AN ECONOMIC COMPARISON OF TIMOTHY HARVESTED AS HAY, DIRECT-CUT SILAGE, OR WILTED SILAGE

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A computer model was used to compare three modes of harvesting and storing timothy: direct-cut silage, wilted silage, and hay. Hay was found to be the most profitable of the harvest modes for 40-, 80- and 120-cow herds when two cuts of timothy were taken, in the circumstances where land was not a constraint. In the situation where land was a constraint (the area available on which to grow forage could not be increased) and the herd size could be increased to consume all the forage available, the silage systems were more profitable than the hay system, with direct-cut silage being more profitable than wilted silage. If both land and herd size were constraining the expansion of the dairy farm, the hay system would be the most profitable one.

INTRODUCTION

Timothy is the most commonly grown forage crop in Eastern Canada. It is harvested and stored as hay, wilted silage, or direct-cut silage. There are many substantial differences in capital and operating costs among the three principal harvest modes and in the quality and quantity of the crop harvested by them.

The purpose of this paper is to compare the harvesting and storing of timothy as direct-cut silage, wilted silage, and hay on a dairy farm and to examine the effect that the mode of harvest has on the returns to management. (The estimates of receipts, expenses, and net returns shown in this paper are particular to the assumptions used in constructing the forage-based dairy farm model. They should not necessarily be taken as representative of the dairy industry.) This examination was made using a forage-milk production model (Lovering and McIsaac 1981; Russell et al. 1977).

Model Description

The model deals with (1) the growth of the timothy plant, in which the dry matter yield, crude protein, and metabolizable energy concentrations of the plant are predicted day by day; (2) the harvest of the timothy either as direct-cut, wilted silage, or hay, simulated day by day taking account of the stage of growth of the timothy, precipitation, and harvest equipment capacity; (3) the storage of the harvested crop estimating dry matter, digestable protein, and metabolizable energy losses from several different kinds of silo (with or without formic acid) and a hay barn; (4) the determination of optimum ration and milk production from a cow whose forage is the forage grown, harvested, and stored in the preceding parts of the model; and (5) the estimation of labor, energy, and facilities required to house, feed, milk, and remove manure from the dairy herd. Estimates of investment and annual operating costs are made in each part of the model.

Hay System

Hay-harvesting machinery consists of a mower-conditioner, side-delivery rake, conventional baler, two bale wagons, and a bale escalator. Three tractors are used; one on the mower-conditioner and rake, one on the baler, and one hauling the wagon from the field to the hay barn. The wagons are pulled behind the baler and are loaded with a bale thrower attached to the baler. The bales are unloaded by hand from the wagons to a bale escalator. The bales are randomly piled in the hay barn.

Wilted Silage System

For wilted silage the timothy is cut and windrowed with a mover-conditioner. It is harvested with a pull-type forage harvester equipped with a windrow pick-up and is chopped and blown into a trailing self-unloading wagon. Two wagons are used. The full wagons are hauled to the silo where the chopped forage is loaded into a tower, horizontal, or stack silo. A tractor with a blower loads the tower silo or with a loader, spreads and packs the horizontal and stack silos. Four tractors are involved: one on each of the mower-conditioner, harvester, and silage blower or front-end loader, and one hauling full wagons from the field to the silo and returning the empty wagons to the field.

Direct-cut Silage System

The machinery used in the direct-cut silage system is similar to that used in the wilted silage system except that the crop is not cut with a mower-conditioner but is cut, chopped, and blown into a forage wagon in one operation. A flail-type forage harvester or a cylinder or flywheel-type forage harvester with a direct-cut attachment is used. Three tractors are used; one on the harvester, one hauling full wagons from the field to the silo and returning the empty wagons to the field, and one on the blower or front-end loader.

Forage Storage and Animal Housing

Gunn (1978) and Lovering and McIsaac (1980) indicate that free-stall barns with milking parlors are more economical than stanchion barns and it is more economical to handle manure as a solid. The most economical silo for storing timothy silage for most circumstances is the horizontal silo with formic acid added (McIsaac and Lovering 1980).

In this analysis, dairy herds of 40 and 80 milking cows are used in comparing the forage harvest modes. The cows are housed in a free-stall barn and milked in a double-four herringbone milking parlor with automatic milker detachers. The manure is handled as a solid. The silage is stored in horizontal silos with formic acid added. The cows are fed from the silo by a feed wagon which is loaded by a tractor with a front-end loader. The hay is stored in a pole-type hay barn. The animals are fed from the hay barn using feed carts. The cows are fed conserved forage 365 days per year.

Forage Grown

The only forage grown on the farm is timothy. Except for hay that can be purchased to help meet the minimum forage requirements of the herd, the only forage available to the herd is the home-grown timothy.

The timothy is harvested twice each year. Eighty kilograms per hectare of nitrogen fertilizer are applied to the growing timothy in the spring and after the first cut each year. Every 10 yr the timothy is plowed down and reseeded.

Crop Drying Function

The crop drying and harvesting were simulated day by day for 10 yr. In order to estimate the crop moisture on an hourly basis a crop-drying function was used. Dyer and Brown (1977) developed a function to estimate crop moisture on a daily basis. Russell (1978, unpubl. data) modified the Dyer and Brown function. The authors have further modified the function by changing the drying term constant.

The drying function is as follows:

$$Mn\ (0830) = Mo - \sum_{i=2}^{n} DRY_{1-1} + \sum_{i=2}^{n} REWET_{1-1}$$

$$Mn\ (1630) = Mo - \sum_{i=2}^{n} DRY_{1} + \sum_{i=2}^{n} REWET_{1-1}$$

where

Mo = moisture content of the standing crop (percent wet basis)

Mn (0830) = moisture content of the crop in the windrow at 0830 h on day n after cutting at 0830 h on day 1

Mn (1630) = moisture content of the crop in the windrow at 1630 h on day n after cutting at 0830 on day 1

$DRY_n = 5.0\ (PE_n - 0.2P_n)$

PE_n = potential evaporation on day n (mm)

P_n = precipation on day n (mm)

$REWET = DM/M_{n-1}(1630) * 10.0$, if P_n does not exceed 6.4 mm

$= 0.5P_n + 3.0$, if P_n exceeds 6.4 mm

DM = dry matter content of standing crop (% wet basis)

The drying term constant (5.0) used in the model runs for this analysis was derived from data obtained from experiments conducted at the Agriculture Canada, Research Station, at Charlottetown, Prince Edward Island (Narasimhalu 1980 pers. commun.) on the drying rate of timothy.

The value of the drying term constant has a large influence on the results from the model. Since the value of the constant is not well established, it is important to determine the sensitivity of the model to changes in the drying term constant.

In order to investigate the sensitivity of the model to changes in the drying term constant and to check the influence of changes in the constant on the returns to management, model runs were made to find the drying term constant that would make the returns to management for the hay system and direct-cut silage system for the 40-cow herd equal. This would give an indication of how severe the hay drying weather would have to be to make the profitability of hay as low as the profitability of direct-cut silage. When the drying term constant is 4.1, the returns to management for the 40-cow herd for the hay and direct-cut sytems are similar. The 4.1 drying term constant increased the hay-drying time by 2 days over the drying time simulated by the 5.0 drying term constant. (A low drying term constant represents a slower drying rate than a high drying term constant.) With a low drying term constant, the crop takes longer to dry in the field, has increased weathering losses associated with it, and has increased chances of being left in the field unharvested. In the simulation run using the 4.1 drying term constant, it was possible to harvest the first cut and one third of the second cut when 1980 weather data from Charlottetown, P.E.I. was used.

The drying term constant of 4.1 simulates field drying conditions that are more severe than those expcted in real life. For drying term constants higher than 4.1 the hay system is more profitable than the silage systems.

RESULTS

The following results are based on 1980 machinery and crop input prices, labor costs, and milk value. The model used (Lovering and McIsaac 1980) to obtain the results was run for 40- and 80-cow dairy herds, two harvest strategies, and three harvest modes of timothy (direct-cut silage, wilted silage, and hay). The harvest strategy is defined as the minimum crop yield at which harvest can begin. The area of forage grown is not the same for all harvest modes or harvest strategies. The amount of forage is near, but does not exceed the maximum forage that the herd can consume.

Table I shows that for 40 cows, the most profitable mode of harvest is hay. The direct-cut timothy is less profitable than hay but more profitable than wilted timothy. Although 42.5 ha have to be grown to meet the forage requirements of the herd, and the growing costs are high com-

TABLE I. THE TOTAL COSTS AND RETURNS TO MANAGEMENT FOR THREE HARVEST MODES OF TIMOTHY FOR A 40-COW DAIRY HERD

	Direct-cut silage	Wilted silage	Hay
Hectares	22.3	30.4	42.5
Harvest start yield (t/ha) (cut 1/cut 2)	3.1/2.7	3.1/2.7	3.1/1.8
Type of storage	HPF†	HPF	Hay barn
Type of barn	FSAW‡	FSAW	FSAC§
DM¶ of forage harvested (%)	18	32	81
Total DM harvested (kg/ha)	6248	6014	4512
Total DM fed (kg/ha)	5435	5242	4422
Average crude protein as fed (%, DM basis)	13.1	12.4	14.3
Avg energy concentration as fed (MJ/kg ME¶, DM basis)	9.3	9.1	9.0
Milk produced ($kg \cdot cow^{-1} \cdot yr^{-1}$)	5797	5849	5797
Timothy fed ($kg \cdot cow^{-1} \cdot yr^{-1}$)	3024	3960	4697
Barley ($kg \cdot cow^{-1} \cdot yr^{-1}$)	1768	1356	878
Oats ($kg \cdot cow^{-1} \cdot yr^{-1}$)	540	337	259
Sbom¶ ($kg \cdot cow^{-1} \cdot yr^{-1}$)	0.0	72	10
Urea ($kg \cdot cow^{-1} \cdot yr^{-1}$)	35	36	19
Total supplements ($kg \cdot cow^{-1} \cdot yr^{-1}$)	2358	1808	1171
Total labor (hs/yr)	2038	2038	2064
Annual cost			
Growing ($)	8164	11133	15586
Harvesting ($)	6507	9120	7300
Storage ($)	3913	4985	3435
Supplements ($)	18193	14731	9189
Barn ($)	19672	19838	18232
Cows ($)	18242	18242	18242
Total ($)	74692	78049	71987
Total revenue ($)	79236	79953	79236
Returns to management			
$/farm	4544	1904	7249
$/cow	114	48	181

†Horizontal silo with a polyethylene covering and formic acid added.
‡Free stall barn, solid waste, milking parlor with automatic milker detachers, animals fed using feed wagons.
§Free stall barn, solid waste, milking parlor with automatic milker detachers, animals fed from hay barn using feed carts.
¶DM = dry matter; ME = metabolizable energy; Sbom = Soybean oil meal.

pared with the direct-cut and wilted systems, the hay system is the most profitable one for handling timothy. The harvesting and storage costs associated with the hay system are less than the harvesting and storage costs for the silage systems.

The growing and harvesting costs for the direct-cut system are lower than the costs of the same operations for the wilted system because fewer hectares are grown and harvested with the direct-cut system.

The total capital investment, that is the capital investment in land, machinery, buildings, equipment and animals, for the direct-cut silage system is lower than that for the hay system. There is less capital invested in harvest machinery and in storage for the direct-cut forage system than for hay. The hay barn is more expensive to construct than the horizontal silo, but more money is spent in the operation of the silo than in the operation of the hay barn. Because the silage has a higher moisture content than the hay, more weight of material is handled which involves more tractor use in loading and unloading the silo. Formic acid is added to the silage which also adds to the silo operating cost.

The only harvest machinery involved with the direct-cut system is the forage harvester and silage wagons. With the hay system, more machinery (mower-conditioner) is involved. But with the hay system, less weight of material is handled making the annual cost of hay harvest less than the annual cost of direct-cut silage harvest as shown in Table I.

It should be noted that the minimum yield at which harvest begins for the hay system is lower than that of the other systems. The reason being that, in some years, according to the model, it is not possible to harvest all of the second cut as hay if the second cut does not begin soon enough.

A large part of the difference between direct-cut and wilted silage costs is the difference in the harvesting costs. In the direct-cut harvesting system, a mower-conditioner and the tractor associated with it are not needed as they are in the wilted silage.

TABLE II. RETURNS TO MANAGEMENT ($/COW) FOR TWO HERD SIZES AND TWO CUT STRATEGIES

	Cut strategy†	40 cows ($/cow)	80 cows ($/cow)	Cut strategy	40 cows ($/cow)	80 cows ($/cows)
Direct-cut	3.1/2.7	114	318	4.0/2.2	108	310
Wilted	3.1/2.7	48	287	4.0/2.2	57	279
Hay	3.1/1.8	181	345	4.0/1.3	163	322

†Yield (t/ha) cut 1/cut 2.

The crude protein of the hay is higher than that of the silages. This is due to the fact that the second cut of hay is taken earlier than the second cut of the silages. The earlier second cut of timothy will have a higher protein concentration than the later second cut.

Table II shows that the hay is the most profitable system for the 80-cow herd for two different cut strategies (one harvest strategy has a later harvest start date for the first cut than the other harvest strategy).

The total revenues, total annual costs, and returns to management ($/cow) for a range of herd sizes are shown in Table III for hay, wilted silage, and direct-cut silage systems. Changes in the herd size and type of forage fed (hay, wilted, or direct-cut) do not have much effect on the milk production per cow and hence the revenue per cow. As the herd size increases, the total annual costs decrease and the returns to management increase.

It is assumed that, for the larger herd sizes and larger areas of forage, the forage-harvesting system will be the same as those outlined earlier in this paper. Changes in the harvesting system could affect the cost of the system and change the returns to management to the extent that hay would not be the most profitable. For example, in the hay system, there is one man at the hay barn unloading the wagons by hand. For the larger hay area (127 ha) the harvesting system capacity is 6.4 t/h. It is assumed that one man can unload the hay wagons at this rate. The addition of another man to help with the harvest of hay adds $5.54 per cow per year to the total annual cost. There is $24 per cow difference in the returns to management between the hay and direct-cut silage systems in favor of the hay. If the extra man was added, the hay system would still be more economically favorable than the silage system.

CONSTRAINTS

On some farms there may be constraints limiting the land available to grow forage or there may be capital or other constraints limiting the herd size.

Table IV represents the case where there are constraints on the expansion of the herd size and land area. It shows the returns to management for a 40-cow herd for each of the hay, and wilted and direct-cut silage systems for the case where the area of forage is limited to 26 ha. Although there is less forage dry matter available to be fed and more supplements are fed, the hay system has higher returns to management than the silage systems.

On other farms, land may be the only constraint. To investigate this, the model was run for the hay, and wilted and direct-cut silage systems with the area of forage to be harvested constant at 42.5 ha. The number of cows on the farm was determined by the amount of forage available. There is less forage harvested in the hay system than in the silage systems, so the amount of forage as hay would support fewer cows than the silage (Table V). The direct-cut silage system is more profitable than the hay or the wilted silage systems for the situation where land is limited and capital is not. The direct-cut forage from 42.5 ha would support 79 cows. In each case in Table V, the cows consume the maximum amount of forage allowed by the model. The intake of silage is limited

TABLE III. TOTAL REVENUE, ANNUAL COSTS, AND RETURNS ($/COW) FOR DIRECT-CUT AND WILTED SILAGE, AND HAY SYSTEMS ON DAIRY FARMS OF 40, 80 AND 120 COWS

	40 cows			80 cows			120 cows		
	Revenue	Total cost	Returns	Revenue	Total cost	Returns	Revenue	Total cost	Returns
Direct-cut	1981	1867	114	1981	1663	318	1960	1583	377
Wilted	1981	1932	48	2000	1709	287	1977	1623	354
Hay	1981	1800	181	1981	1636	345	1977	1586	391

TABLE IV. RETURNS TO MANAGEMENT ($/COW) FOR A 40-COW DAIRY HERD AND 22.3 ha FOR WILTED AND DIRECT-CUT SILAGE AND HAY

	Hay	Direct-cut silage†	Wilted silage†
Cut strategy (t/ha)	3.6/1.8	3.1/2.7	3.1/2.7
Crude protein as fed (%, DM basis)	14.0	13.2	12.7
Metabolizable energy as fed (MJ/kg, DM basis)	9.0	9.3	9.17
Timothy fed ($kg \cdot cow^{-1} \cdot yr^{-1}$)	2544	3024	2848
Total cost ($)	73732	74692	77715
Total revenue ($)	79236	79236	79236
Returns to management ($/cow)	138	114	38

†Silage is stored in a horizontal silo with formic acid added and covered with a polyethylene covering.

TABLE V. RETURNS TO MANAGEMENT ($/COW) FOR 42.5 ha OF FORAGE HARVESTED AS WILTED AND DIRECT-CUT SILAGE AND HAY

	Hay	Direct-cut silage†	Wilted silage†
Number of cows	40	79	59
Timothy fed ($kg \cdot cow^{-1} \cdot yr^{-1}$)	4697	3077	3887
Total supplements fed ($kg \cdot cow^{-1} \cdot yr^{-1}$)	1171	2373	1898
Total capital investment ($)	245956	315593	308910
Total annual cost ($)	71937	131149	106020
Total annual revenue ($)	79236	156491	117970
Returns to management ($/cow)	181	320	202

†Silage is stored in a horizontal silo with formic acid added and covered with a polyethylene covering.

to a maximum of 45 kg per cow per day. With the direct-cut silage situation, where the moisture content of the forage is high (82% moisture), 45 kg of silage, as fed, represents 8.2 kg of dry matter. As a result, many cows are needed to consume all the silage.

Previous runs of the computer model show that the cost of the energy and protein from the supplements is similar to the cost of the energy and protein from the forage. As a result, substituting forage for grain does not reduce the total cost significantly. The fact that more forage and less supplements are fed in the system does not decrease the cost of hay enough to make it as economically attractive as the silages in the situation where land is a constraint and the herd size can be expanded to consume all the forage grown on that land.

SUMMARY

A computer model was used to compare three modes of harvesting and storing timothy: direct-cut silage, wilted silage, and hay. Hay was found to be the most profitable of the harvest modes for 40-, 80-, and 120-cow herds when two cuts of timothy were taken, in the circumstances where land was not a constraint.

In the situation where land was a constraint (the area available on which to grow forage could not be increased) and the herd size could be increased to consume all the forage available, the silage systems were more profitable than the hay system, with direct-cut silage being more profitable than wilted silage.

If both land and herd size were constraining the expansion of the dairy farm, the hay system would be the most profitable one.

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