A Cost Analysis of Alternative Forage Systems from Harvest through Feeding

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Cover photo: Cubed forage produced at Oregon State University. Feeding trials are under way at OSU and in Japan. Cubes are shown actual size. Cubing increases density three to four times as compared to baled forage, an obvious advantage for long-distance shipping.

Cooperative Extension work in Agriculture and Home Economics, Lee Kolmer, director. Oregon State University and the United States Department of Agriculture cooperating. Printed and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914.

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The agricultural sector of Oregon's economy is taking renewed interest in economic information related to harvesting, storing, handling, and feeding of forage in various densified forms. There are several reasons for this interest:

1. Economic pressures result in continuing interest in the feed cost component for dairy and beef livestock operations. Feed, as the single largest item of cost, accounts for 40 to 80 percent of the total cost of livestock feeding operations in Oregon [3,4,7].

2. As livestock operations become more specialized in livestock feeding, the proportion of purchased feed tends to increase relative to that feed produced by the livestock operations. This is particularly true for dairy and feed lot operations. When this occurs, the densification, handling, transporting, storing, and feeding costs can become important components in the total cost of operation. In so doing, the relative positions of alternative forage systems may change, which could favor some systems over others in achieving cost reductions.

3. Environmental factors are precipitating the termination of open field burning as a cultural practice for Willamette Valley grass seed producers. Removal of grass straw residue and conversion to a marketable product is perceived as an important means for disposal of residue formerly accomplished by open field burning. Densification, handling, storing, and transportation costs of grass residues represent significant elements in determining whether it can compete as a raw material in various domestic and foreign markets [2].

This study is intended to serve two purposes. The first is to identify the nature and composition of costs associated with selected (1) harvest, (2) storage, and (3) handling and feeding activities which accommodate

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forages in loose, baled, cubed, and silage forms. The second purpose is to compare the economic merits of each system for livestock feeding.

Selected Harvest, Storage, Handling, and Feeding Systems

Four forms of forage are considered in the study. They are loose, baled, and cubed dry forage and silage (haylage). The form in which forage is harvested affects the choice of methods available for handling, storing, and feeding forage. In general, many mechanical processes are available to choose from both within and between systems. In this analysis the process of getting forage of a particular form from its field source to the consuming livestock is treated as a single integrated system. The system selected for each forage type represents, in the authors' best judgment, the combination of alternative activities which provide the lowest commercial cost per ton at or near operating capacity for the volume levels specified in this study. Volume levels used include 300, 500, and 1,000 ton dry hay equivalent capacities.

System 1 accommodates loose dry forage. Forage is swathed in the field, then picked up and stacked with a stack former-mover. The forage is stored in an open hay shed. A tractor-mounted buck rake (unloader) is used to distribute the dry forage for feeding.

System 2 is used for baled dry forage. The forage is swathed, baled, picked up by mechanical bale loader wagon, then hauled to an open shed for storage. Bales are distributed by hand for feeding.

System 3 handles cubed dry forage. The forage is swathed, cubed from the windrow with a field cuber, and transferred by means of a screened wagon or truck to the storage shed. A conveyor is used in the shed for unloading and distribution of the cubes, as well as for transferral to self-feeding bunks.

System 4 is used for silage (haylage). The forage is swathed, permitted to wilt (50-65% moisture), chopped by a field chopper, and blown into a self-unloading wagon for transport and unloading into a bunker silo. Silage is removed from the silo by tractor-mounted buck rake and offloaded into a self-unloading wagon for transport to feed bunks.

A brief description of facilities, equipment, and labor requirements for each of the four systems are included. Costs are expressed as ownership and operating components. Included in ownership costs are taxes, insurance, depreciation, interest on investment, spoilage, and waste. Operating costs include labor, repairs, gas, electricity, oil, and lubrication.

Cost data used in the study were obtained from available published sources, primarily from research conducted in California, Minnesota, and Montana [1,5,10,12]. Adjustments were made in the data when they did not appear to reflect Oregon conditions.

Capital Investment Requirements by System

Estimated capital investment requirements for each of the four forage systems are presented in Table 1. The requirements are separated into (1) harvest, (2) storage, and (3) handling and feeding components. Tractors used with swathing, stack forming, buck raking, baling, field chopping, and wagon pulling operations are assumed to have been purchased for general farm use, so would be available regardless of hay operations. For this reason, no investment and ownership cost charges for tractors are included in the study.

Capital investment levels for the harvest component are similar for loose forage, baled forage, and silage systems. They range from $14,000 to $17,000. Higher capital requirements for a field cuber result in a $50,000 capital investment level for the cubed forage system.

Storage investment levels range from a low of $3,600 for cubed forage to a high of $8,000 for loose forage, with differences reflecting the inverse

TABLE 1. Estimated Capital Investment in Harvest, Storage, and Handling and Feeding Components with Four Forage Systems.

Operation	System 1 Loose	System 2 Baled	System 3 Cubed	System 4 Silage
Harvest				
Swather	$ 6,000	$ 6,000	$ 6,000	$ 6,000
Stack former and mover	8,000			
Baler		4,000		
Bale loader wagon		6,000		
Field Cuber			38,000	
Self-unloading wagon (2)[a]			6,000	6,000
Field chopper				5,000
HARVEST SUB-TOTAL	$14,000	$16,000	$50,000	$17,000
Storage[b]				
Open forage shed, 18'H x 40'W x 200' L with concrete floor	8,000			
Open forage shed, 18'H x 40'W x 100' L with concrete floor		4,000		
Enclosed shed with concrete floor, 12'W x 15'H x 150'L			3,600	
Bunker silo with concrete sides and floor, 12'H x 30'W x 110'L				6,000
STORAGE SUB-TOTAL	$ 8,000	$ 4,000	$ 3,600	$ 6,000
Handling and Feeding				
Tractor-mounted buck rake or unloader	1,700			1,700
Conveyor and elevator			3,000	
Feed bunks	1,500	1,500	1,500[c]	1,500
HANDLING & FEEDING SUB-TOTAL	$ 3,200	$ 1,500	$ 4,500	$ 3,200
TOTAL INVESTMENT	$25,200	$21,500	$58,100	$26,200

[a] Used both for harvesting and feeding with silage.

[b] 300-ton, dry hay equivalent capacity, using a density of 4.2#, 8.4#, 22.2#, and 16# per cu. ft. for loose, baled, cubed, and silage forage respectively.

[c] Attached to enclosed shed to permit self-feeding.

relationship between forage density and storage space requirements. Handling and feeding investment levels range from $1,500 to $4,500 per system, again reflecting forage density differences between systems.

Labor Requirements and Costs by System

Components for each of the four systems purposely include machinery intensive choices. This reflects the continuing trend of machine substitution for labor in commercial agriculture. Labor requirements and costs are specified by individual machines in Table 3 and as a portion of total costs per ton in Table 4. (See reference to Table 2 under "Operation Costs by System".) Labor costs are charged at $2.50 per hour. Labor costs comprise but 5 to 15 percent of total cost per ton of forage fed at the 300-ton forage equivalent volume level. The proportion of labor cost to total cost increases, however, as the volume of forage handled for each system increases. This reflects the nearly constant labor cost per ton of forage fed, regardless of total forage volume.

Operation Costs by System

System costs are shown by cost components (ownership and operating costs) and by operation (activity). Annual ownership costs are shown in Table 2. Loose, baled, and silage forage systems have similar ownership costs ranging from $3,980 to $4,230 per year. The cubed forage system ownership costs are much higher, approaching $13,000 per year, due principally to the high capital investment and 5-year useful life of the field cuber. Obsolescence is the principal factor for the estimated short life of the cuber. Operating costs are presented on a machine unit basis in Table 3.

Ownership and operating cost components are combined in Table 4 to show total costs per ton for each of the four systems. A 300-ton, dry hay equivalent volume is assumed. Total costs per ton are similar for the loose, baled, and silage systems, ranging from $20.58 to $22.97 per ton. Total costs of $52.08 per ton for the cubed system are more than double

TABLE 2. Estimated Annual Ownership Costs in Harvest, Storage and Handling and Feeding Components with Four Forage Systems.[a]

Operation	Estimated useful life	System 1 Loose	System 2 Baled	System 3 Cubed	System 4 Silage
	(years)	($)	($)	($)	($)
Harvest					
Swather...........	5	1,500	1,500	1,500	1,500
Stack former and mover............	10	1,200			
Baler..............	10		600		
Bale loader wagon............	6		1,300		
Field cuber........	5			9,500	
Self-unloading wagon (2)........	10			900	900
Field chopper......	10				750
Storage					
Open shed with concrete floor...	20	800	400		
Enclosed shed with concrete floor...........	20			360	
Bunker silo with concrete floor...	20				600
Handling & Feeding					
Buck rake or unloader.........	10	255			255
Conveyor & elevator.........	10			450	
Feed bunks.........	10	225	225	225	225
TOTAL........		3,980	4,025	12,935	4,230

[a] Annual ownership cost calculations include depreciation, interest, housing, taxes, and insurance. Straight line method of depreciation with no salvage value was assumed. Interest on average investment was charged at 8%, while insurance, taxes, and housing were charged at 2% of average investment.

TABLE 3. Estimated Operating Costs Per Hour for Harvest, Handling and Feeding Equipment.

Implement	Size	Field or operating rate in dry hay equivalent	Tractor req'mt	Crew size	Operating cost per hour[a/] Fuel	Repair	Labor	Total	Cost per ton of dry hay equivalent
Swather..........	10'	.29 hours/acre	1	1	.24	3.61	2.50	6.35	$2.54[b/]
Stack former and mover..........	4 ton	2.5 loads/hour	1	1	.75	1.78	2.50	5.03	.50[c/]
Baler............	2 twine	.15 hours/ton	1	1	1.45	2.25	2.50	6.20	1.53[d/]
Bale loader wagon..........		2.5 tons/hour	1	1	.75	1.48	2.50	4.73	1.89[c/]
Field cuber......		3 tons/hour		1	1.20	5.67	2.50	9.37	3.12
Self-unloading wagon (2)......		3 tons/hour	1	1	.75	1.70	2.50	4.95	1.65[e/]
Field chopper....		.21 hours/ton	1	1	.75	2.50	2.50	5.75	1.21
Buck rake or unloader.......		2.5 tons/hour	1	1	.75	1.42	2.50	4.67	1.87
Conveyor & elevator.......									.05

a/ Includes operating costs for an 80-110 H.P. diesel tractor.

b/ Field production of 2.5 tons/acre was assumed.

c/ Assumes forage is stored in facility located 1 mile from field.

d/ Includes $0.60/ton for twine.

e/ Rate calculated for cubed forage hauled 1 mile to storage site; cost/ton for feeding and handling is assumed to be 1/3 as high as harvesting rate.

TABLE 4. Total Harvesting, Storage and Handling and Feeding Costs Per Ton Fed with Four Forage Systems and 300 Tons Dry Hay Equivalent Fed.

Operation	System 1 Loose	System 2 Baled	System 3 Cubed	System 4 Silage
Harvesting costs				
Ownership costs.............	$ 9.00	$11.33	$39.67	$10.50
Operating costs.............	3.04	5.96	7.31	5.40
TOTAL................	$12.04	$17.29	$46.98	$15.90
Storage costs				
Ownership costs.............	2.67	1.33	1.20	2.00
TOTAL................	$ 2.67	$ 1.33	$ 1.20	$ 2.00
Handling & feeding costs				
Ownership costs.............	1.60	.75	2.25	1.60
Operating costs.............	1.87	.67[a]	.25[b]	1.17
TOTAL................	$ 3.47	$ 1.42	$ 2.50	$ 2.77
Harvest, Storage, & Feeding[c] Losses......................	2.40	2.70	1.40	2.30
TOTAL COSTS..........	$20.58	$22.74	$52.08	$22.97
Components of total costs				
Labor cost..................	$ 2.25	$ 3.53	$ 2.85	$ 3.27
Non-labor cost.............	18.33	19.21	49.23	19.70

a/ Involves hand labor only.

b/ Operating cost of 5¢ for power and repairs on conveyors and elevators, and 20¢ for labor.

c/ Estimated at 24%, 27%, 14%, and 23% for Systems 1, 2, 3, and 4 respectively [6]; harvest losses are due to weathering, mechanical loss, and damage, etc., while storage losses are for spoilage and feeding losses are for wastage. Forage lost is valued at $10/ton in this study.

that of the other three systems. Harvest, storage, and feeding losses are included in the total cost structure with forage loss valued at $10 per ton. Losses for the cubed system were estimated at about one-half that found in the other systems.

Factors Influencing Operation Cost Composition

Many factors influence both cost composition and cost levels when projected on a per-ton basis. Several of these are identified and discussed below.

Volume Considerations

For highly mechanized systems such as those considered in this study, changes in the volume of forage handled are important. Since ownership costs are constant, regardless of the volume of forage handled, increased volume can significantly reduce the influence of ownership costs per ton for machines, until machine capacity is reached. Total costs/ton associated with 300, 500, and 1,000 ton levels are shown in Table 5. For loose forage,

TABLE 5. Total Harvesting, Storage, Handling and Feeding Costs Per Ton Fed of Dry Hay Equivalent with Four Forage Systems at Varying Volumes.

Volume	System 1 Loose	System 2 Baled	System 3 Cubed	System 4 Silage
300 tons................	$20.58	$22.74	$52.08	$22.99
500 tons................	16.32	17.38	35.76	17.33
1,000 tons................	13.38	13.35	23.41	13.10

costs are reduced from $20.58 per ton to $13.38 per ton by expansion from 300 to 1,000 tons, a $7.20 per ton or 35% reduction. With baled forage, costs are reduced $9.39 per ton or 41% by a similar expansion. With cubed forage, costs are reduced $28.67 per ton or 55% by expansion to 1,000 tons.

The greatest economies of size come with the cubed forage system, since it carries the highest percentage of ownership costs. An Arizona study indicates further cost reductions on a per-ton basis are achieved with the cube system by expansion to 3,000 or 4,000 tons annually [8]. This is not the case with the other three systems. Only minor cost reductions are achieved with them by expanding volume beyond 1,000 tons annually. In all four systems, economies of size are confined almost entirely to the harvesting component. With the storage component any increases in volume of forage stored beyond existing capacity requires construction of additional facilities. Cost economies in the handling and feeding components exist primarily with the cubed forage system which utilizes mechanized unloader, conveyor, and elevator facilities. Construction of additional feed bunks are required for all four systems as volume is extended beyond 300 tons. Of particular note are the essentially identical costs for loose, baled, and silage systems when 1,000 tons or more of forage are handled.

Transportation Costs

Commercial hauling of forages would appear as an important cost component where forage production areas are spatially separated from dairy and beef producing areas. This is somewhat the case in Oregon, particularly for dairy operations. Intuition suggests that bulk density of forage and haul distances are important variables when commercial transportation of forage is required. A review of transportation rate structures subject to Interstate Commerce Commission regulation confirms that cost/ton mile decreases as haul distances increase. However, almost no freight advantage exists by increasing the bulk density of forage, since ICC regulations impose gross weight limits of 78,000 pounds on 52-foot truck-trailers, and 73,250 pounds on 40-foot semi-tractor trailers [9]. The net result is that a semi-tractor trailer is limited to about 22 or 23 tons of net load weight. If loaded with baled forage, the semi unit would effectively utilize its physical haul capacity, whereas with forage pellets (approximately four times as dense as bales), the weight load limit would be met at approximately one-fourth of the physical load capacity. In the case of haul distances with a 40-foot semi unit hauling a 22-ton load of forage, the cost per mile is as follows:

Up to 100 miles......	50¢/mile
100 to 250 miles.....	40¢/mile
250 miles & over.....	35¢/mile

The net cost for the 22 ton load results in the following costs:

Haul distance	Cost/mile	Total cost	Total cost per ton
50 miles	50¢	$25	$1.14
100 miles	50¢	50	2.27
200 miles	40¢	80	3.64
400 miles	35¢	140	6.36
600 miles	35¢	210	9.55
800 miles	35¢	280	12.73
1,000 miles	35¢	350	15.91

The rates represent only generalized rules-of-thumb which are subject to wide seasonal variations and back-haul opportunities. Nevertheless, this implies that absolute freight rate differences are not of great economic consequence, since all forage types would be affected by the same rate, regardless of seasonal variation. The rates quoted exclude loading and unloading charges at pick-up and delivery points. It is the loading and unloading charges for which cubes will have an advantage over loose or baled forage forms. The extent of discount offered for ease in loading and unloading cubes will vary according to local conditions.

Other Variables

Use of synthetic budgets employed in the study do not account for wide variation in cost between and within systems which are encountered in the field. Instead, they are intended to represent the more efficient or optimal situations to permit economical operation in a highly competitive environment. Individual commercial operations, however, are fraught with unique technical and economic factors peculiar to individual farm, local, and regional conditions. The discussion here is limited to identification of those variables which likely will influence individual operations involved in harvest, storage and handling and feeding of forages beyond those identified in the previous two sections.

Harvest Variables

Field Condition

- Density of forage stand
- Length of forage harvest season
- Weather conditions
- Terrain
- Length of haul to storage site

Operator Skill

Machine Use

- Field rate
- Machine capacity
- Extent of use-volume
- Degree of obsolescence
- Tractor size

Type of harvest system - labor vs. capital intensive

Capital charge and wage rates

Alternative uses of operator time

Degree of harvesting losses

Storage, Handling, and Feeding Variables

Degree of storage, handling, and feeding losses

Number of times storage unit is filled annually

Type of feeding operation

Marketing Considerations

Flexibility in selling baled or cubed forage

While it is beyond the scope of this study to measure the economic impact of each variable identified, individual operators must recognize and incorporate these items into their own cost structure. Accounting for these items is essential in determining which forage systems to select, whether the operator should perform the operation, or whether use of custom operators provides a lower cost choice. Even then, only a partial answer is achieved. Accounting for operator risk preference is also needed where production and/or weather uncertainty during harvest is important. For commercial or custom operators, accounting for these variables is important in determination of competitive capability with other operators also engaged in commercial forage operations.

Summary

Results of this study indicate that loose, baled, and silage systems which accommodate forage from field to feed bunk are economically comparable within a 300 to 1,000 ton volume range annually. The loose forage system maintains a slight ($1-$2 per ton) advantage over baled and silage forms until volumes in excess of 1,000 tons are reached. Because this advantage is small and disappears entirely at high tonnage levels, results should be tempered with consideration of "Other Variables" discussed in the previous section, when individual operators evaluate alternative systems relative to their own farm case. Evidence from comparison of several forage studies conducted in various parts of the United States suggest, with exception of the cubed system, that equal or greater cost variability, as affected by "Other Variables" specified in the study, exists between various alternative machine processes within a system than exist between systems. The cubed system, within the volume levels considered, does not compete with the other three systems. However, volume increases markedly reduce the cubed system costs, so that at 1,000 tons it is only at an $8 to $10 per ton competitive disadvantage, while at 300 tons a near $30 per ton disadvantage prevails. These results are consistent with an Arizona study which suggests that 3,000 or 4,000 tons per year for the cubed system would be required to place it in a competitive range with the other three systems [8]. ICC regulations which do not permit a transportation advantage for increased bulk density also discourage use of cubes. This may be partially offset by trucker discounts in loading and unloading of cubes. Nevertheless, cost data from this study suggest that forages in baled form likely will continue to dominate the Oregon forage market for sometime to come, in spite of the fact that marked reduction of forage loss and storage and handling costs exist for forage in cubed form. This situation may not prevail for overseas shipment of forage where decided ocean freight advantages exist for forage in highly densified forms [11].

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