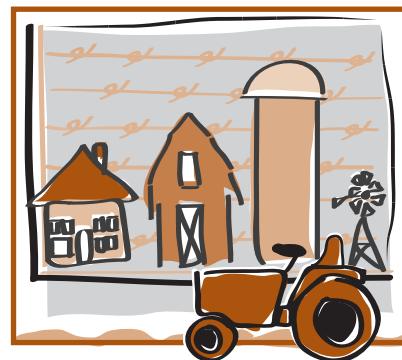


The Economics of Hay Storage Structures

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Alfalfa is an important crop for Colorado agriculture. Producers in many parts of the state grow alfalfa because environmental conditions are favorable and regional demand is strong. According to the USDA/NASS, Colorado alfalfa producers grew hay on 820,000 acres in 2010. Depending on conditions and location, growers in Colorado report 4-8 tons of alfalfa per acre annually on irrigated ground. In 2010, Colorado alfalfa hay production was valued at over \$361 million (USDA/NASS).

During fall of 2011 limited forage supplies, coinciding with robust demand, pushed prices for supreme quality alfalfa in southern Colorado to \$300 per ton. (This alfalfa price is almost triple the national average price that occurred between the years 2000 and 2010.) Nationally, forage supplies were tight in 2011 as drought affected many parts of Texas, Oklahoma, Kansas and New Mexico. The demand outlook for forage should remain positive in the next few years provided higher cattle prices entice producers to rebuild liquidated herds.

In the U.S., both large round and large square bales became popular in the 1970s, primarily because of low labor requirements. Previously, small squares had been the standard—but since each small bale must be handled multiple times, they are much more labor intensive. As labor became scarce, hay producers gradually discarded small square balers and adopted large bale machinery. This technology gave producers the opportunity to substitute mechanization for increasingly expensive labor.

Unfortunately, the substitution of large bales for small square bales has resulted in greater hay storage losses because large bales are frequently stored outside and uncovered. For example, it is common to find round

bales stacked unprotected in fields because their shape allows the shedding of some precipitation (Huhnke). Large squares are also frequently stored outside and uncovered but their shape does not provide them the same level of moisture protection. And while much of Colorado does not receive significant precipitation amounts, storing large squares in an unprotected environment will negatively impact both forage quantity and quality. Because these losses are difficult to estimate, the exact costs of leaving hay unprotected are unknown.

Hay Storage

At safe moisture levels (< 20%) dry matter losses for hay stored inside are generally around 3-5% (Ball et al.; Huhnke). These unavoidable losses are the result of continued plant respiration and microbial action (Ball et al.). Hay baled at higher moisture levels, or exposed to excessive humidity or precipitation, can suffer significantly greater losses. When stacked on bare ground, deterioration on the bottom of bales will be substantial if significant moisture is wicked into the bale. In addition to dry matter reduction, spoilage also degrades hay quality, eroding value.

Hay losses from large bales stored uncovered on the ground are as much as three times greater than with bales stored inside (Cattle Producer's Library). In areas with low humidity and precipitation, dry matter losses from uncovered hay stored on the ground can be 15% in a 12-18 month period (Huhnke). In the eastern U.S., hay bales stored outside for up to a year will result in 4-8 inches of spoilage around the tops and sides (Ball et al.). For a round bale, 3 inches of outside diameter is 27% of volume for a bale that measures 5' x 5'.

With Colorado's relatively low precipitation and humidity, it is unclear whether structures that protect hay from moisture are economically defensible.

Quick Facts

- In Colorado, a popular structure for storing hay is a post frame shed, which is essentially a high roof over a dirt floor. These structures help shield the tops of hay stacks from direct rain and snowfall.
- Another common hay storage configuration in Colorado—a column-free steel frame structure—requires less maintenance than a post frame shed and has a longer life. These facilities can also be larger than wooden-post sheds.
- The Payback Method uses the initial investment cost and the additional annual revenue to determine economic efficiency. The payback period is the length of time (in years) it takes to recapture the initial investment.

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Therefore, hay producers will benefit from knowing whether the losses associated with leaving hay unprotected justify the construction of a facility that prevents hay losses. The purpose of this publication is to determine whether or not the cost savings from storing large alfalfa square bales (4' x 4' x 8') under a covered facility is cost effective.

Wooden-Post Frame Shed

In Colorado, a popular structure for storing hay is a post frame shed. Essentially a high roof over a dirt floor, these structures help shield the tops of hay stacks from direct rain and snowfall. The roof also helps prevent moisture from accumulating around the bottom of hay bales. Frequently producers will construct sheds which feature one or more side walls to deflect windblown moisture.

A structure measuring 20'H x 50'W x 80'L will shelter approximately 360 tightly-packed large square bales. The top and bottom area of this hay stack is 2,880 ft²,

and the dimensions of the stack are four bales high, five bales wide and eighteen bales in length. Each bale's volume is 128 ft³, and assuming each bale weighs 1,400 lbs, the hay weight is 10.94 lbs per ft³. Assuming a cost of \$6 per ft², the initial construction cost for this structure is \$24,000.

Compared to no storage, this type of structure has the potential to prevent significant hay quantity and quality losses. For purposes of this publication, only hay deterioration on the top of the stack is assumed. Table 1 provides estimates of hay loss prevented by the shelter, in volume and weight, assuming five different levels of potential deterioration. The table also lists estimates of the value of the hay loss prevented for different alfalfa prices (\$160, \$180, \$200 and \$220 per ton respectively). For example, an average loss of 2" of hay from the top of this stack represents 480 ft³ or 2.62 tons, valued at \$419 (when alfalfa is \$160/ton). (These losses are in addition to normal dry matter losses from hay stored in an enclosure.)

Column-Free Steel Frame Structure

Another common hay storage configuration in Colorado—a steel frame structure—requires less maintenance than a post frame shed and has a longer life. These facilities can also be larger than wooden-post sheds. A structure sized 20'H x 70'W x 120'L will store 784 bales. The top and bottom area of this hay stack is 6,272 ft², and the dimensions of the stack are four bales high, seven bales wide and twenty-eight bales in length. Assuming a construction cost of \$10 per ft², the initial cost for this structure is \$84,000. Table 2 provides estimates of hay loss prevented by the shelter, in volume and weight, assuming five different levels of potential deterioration. The table also lists estimates of the value of the hay loss prevented for different alfalfa prices (\$160, \$180, \$200 and \$220 per ton respectively).

Capital Budgeting

Agriculture producers, like other business owners, recognize growth as

Table 1. Annual Hay Loss Prevented (Volume & Weight) & Value for Post Shed

Inches (top)	Cubic feet	Tons	Hay price per ton			
			\$160	\$180	\$200	\$220
2"	480	2.62	\$419	\$472	\$524	\$576
4"	960	5.25	\$840	\$945	\$1,050	\$1,155
6"	1,440	7.88	\$1,261	\$1,418	\$1,576	\$1,734
8"	1,920	10.50	\$1,680	\$1,890	\$2,100	\$2,310
10"	2,400	13.13	\$2,101	\$2,363	\$2,626	\$2,888

Note: 2" loss from top represents approximately 1% of total stack volume, and
 4" loss represents 2%
 6" loss represents 3.1%
 8" loss represents 4.2%
 10" loss represents 5.2%

Table 2. Annual Hay Loss Prevented (Volume & Weight) & Value for Steel Structure

Inches (top)	Cubic feet	Tons	Hay price per ton			
			\$160	\$180	\$200	\$220
2"	1,045	5.72	\$915	\$1,030	\$1,144	\$1,258
4"	2,091	11.44	\$1,830	\$2,059	\$2,288	\$2,517
6"	3,136	17.15	\$2,744	\$3,087	\$3,430	\$3,773
8"	4,181	22.81	\$3,650	\$4,106	\$4,562	\$5,018
10"	5,227	28.59	\$4,574	\$5,146	\$5,718	\$6,290

Table 3. Payback Period in Years for Post Frame Shed

Inches (top)	Hay price in tons			
	\$160	\$180	\$200	\$220
2"	57.3	50.8	45.8	41.6
4"	28.6	25.4	22.9	20.8
6"	19.0	16.9	15.2	13.8
8"	14.3	12.7	11.4	10.4
10"	11.4	10.2	9.1	8.3

an opportunity to increase profit. When growth includes the possibility of facility expansion, managers consider whether the construction of a new facility is cost effective. Assuming a new structure generates additional revenue - or reduces costs - the initial construction and future maintenance costs must be less than the projected future revenue for the project to be economically acceptable. The initial dollar amounts required to finance these projects are called capital expenditures. Analysis of whether or not a capital expenditure is economically efficient is called capital budgeting. There exist several popular methods for analyzing the profitability of capital investments. One is called the Payback Method.

Payback Method

The Payback Method uses the initial investment cost and the additional annual revenue to determine economic efficiency. The payback period is the length of time (in years) it takes to recapture the initial investment. Obviously, a shorter payback period is preferred to a longer one. The payback period is determined by using the following formula.

$$\text{Payback Period (years)} = \frac{\text{Initial Investment Cost}}{\text{Additional Revenue/Year}}$$

Using an investment cost of \$24,000, and the value of hay loss prevented from Table 1 as additional revenue, payback periods for the post frame shed are given in Table 3.

As expected, both higher damage levels and higher alfalfa hay prices reduce the number of years that are required to recoup the initial investment. Considering a useful life of 20 years, the cumulative revenue provided by the post frame shed will exceed the initial cost at each hay price when damage is 6" or greater.

Using an investment cost of \$84,000, and the value of hay loss prevented from Table 2 as additional revenue, payback periods for the steel frame structure are given in Table 4.

Table 4 shows longer payback periods than Table 3. One reason is because the steel frame structure is more expensive than the post frame shed. However, it is also reasonable to assume that the steel frame structure has a longer useful life (25-35 years). At high damage levels (≥ 6") the steel frame structure is paid for in 30 years or less at each hay price.

Net Present Value (NPV) Method

The Payback Method is straight-forward and simple. However, one of its shortcomings is that it fails to account for the time value of money. NPV does incorporate the time value of money concept and is therefore considered a superior capital budgeting procedure. However, the NPV Method is a more complicated procedure and requires more managerial input.

The NPV Method uses discounting to determine present values, and NPV is the difference between the present value (discounted value) of all future revenue and the initial investment. Discounting future

revenue converts future dollars into current dollars.

In equation form the NPV is calculated as:

$$NPV = -II + AR_1 * CF_1 + AR_2 * CF_2 + \dots + AR_N * CF_N$$

Where II = Initial Investment
AR = Additional Revenue for years 1,2, ..., N
CF = Conversion Factor for years 1,2, ..., N

The initial investment (construction cost) is a negative number because it represents an initial cost. Additional revenue is the annual value of the hay loss prevented. NPV is calculated as future additional revenue, discounted and summed, less the initial investment. Specific conversion factors are associated with different discount rates. Conversion factors convert future dollars into current dollars and are taken from annuity tables. The discount rate (i) is an interest rate that reflects the required rate-of-return.

The decision rule for NPV models is simple: Accept an investment if the NPV is positive. A positive NPV implies that the investment analyzed is earning a rate-of-return greater than the rate (i) specified in the model. A negative NPV means the investment fails to earn the required rate-of-return. The NPV model requires the decision maker to select i – the discount rate – which is the required rate-of-return. This discount rate is best understood as an opportunity cost.

Table 5 is an example of how NPV is calculated. In the fourth column are present values for a 2" level of hay deterioration and hay price of \$160 per ton. Present values are found by multiplying revenue values in column 2 by conversion factors in column 3. The initial investment is subtracted from the sum of the present values to find NPV.

For this publication revenue is increased 0.5% each year to account for inflation. A

Table 4. Payback Period in Years for Steel Frame Structure

Inches (top)	Hay price in tons			
	\$160	\$180	\$200	\$220
2"	91.8	81.5	73.4	66.8
4"	45.9	40.8	36.7	33.4
6"	30.6	27.2	24.5	22.3
8"	23.0	20.5	18.4	16.7
10"	18.4	16.3	14.7	13.3

Table 5. NPV for Post Frame Shed (2" loss, \$160/ton hay price)

Year	Additional Revenue	Conversion Factor	Present Value
0			(24,000)
1	419	0.97	407
2	421	0.94	397
3	423	0.92	387
4	425	0.89	378
5	427	0.86	369
6	430	0.84	360
7	432	0.81	351
8	434	0.79	342
9	436	0.77	334
10	438	0.74	326
11	440	0.72	318
12	443	0.70	310
13	445	0.68	303
14	447	0.66	295
15	449	0.64	288
16	451	0.62	281
17	454	0.61	274
18	456	0.59	268
19	458	0.57	264
20	461	0.55	255
NPV			-17,493

Table 6. NPVs for Post Frame Shed

Inches (top)	Hay price in tons			
	\$160	\$180	\$200	\$220
2"	-17,493	-16,670	-15,862	-15,055
4"	-10,955	-9,324	-7,694	-6,063
6"	-4,417	-1,979	475	2,929
8"	2,090	5,351	8,613	11,874
10"	8,628	12,697	16,781	20,850

Table 7. NPVs for Steel Frame Structure

Inches (top)	Hay price in tons			
	\$160	\$180	\$200	\$220
2"	-69,790	-68,004	-66,234	-64,463
4"	-55,580	-52,024	-48,468	-44,911
6"	-41,386	-36,059	-30,733	-25,406
8"	-27,316	-20,234	-13,153	-6,071
10"	-12,982	-4,114	4,769	13,652

discount rate of 3% was selected because it was assumed to be a minimum acceptable rate-of-return level. (Higher discount rates will result in positive NPVs only at deeper hay deterioration levels and higher hay prices.)

Post Frame Shed NPV Assumptions

Initial Investment Expenditure....\$24,000

Rate-of-Return.....3%

Revenue is increased 0.5% each year for inflation

Table 6 shows the NPV for the post frame shed for each level of hay loss prevented, at each hay price. Notice that the frame shed is not cost effective until the hay loss prevented reaches the 6" depth at a hay price of \$200 per ton.

Steel Frame Structure NPV Assumptions

Initial Investment Expenditure....\$84,000

Rate-of-Return.....3%

Revenue is increased 0.5% each year for inflation

Table 7 shows the NPV for the steel frame structure for each level of hay loss prevented, at each hay price. Notice that the steel structure is not cost effective until hay loss prevented reaches the 10" depth at a hay price of \$200 per ton.

Conclusion

The Payback Method estimates the length of time required for an investment to pay for itself. With the post frame shed, the investment cost is regained in less than 20 years at the 6" or greater level of loss prevented for all hay prices. The steel frame structure is paid for in 30 or fewer years at all hay prices when loss prevented is 6" or greater. However, the Payback Method fails to address the time value of money and the length of the revenue stream.

The NPV Method determines whether or not discounted future returns exceed the initial investment level. An investment with a positive NPV is cost effective; a negative NPV signifies an unprofitable investment. In this analysis, the post frame shed is economically efficient at lower levels of damage prevention and at lower hay prices than is the steel frame structure. Because

the steel frame structure is relatively expensive, only at the highest level of damage prevention, and at high hay prices, does it become cost effective.

In this publication, weather-caused hay deterioration was assumed to occur only on the tops of hay stacks. However, the two enclosures discussed here will also prevent some hay deterioration on the sides and bottoms of bales. A cover that prevents some of these additional side or bottom losses will make each structure more economically attractive than indicated in the preceding tables. Also note that an initial construction cost that is higher or lower than those assumed here will impact the economic feasibility of a hay storage structure.

When deciding whether or not a hay storage structure is warranted, producers should also consider the effect precipitation has on hay quality. Producers should know that precipitation can cause significant reductions in hay quality in addition to dry matter losses. Hay without appropriate cover may enter storage as superior quality but over time will transition to lower quality (and lower value) hay. Although hay quality levels are somewhat subjective and difficult to measure, significant quality reductions will negatively impact price and producers must consider this when formulating hay storage plans.

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