5	.4	.4	.4	.4
System No. 4	.4	.3	.2	.2	.2	.2
System No. 5	.5	.4	.3	.3	.3	.3
System No. 6 [3]	.5	.4	.3	.3	.3	.3
Total cost of feeding: [4]						
System No. 1	$ 2.95	$ 2.73	$ 2.49	$ 2.49	$ 2.49	$ 2.49
System No. 2	2.66	2.40	2.13	2.13	2.13	2.13
System No. 3	1.98	1.57	1.23	1.20	1.20	1.19
System No. 4	1.26	.88	.59	.53	.52	.50
System No. 5	1.71	1.41	1.10	1.10	1.10	1.10
System No. 6 [5]	4.87	3.00	1.96	1.56	1.33	1.21

[1] Investment for equipment used only for feeding. See footnotes 1 and 2, table 6.

[2] Estimates based on Van Arsdall, op. cit., and estimates from farmers interviewed. Labor requirements may vary considerably depending upon distance feed hauled, design of storage facilities, etc.

[3] Includes 1/3 of the operation time for silo unloader. If the operator has no other work to do while the unloader is operating, then the full operational time should be charged to labor. (In this case add approximately .4 hours per ton.)

[4] Total cost of feeding when labor is valued at $1.50/hour. See table 7.

[5] If the full operational time of the silo unloader is charged to labor add $.60 per ton to costs for System No. 6.

at most volumes. System 6, the alternative with the greatest capital requirement was the most expensive system at the lowest volume and the third to least expensive at the highest volume.

Table 13. Total harvesting, storage, and feeding costs per ton at varying volumes[1/]

System	Tons fed					
	62.5	125	250	500	750	1,000
No. 1	$19.47	$17.06	$14.41	$12.54	$11.89	$11.54
No. 2	19.49	16.60	13.83	11.62	10.84	10.41
No. 3	15.84	12.20	10.26	9.19	8.65	8.51
No. 4	15.12	11.51	9.62	8.52	7.97	7.82
No. 5	17.80	13.75	11.29	9.93	8.27	7.69
No. 6	21.93	15.34	11.75	9.75	8.50	7.85

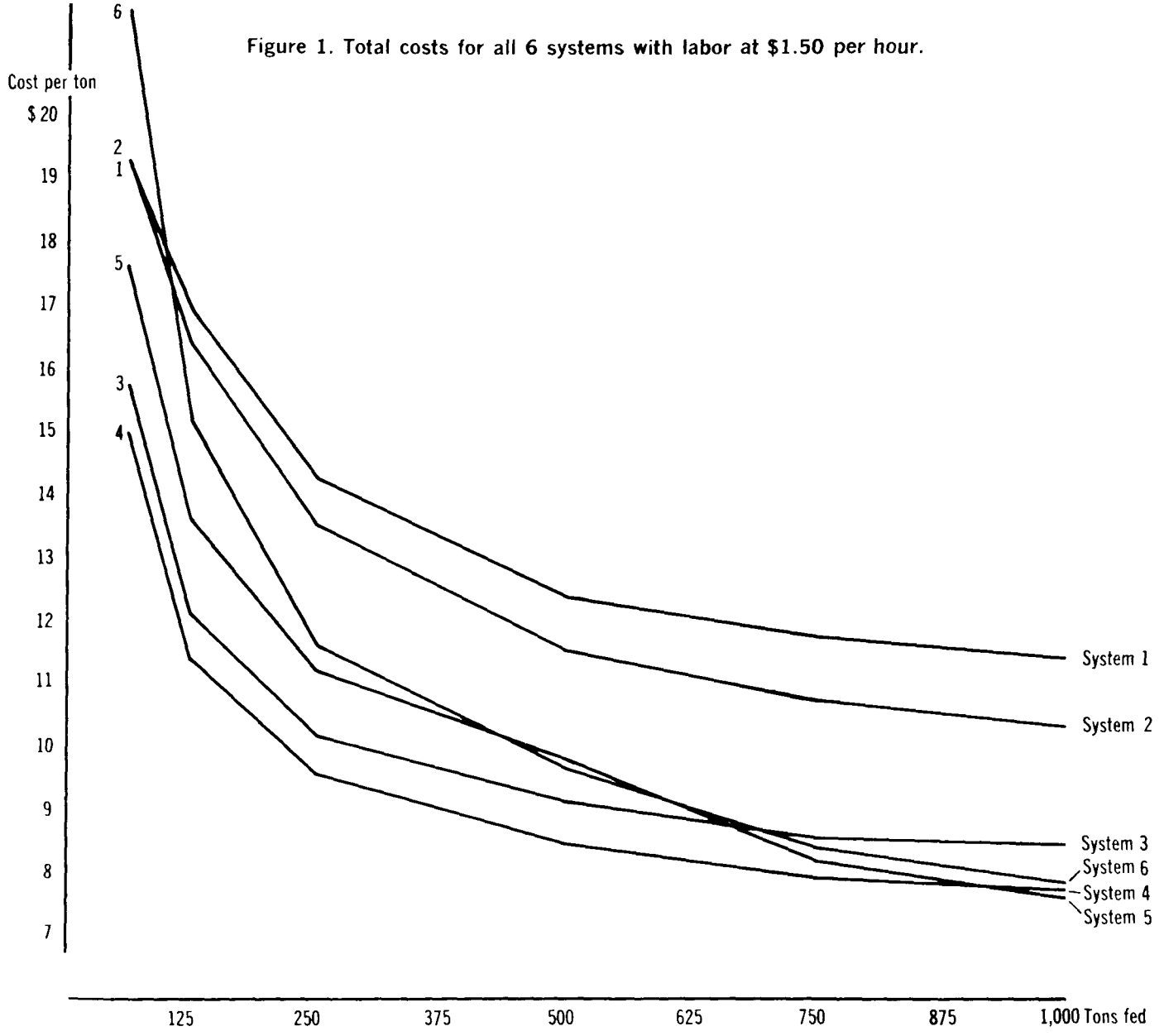
1/ Total costs per ton of hay equivalent (85% D.M.) fed when labor costs $1.50/hr.

The data in table 13 are presented in figure 1 to graphically illustrate the relationship between the cost curves of the six alternative systems.

The cost curves are based on labor at $1.50 per hour. Since the cost or value of the labor for forage handling may be significantly more or less than $1.50 per hour, these effects upon the relative costs of the various systems are discussed in the following section.

When selecting a forage harvesting system, the comparative costs of the alternative systems under average conditions must be considered carefully; but, also, the capacity of the various systems to harvest the required volume of hay under less than ideal conditions must be considered. The following section of this report compares the harvest capacities of the alternative systems.

Figure 1. Total costs for all 6 systems with labor at $1.50 per hour.



IV. Labor Costs, Labor Requirements, and Harvest Capacity Considerations

Availability and cost of labor and of the capacity of the various systems to harvest and handle the required volume of hay during the time available for harvest are important considerations when comparing hay handling systems.

Effects of the Cost of Labor on the Relative Costs of the Systems

The cost data in preceding portions of this report were based on an approximate cost for hired labor of $1.50 per hour. However, hired labor may not be available at this price, or the value of the operator's labor may be worth more or less than $1.50 per hour. For instance, if the operator has a more profitable competing use for his time and labor he should place a higher value on his labor. Conversely, if he has no alternative productive use for the labor he uses in the forage handling enterprise he may place a lower value on his labor. By the above reasoning, it may be that a high price should be charged for labor used for the harvesting operation and a lower value should be placed on labor used for feeding during the winter.

To determine the effects of differing labor costs the total costs of harvesting, storing, and feeding for the six systems have been calculated for three labor price situations in addition to the $1.50 per hour basis used in the preceding sections. The three additional situations are: no value placed on labor, $3.00 per hour for all labor, and $3.00 per hour for harvesting labor with labor for feeding valued at $1.50 per hour.

When the cost of labor changes, the most economical size of machinery to use for each volume harvested and fed changes. As labor becomes more expensive it becomes cheaper to use larger or higher capacity machinery at any given volume of production. Therefore, the optimum sets of machinery determined in the previous section for each volume changed somewhat when cost of labor changed. The costs presented in this section are based on the optimum or least cost sets of machinery for the labor costs being considered, with one exception. Under the assumptions used here it became cheaper to use custom harvesting at all volumes through 750 tons fed per year for Systems 3, 4, 5, and 6, with all labor valued at $3.00 per hour or with only harvesting labor valued at $3.00 per hour. Custom charges were assumed to not change when labor costs varied. Due to the unlikelihood of custom harvesting being available for extremely large volumes of hay an arbitrary limit of 250 tons maximum was placed on the custom harvesting alternative when calculating the harvesting costs and total costs for these systems.

Table 14 presents the total harvesting, storing, and feeding costs for the 6 systems at varying volumes of hay fed when three different costs for labor were used.

System No. 4, loose hay, self-fed, appears to be the lowest cost system except when all labor is valued at $3.00 per hour or when harvest labor is valued at $3.00 per hour with feeding labor valued at $1.50 per hour. At those labor values, System 6, haylage, became cheaper than System 4 when 750 or more

Table 14. Total harvesting, storing, and feeding costs per ton at varying costs of labor

Item	Tons fed					
	62.5	125	250	500	750	1,000
Free labor:						
System No. 1	$15.96	$13.70	$10.12	$ 8.25	$ 7.65	$ 7.46
System No. 2	17.54	14.80	11.08	8.87	8.15	7.87
System No. 3	14.52	11.03	8.46	6.77	6.23	6.20
System No. 4	14.10	10.62	8.13	6.41	5.85	5.86
System No. 5	16.94	13.06	10.71	8.01	6.82	6.07
System No. 6	21.18	14.74	11.30	8.04	6.93	6.37
$3.00/hr. all labor:						
System No. 1	$22.98	$20.42	$18.70	$16.90	$15.97	$15.62
System No. 2	21.44	18.40	16.58	14.25	13.38	12.95
System No. 3	17.16	13.37	11.28	11.61	11.07	10.72
System No. 4	16.14	12.36	10.34	10.65	10.09	9.78
System No. 5	18.70	14.49	11.87	11.62	10.19	9.31
System No. 6	22.68	15.94	12.20	11.28	9.93	9.31
$3.00/hr.-harvest labor and $1.50/hr.-feeding labor:						
System No. 1	$21.03	$18.62	$17.05	$15.05	$14.32	$13.97
System No. 2	19.94	17.06	15.37	13.05	12.18	11.75
System No. 3	16.26	12.62	10.68	11.01	10.47	10.12
System No. 4	15.54	11.91	10.04	10.35	9.69	9.48
System No. 5	17.94	13.89	11.43	11.16	9.73	8.86
System No. 6	21.93	15.34	11.75	10.82	9.47	8.85

tons of hay are fed per year. System 5, the other haylage system, also had lower costs than System 4 when 1,000 tons were fed per year. The other loose hay system was lower in cost than the haylage systems for the free labor situation, except at 1,000 tons where it was higher in cost than System 5, and for volumes up to 500 tons per year for the two higher cost of labor situations.

When low values are placed on labor, the baled hay Systems (1 and 2) were competitive with the haylage Systems (5 and 6) at the lower volumes. The loose hay Systems (3 and 4) are least expensive at nearly all volumes when labor is low priced. At higher labor prices the baled hay systems are substantially more expensive than all the alternative systems at all volumes except at 62.5 tons fed per year where the costs for the baled hay and haylage systems are similar, both being considerably more expensive than the loose hay alternatives at this volume. In the high labor cost situations the haylage Systems (5 and 6) became competitive (nearly equal in cost) with the loose hay Systems (3 and 4) at volumes of 500 or more tons of hay fed per year. When labor is moderately priced at $1.50 per hour (see table 13), the haylage systems did not approach the loose hay systems in cost until 750 to 1,000 tons of hay were fed per year.

Figure 2 illustrates the effects of varying costs of labor by showing the cost curves for Systems 1, 3, and 6 when labor is free and when it is priced at $3.00 per hour.

Labor Requirements

The majority of the beef cow farmers in northern Minnesota who were interviewed in conjunction with this study mentioned limited labor -- both labor available for hire and operator labor available for the forage handling enterprise -- as probably the most serious problem in the selection of forage harvesting and handling systems.

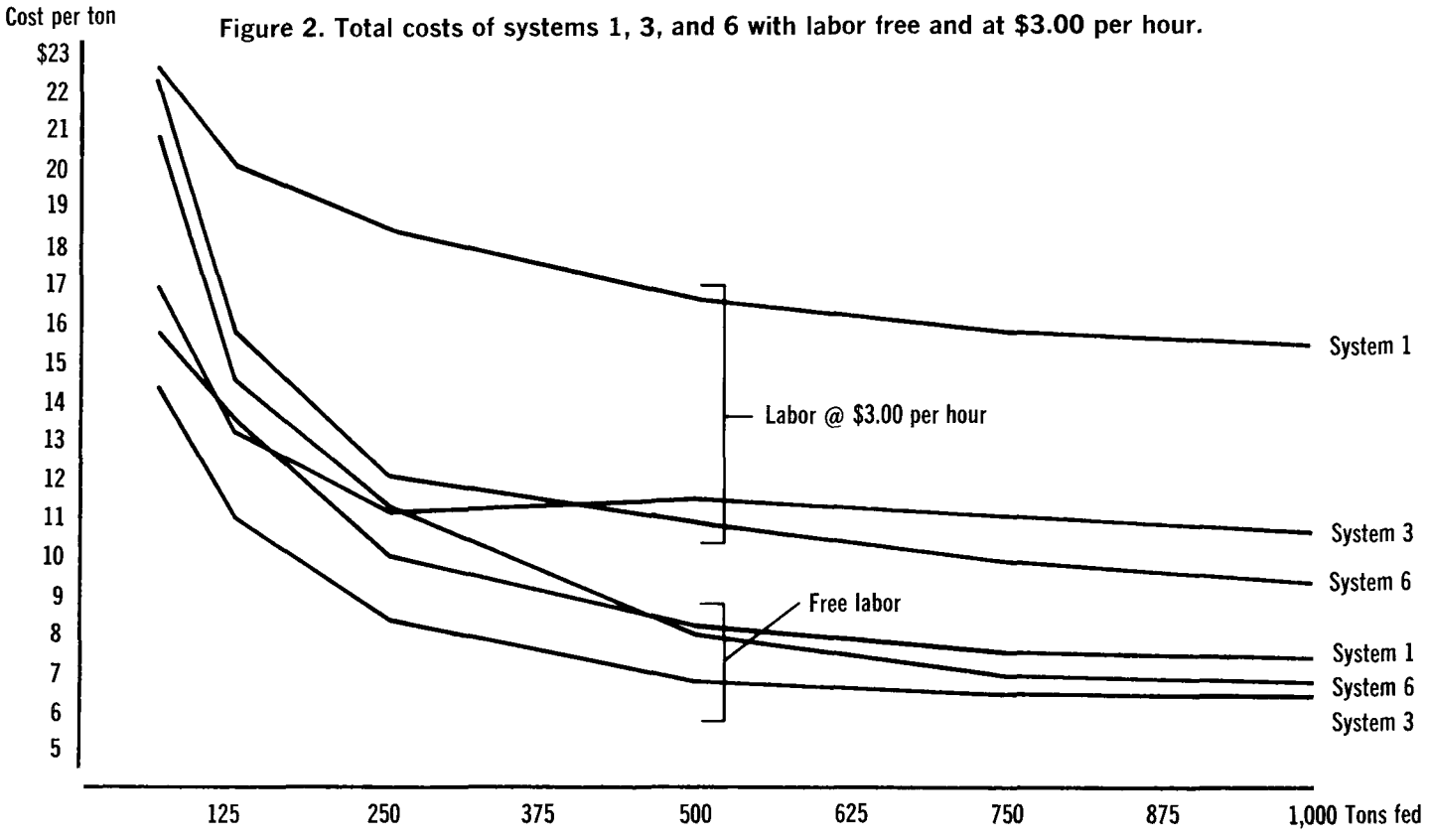


Figure 2. Total costs of systems 1, 3, and 6 with labor free and at $3.00 per hour.

When choosing a forage handling system it is important to be able to meet the labor requirements for the system selected. Where available labor is quite limited it is desirable to select a forage handling system which is economical at high labor costs. The man hours of labor required for a system should not exceed amount reasonably available.

Table 15 presents the estimated hours of labor required per ton of hay for harvesting and feeding 250 tons of hay per year in each of the six systems. The typical number of men in the harvesting crew for each system are also listed in table 15.

In terms of man hours per ton, the haylage Systems (5 and 6) have the lowest labor requirements. However, the harvesting requirements listed for loose hay (systems 3 and 4) include the labor for moving the stacks which need not be done until feeding time. When the approximately .2 hour per ton for stack moving is deducted from the labor requirements for harvesting in Systems 3 and 4, it can be seen that they require only slightly more harvesting labor than the haylage systems and approximately the same amount of harvesting labor as System No. 2, the mechanized bale handling system. However, in terms of the number of men required for the harvesting operation, Systems 3 and 4, may have the advantage of fewer men required or, at least, more flexibility in their use. Systems 1, 5, and 6 require two or more men working simultaneously, while Systems 2, 3, and 4 do not necessitate multiple numbers of men working together.

Table 15. Labor requirements of alternative systems at 250 tons per year

Item	System No. 1	System No. 2	System No. 3	System No. 4	System No. 5	System No. 6
Labor hrs./ton fed:						
a. Harvesting: 1/						
Machinery set A	1.04+custom operator	.30+custom operator	.28+custom operator	.28+custom operator	.09+custom operator	Custom Operator
Machinery set B	1.76	1.03	1.21	1.21	.99	.85
Machinery set C	1.62	.89	1.11	1.11	.80	.67
b. Feeding 2/	1.1	.8	.4	.2	.3	.3
Typical harvest crew --number of men	2-3	2	1-2	1-2	2-3	2

1/ Derived from White, R. G., Selecting a Forage Harvesting System, Information Series 255, Agricultural Engineering Department, Michigan State University, February 1968, and from estimates of farmers interviewed.

2/ Add .4 hours to System No. 6 if full operational time of silo unloader is charged to labor. (See table 6, footnote 4.)

Harvest Capacities of Alternative Systems

Beef cow farmers in Minnesota also face the problem of trying to harvest the large volume of hay required for the long wintering season during a short growing and harvesting season. For this reason as the size of the cow herd grows larger, say at 100-200 or more cows, the capacity of the harvesting system to handle a sufficient volume of hay during the available season becomes critical.

To indicate the differences in the capacities of the various systems table 16 lists estimates of the rate of harvest for each system and the number of harvesting days which would be required to bale, stack, or chop enough hay to feed 750 tons of dry hay equivalent.

Table 16. Estimated harvest capacities [1]

Machinery set [2]	Systems 1 & 2 (baled hay)		Systems 3 & 4 (loose hay)		Systems 5 & 6 (haylage)	
	B	C	B	C	B	C
Tons harvested per hour [3]	6	8	4	8	6	8
Hours suitable to harvest per day	6	6	8	8	10	10
Tons harvested per day	36	48	32	64	60	80
Days required to harvest 750 tons [4]	21.7	16.2	26.0	13.0	14.0	10.5

[1] Estimates in terms of tons of dry hay equivalent.

[2] See table 9 and appendix tables I and II.

[3] See White, op. cit.

[4] Full days of baling, stacking, or chopping to handle enough hay to feed 750 tons of dry hay equivalent.

The capacities per hour of harvesting are quite similar for all of the alternative systems, however, the number of hours available for harvesting each day favor the haylage systems because of dew and drying conditions. Hay may be loose stacked slightly wetter than it can be baled. Haylage has an advantage in that it can be put up under more moist conditions than either loose hay or baled hay.

A much shorter drying time is required for haylage. Not only can the haylage systems harvest more hay per day; but they should be capable of harvesting on days that are too wet for the dry hay systems.

V. The Selection of a Forage Harvesting and Handling System

When selecting a system one should examine the various possible complete systems of harvesting, storing, and feeding, since all three are interrelated. The costs, and labor and capital requirements of each system should be compared to determine which most nearly meets the requirements and objectives of the individual farmer.

When determining the most practical hay handling system for an individual farm, several factors in addition to the cost must be considered. Availability of capital is important. If capital is limited or more profitable alternative uses exist, then capital intensive systems (e.g. Systems 5 and 6) may be ruled out.

Limited labor or high labor costs may necessitate that only low labor requirement systems be considered.

The skill and experience of the operator with various systems and methods of harvest should be considered. The differences in costs among most of the systems budgeted were small. This should indicate that for any given situation there may be several alternative systems of similar desirability from a cost standpoint. In such cases the efficiency with which the chosen system is managed will be as important or more important than the choice of system. Good management is necessary for satisfactory performance with any system. If the operator is likely to be considerably less efficient than average with a particular system, his costs for that system will be greater. For example, increasing the storage losses of loose stacked hay from the estimated 12.5 percent to a level of 15 percent

would increase the costs for the loose hay systems about $. 50 per ton fed under the assumptions used previously. This change would significantly alter the cost relationship between loose hay and the other systems at certain levels of production. (The amount of rainfall also affects the storage losses in loose stacked hay. Areas with more than approximately 24 inches of rainfall annually may have loose hay storage losses exceeding the estimates used here.)

Some systems may have an advantage over others on a given farm because of the availability of certain fixed assets. For instance, a silo which was no longer used on a given farm might reduce the cost of the haylage system since the fixed costs for the silo will be incurred whether it is used or not. Therefore, this fixed cost could be ignored when calculating the cost of a haylage system.

The system's capacity to harvest a sufficient volume of forage during the available harvesting season is an important consideration at larger volumes. Other things being equal, the system with the greater potential capacity has the advantage since a short or unfavorable harvest season will be less likely to prevent the harvesting of a sufficient amount of hay.

The analysis in this report has not included a complete comparison of the quality or feeding value of the various forms of hay. Losses of dry matter in harvesting and storage for the various systems were estimated and the value of these losses included in the costs for each. Any losses of feeding value in addition to the dry matter losses were not accounted for, however.

All the systems studied can produce hay of more than adequate quality for beef cows, if the hay is cut at the proper time, not rained on excessively, etc. If a forage handling system was being selected for other livestock enterprises in which hay quality is more important, such as dairy, then a value for differences in hay quality should be included in the comparison of the systems if it is believed that differences exist.

Advantages and Disadvantages of the Six Systems

System No. 1 -- This system of conventional handling of baled hay had the highest labor requirement. It is a high cost system, particularly when labor is limited or expensive. Baled hay, however, is the most readily marketable form of hay. Capital requirements for this system are moderately low.

System No. 2 -- This is a more mechanized system of bale handling which reduces labor requirements. Capital requirements are fairly high. This is a high cost system under most conditions.

No producers with more than 75 cows interviewed for this study used baled hay exclusively. Apparently only a few large herd operations rely exclusively on baled hay, at least, in northern Minnesota. Some large operators were using baled hay in combination with silage or haylage, however.

System No. 3 -- Loose stacked hay is a low cost method of handling hay. Investments are low and labor requirements are low to moderate. Storage losses in the stacks are hard to estimate, and in some situations additional charges for storage losses may be necessary.

System No. 4 -- This is the same as System No. 3 except that self-feeding is used to lower labor requirements and costs slightly. Systems No. 3 and 4 are the lowest cost systems under many conditions.

The majority of producers interviewed in this study who had medium sized herds (50-75 cows) or larger were utilizing loose stacking, particularly in the western half of the state. Experience with loose stacks is more limited in the eastern part of the state and some doubts about higher storage losses due to the higher rainfall exist.

System No. 5 -- This system of storing haylage in a bunker silo requires a high investment but labor requirements are low. It is a low cost system at high volumes. Proper procedures in cutting haylage and filling silos are very important to prevent excessive storage losses.

System No. 6 -- Storing haylage in a concrete stave silo, requires more capital than the other systems; however, it does have the lowest labor requirement. It is a low cost system at high volumes; but good management is important. Both Systems No. 5 and 6 have the potential capacities to harvest more hay during the season than the other systems. They are less susceptible to interference by weather. On farms where corn is harvested as silage haylage systems can use much of the same equipment.

The use of haylage by beef cow herd operators, at least, in northern Minnesota is fairly limited. Probable reasons for this may include the lack of experience with haylage on the part of the manager and the high capital requirements for haylage systems.

Summary and Conclusions

The costs and resource requirements for six different systems for harvesting, storing, and feeding hay suitable for beef cow enterprises are compared in this report. Two handling systems in each of three forms: baled, loose, and haylage, are compared. Costs and resource requirements were synthesized from various previous research reports and from the data obtained from several beef cow producers interviewed in northern Minnesota.

The results indicate that, at least, in areas with less than about 24 inches of annual rainfall loose stacked hay seems to have an advantage over the other systems for beef cow herds up to 200 cows. For large herds of 200 or more cows the haylage systems may be feasible alternatives with comparable costs and probably greater harvest capacity for the season than the loose hay systems. However, they require possibly more critical managerial skill and more capital than the other systems. Baled hay apparently is practical only in situations where the volume of hay handled is low, labor is cheap and plentiful, and expected losses from loose stacks are excessively large.

In many cases the differences in costs between several of the alternatives budgeted were small, which indicates that for any given situation there may be several alternative systems of hay harvesting and handling which would be of about equal cost. Therefore, the efficiency with which the chosen system is managed may be nearly as important as the choice of system.

Recent studies in Wisconsin[1/] and Pennsylvania[2/] evaluated forage harvesting, storing, and feeding systems on dairy farms. Results of those two studies, while not directly comparable, partially supported the findings of this study in one case (Pennsylvania) and partially contradicted them in the other (Wisconsin).

The Pennsylvania study compared the profitability of various forage handling systems on a representative dairy farm. Profits were based on returns from the sale of milk and the sale of forage not needed by the dairy herd. At both the 30 and 70 cow sizes there were many systems about equal in profitability. At the 70 cow size all of the most profitable systems were silage or combination silage and baled or chopped dry hay systems. The all baled hay or all chopped dry hay systems were less profitable than the systems containing silage for 70 cow herds.

The Wisconsin study found no significant differences in net farm income between dairy farms using baled hay, chopped hay, or haylage as the major forage. However, the total cost of handling a ton of baled hay from the field to feeding for the most efficient baled system was about $1.80 - $2.60 less than for haylage. This finding was opposite of the results of the present study. Several differences in assumptions between the two studies seem to account for this difference. The Wisconsin study did not make a direct comparison of harvest

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1/ Kimball, N. D., G. S. Willett, and R. E. Rieck, Economic Evaluation of Forage Handling Systems, Bulletin 590, Research Division, College of Agriculture and Life Sciences, University of Wisconsin, August 1968.

2/ Taylor, H. H., and W. L. Barr, An Economic Comparison of Forage Harvesting, Storing, and Feeding Systems on Pennsylvania Dairy Farms, Bulletin 751, Agricultural Experiment Station, Pennsylvania State University, October 1968.

losses between the two systems which would have added about $1.90 per ton to baled hay costs. They found that dairy farmers spent the same amount of time for feeding baled hay as for haylage, while the present study estimated that haylage feeding would require considerably less time than baled hay per ton for feeding to beef cow herds. This difference in estimated feeding time gave a $1.00 per ton advantage to haylage in the present study. The Wisconsin study also charged a lower rate for labor, and it did not allow for the use of larger sized silos in lieu of using multiple small silos as volume of haylage increased. These two factors resulted in an additional advantage of $.80 to $.85 per ton for baled hay in the Wisconsin study as compared to the present report. If the two studies had used identical assumptions on these four items they would have reached nearly identical conclusions.

The above discussion indicates the importance of carefully reviewing the applicability of the assumptions of a study before applying the results to a given situation.

Appendix Table I. Estimated investments for three sets of harvesting machinery - Systems 2, 3, 4.

Item	System 2			Systems 3 and 4		
	Set A	Set B	Set C	Set A	Set B	Set C
Mower (7 foot)	$ ---	$ 550	$ ---	$ ---	$ 550	$ ---
Mower (9 foot)	---	---	650	---	---	650
Rake	---	600	600	---	600	600
Baler (medium)	---	2,400	---	---	---	---
Baler (large)	---	---	3,200	---	---	---
Accumulator	---	1,200	1,200	---	---	---
Fork	500	500	500	---	---	---
Loader	1,000	1,000	1,000	---	---	---
Wagon	400	(2) 800	(2) 800	---	---	---
Tractor 30 hp. -10 yr. old	1,100	1,100	(2) 2,200	---	1,100	1,100
Tractor 40 hp. -10 yr. old	---	---	---	1,675	1,675	(2) 3,350
Tractor 45 hp. -10 yr. old	---	2,200	2,200	---	---	---
Buck-stacker	---	---	---	1,600	1,600	(2) 3,200
Stack frame	---	---	---	400	400	400
Stack mover	---	---	---	---	2,000	2,000
Total investment	$ 3,000	$10,350	$11,350	$ 3,675	$ 7,925	$11,300

Appendix Table II. Estimated investments for three sets of harvesting machinery - Systems 5 and 6

Item	System 5			System 6		
	Set A	Set B	Set C	Set A	Set B	Set C
Mower (7 foot)	$ ---	$ 550	$ ---	$ ---	$ 550	$ ---
Mower (9 foot)	---	---	650	---	---	650
Rake	---	600	600	---	600	600
Field Chopper (medium)	---	2,500	---	---	2,500	---
Field Chopper (large)	---	---	3,300	---	---	3,300
Blower	---	---	---	1,000	1,000	1,000
Loader	---	1,000	1,000			
Self unloading wagon	(1) 1,600	(2) 3,200	(2) 3,200	(1) 1,600	(2) 3,200	(2) 3,200
Tractor 30 hp. -10 yr. old	1,100	(2) 2,200	(3) 3,300	1,100	(2) 2,200	(3) 3,300
Tractor 55 hp. -10 yr. old	---	2,500	---	---	2,500	---
Tractor 70 hp. -10 yr. old	---	---	3,250	---	---	3,250
Total investments	$ 3,700	$12,550	$15,300	$ 3,700	$12,550	$15,300

Appendix Table III. Total harvesting costs for three sets of machinery for each system -- Systems 2 through 6.

System	Total harvesting costs per ton fed					
	62.5	125	250	500	750	1,000
System 2						
Set A	$13.12	$10.48	$ 9.18	$ 8.50	$ 8.28	$ ---
Set B	---	12.49	7.97	5.74	5.02	---
Set C	---	13.98	8.54	5.83	4.96	4.53
Systems 3 and 4						
Set A	$10.88	$ 7.64	$ 6.03	$ 5.22	$ 4.95	$ ---
Set B	17.01	10.11	6.66	4.97	4.43	---
Set C	---	12.93	7.96	5.48	4.68	4.30
System 5						
Set A	$11.59	$ 8.28	$ 6.59	$ 5.72	$ 5.39	$ ---
Set B	---	13.77	8.26	5.52	4.61	4.43
Set C	---	15.70	8.94	5.56	4.44	3.89
System 6						
Set A	$11.18	$ 7.87	$ 6.19	$ 5.33	$ 5.06	$ ---
Set B	---	13.48	7.97	5.24	4.36	3.92
Set C	---	15.44	8.67	5.31	4.22	3.69

Appendix Table IV. Estimated investments in harvesting machinery, storage structures, and feeding equipment for various systems - 250 tons fed per year

Item	System No. 1- baled hay	System No. 2- baled hay accumu- lator	System No. 3- loose hay	System No. 4- loose hay self-fed	System No. 5- haylage bunker	System No. 6- haylage upright
Investment in harvesting machinery [1]	$ 8,650	$10,350	$ 7,925	$ 7,925	$12,550	$12,550
Storage structure [2]	3,255	3,255	---	---	4,022	6,200
Feeding equipment [3]	---	---	100	175	300	1,950
Total investment	$11,905	$13,605	$ 8,025	$ 8,100	$16,872	$20,700

[1] See table 1.

[2] See table 5.

[3] See table 6.

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