1980

The Influence of Harvesting Strategies and Economic Constraints on the Feasibility of Farm Grain Drying and Storage Facilities

Otto J. Loewer Jr.
University of Kentucky

Thomas C. Bridges
University of Kentucky, tom.bridges2@uky.edu

G. M. White
University of Kentucky

Douglas G. Overhults
University of Nebraska

The Influence of Harvesting Strategies and Economic Constraints on the Feasibility of Farm Grain Drying and Storage Facilities

Otto J. Loewer, Jr., T. C. Bridges, G. M. White, D. G. Overhults
ASSOC. MEMBER ASAE · ASSOC. MEMBER ASAE · MEMBER ASAE

ABSTRACT

THE economic return to on-the-farm grain drying and storage facilities is influenced by many factors including harvesting strategies, facility management, market conditions, energy considerations, and facility design. This study evaluates the influence of these factors on expected net return.

INTRODUCTION

The economic return to farmers for on-the-farm grain drying and storage facilities is influenced by many factors. These include harvesting strategies, facility management practices, market conditions, energy considerations and facility component costs. These factors have been integrated into the computer model CACHE, acronym for Computer Analysis of Corn Handling Economics, (Loewer et al., 1975a, 1975b, 1975c, 1976d; Loewer et al., 1976a, 1976b) with the model being utilized to assist farmers in evaluating the desirability of purchasing grain drying and storage equipment (Loewer, 1977). The objective of this study is to present the influence of many of the above mentioned factors on the economic return from on-the-farm grain storage facilities as determined by using the CACHE model. In this study the term "storage facilities" is used to designate grain drying, handling and storage equipment and structures associated with a centralized grain facility. Corn is the only grain considered.

PROCEDURE

The factors that were considered in the study are given in Table 1 along with the level of factor for three selected "base" conditions. A base condition is defined as a stated set of resource and management condition inputs and may be viewed as three separate farm systems. A range of input conditions was selected for each of the input factors considered, while holding each of the other base inputs constant. This is commonly referred to as a sensitivity analysis.

In terms of expected economic return, Base Condition 1 might be described as the "pessimistic" view, Base Condition 2 as the "optimistic" view with Base Condition 3 being the "middle" view. In most cases, however, the effects of changing the values of any factor affect all three conditions in much the same way. In other words, the rate of change is very nearly equal in most instances, and the relative importance of this quantity will be emphasized rather than the absolute values as obtained from the sensitivity analysis.

It should be noted that for each of the base conditions, all of the harvested grain is dried, stored, and marketed.

RESULTS

Harvesting Strategy Factors

Field losses are a function of moisture content, yield and length of harvest (Johnson and Lamp, 1966). The CACHE model utilizes the data shown in Figs. 1 and 2 to describe the relationships among these factors. Generally, harvest losses increase with lower moisture contents at the beginning of harvest, and longer harvest times. The economic return to grain storage and drying involves a comparison of a farm with and without a grain facility. In other words, an evaluation will be made of harvesting strategies "with" and "without" the facility. It should be noted that the expected net return per unit volume is based on the quantity of dry grain (15.5 percent wet basis) actually harvested when grain drying and storage were available and that this number may change if the harvesting strategy changes. The total net return for a given system is the product of the net return per unit volume (cubic meters or bushels) and the number of "dry" units harvested.

Calendar Days for Harvesting with Drying: The relationship between the number of calendar days required to harvest the grain if farm storage is available and the expected net return to grain storage is shown in Fig. 3. As harvest time increases, net return to storage decreases, the average rate being approximately -\$0.073/m^3 (-\$0.00258/bushel) per day of harvest delay. This assumes that for the total farm economic system no additional expense is incurred when the total harvest time is reduced.

Calendar Days for Harvesting without Drying: The relationship between the time required for harvesting if no grain facility is available and the net return to farm storage is shown in Fig. 4. As the time required for harvesting "without" a farm facility increases, harvest losses increase. This is reflected by an increase in the desirability of on-the-farm storage as shown in the general increase in expected net return. The net effort is approximately \$0.027/m^3 (\$0.000945/bushel) for each additional day that was required to harvest the grain when no facility was available.

Beginning Harvest Moisture Content with Drying: The earlier that harvest begins, the less the harvest losses. However, more fuel is required for drying. The trade-off in these relationships in terms of net profit is shown in

Article has been reviewed and approved for publication by the Electric Power and Processing Division of ASAE.

This paper is published with the approval of the Director of the Kentucky Agricultural Experiment Station and designated Paper No. 78-2-40.

The authors are: OTTO J. LOEWER, JR., Associate Extension Professor, T. C. BRIDGES, Research Specialist and G. M. WHITE, Associate Professor, Agricultural Engineering Dept., University of Kentucky, Lexington; and D. G. OVERHULTS, Assistant Instructor, Agricultural Engineering Dept., East Campus, University of Nebraska, Lincoln.

TABLE 1. BASE FACTORS CONSIDERED IN DETERMINING THE FEASIBILITY OF ON-THE-FARM GRAIN DRYING AND STORAGE SYSTEMS INCLUDING EXPECTED NET RETURN

			Base 1 Condition	Base 2 Condition	Base 3 Condition
I.	Harvesting strategies				
	A.	If on-the-farm grain drying and storage is not available			
		1. Calendar days required for harvesting	20.0	30.0	45.0
		2. Moisture content when harvest begins, percent	25.0	20.0	30.0
		3. Speed of corn harvester, km/h (mph)	5.6 (3.5)	5.6 (3.5)	4.0 (3.5)
	B.	If on-the-farm grain drying and storage is available			
		1. Calendar days required for harvesting	20.0	20.0	35.0
		2. Moisture content when harvest begins, percent	25.0	25.0	30.0
		3. Speed of corn harvester, km/h (mph)	5.6 (3.5)	4.0 (2.5)	4.0 (2.5)
II.	Facility management strategies				
	A.	Interest, taxes and insurance as a percent of the average value of the grain	10.0	8.0	8.0
	B.	Average number of months that grain is stored	6.0	5.0	4.0
	C.	Moisture content of stored corn, percent	13.5	13.5	13.5
III.	Market conditions				
	A.	Price of corn at harvest, $\$/m^3$ ($/bu)	70.95 (2.50)	70.95 (2.50)	70.95 (2.50)
	B.	Expected percentage increase in the value of stored grain, percent	10.0	15.0	15.0
	C.	Base moisture content of corn, percent	15.5	15.5	15.5
IV.	Energy considerations				
	A.	LP gas used per point of moisture removed, liters (gallons)	0.0053 (0.02)	0.0053 (0.02)	0.0053 (0.02)
	B.	Price of LP gas, $/L ($/gal)	0.106 (0.40)	0.092 (0.35)	0.106 (0.40)
	C.	Average drop per day in field moisture content after harvesting begins (points/day)	0.25	0.25	0.25
V.	Facility design				
	A.	Potential yield, m^3/ha, (bu/acre) (no harvest losses)	1.426 (100.0)	1.569 (110.0)	1.711 (120.0)
	B.	Corn to be dried and stored, ha (acres)	40.5 (100.0)	101.2 (250.0)	121.4 (300.0)
	C.	Drying technique (1 = layer; 2 = batch-in-bin; 3 = portable)	2.0	2.0	3.0
	D.	Degree of mechanization, percent (0 = portable handling system; 50 = bucket elevator and pit; 100 = bucket elevator and pit, center building, scale)	0.0	0.0	0.0
VI.	Net return per dry unit (15.5% wet basis, $\$/m^3$, (¢ /bushel))		- 7.35 (- 25.91)	3.37 (11.89)	0.89 (3.12)

Fig. 5, with the optimum moisture to begin harvesting when on-the-farm storage is available being in the 26 to 28 percent range for the situations shown.

Beginning Harvest Moisture Content without Drying: In recent years, the most common dockage rate scheme used by commerical elevators for excessive corn moisture has been to reduce the price received per wet bushel by 2 percent of the dry bushel selling price for each point of moisture above the base level, 15.5 for No. 2 corn (Loewer and Hamilton, 1974). This approach is used in the CACHE model. As the moisture content at which harvest begins increases with the no-drying situation, the

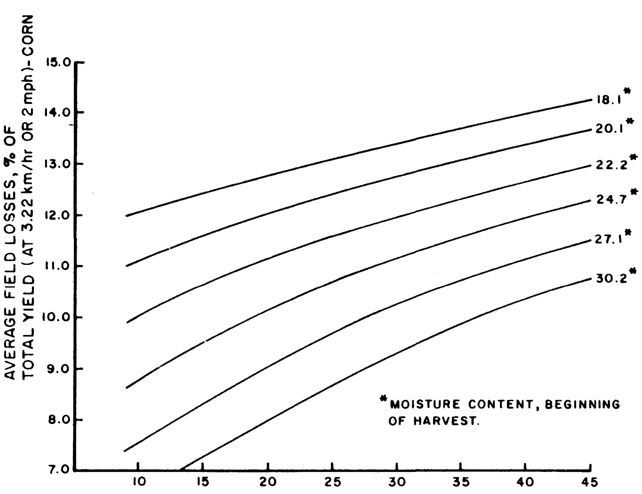

FIG. 1 Average field losses, as a percentage of potential yield, as influenced by the moisture content at the beginning of harvest and the calendar days required for harvesting for a combine operating speed of 2 mph. (Johnson and Lamp, 1966)

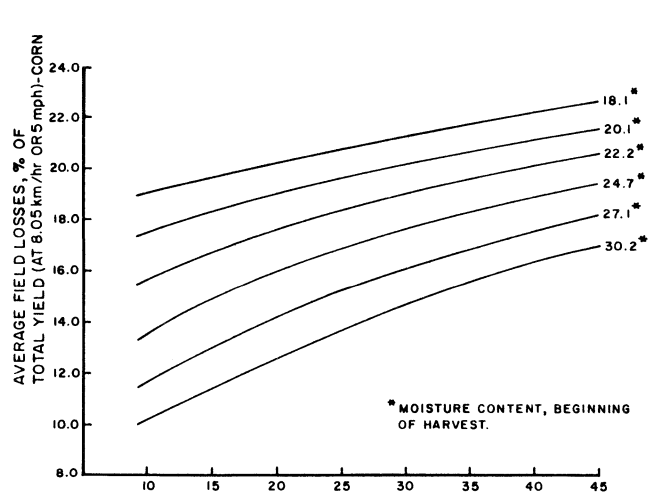

FIG. 2 Average field losses, as a percentage of potential yield, as influenced by the moisture content at the beginning of harvest and the calendar days required for harvesting for a combine operating speed of 5 mph. (Johnson and Lamp, 1966)

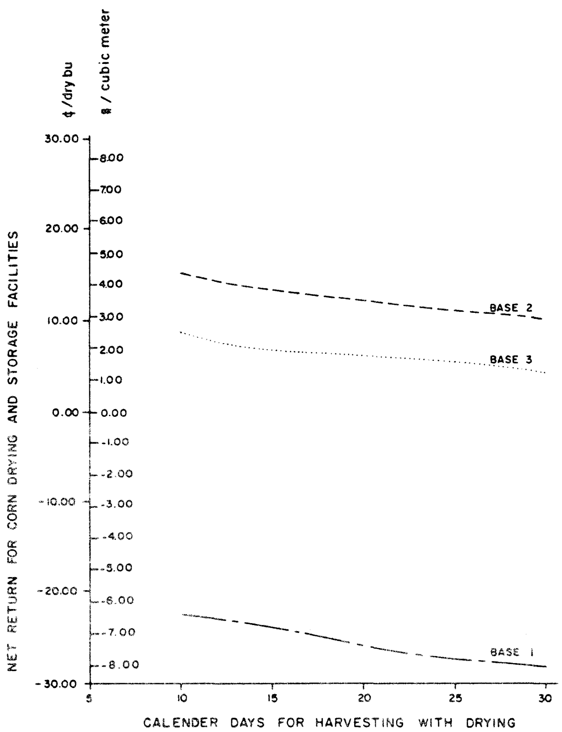

FIG. 3 Net return for on-the-farm corn drying and storage facilities as influenced by the calendar days required for harvesting if on-the-farm grain drying and storage facilities are available.

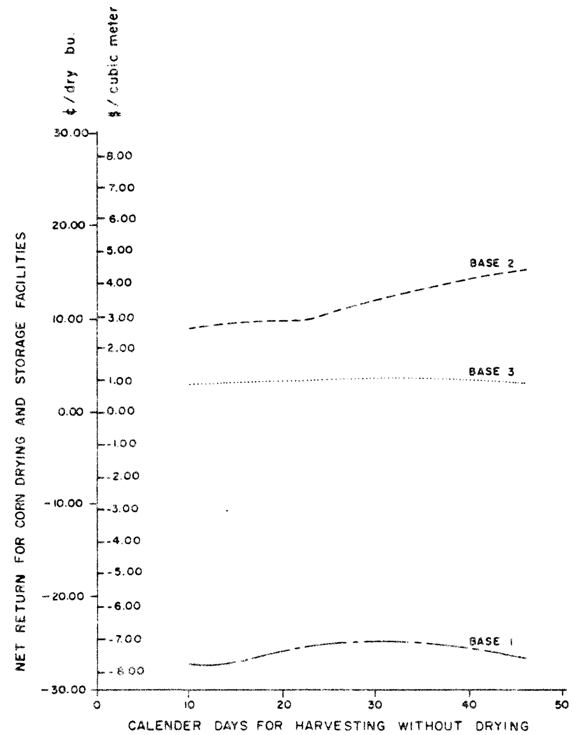

FIG. 4 Net return for on-the-farm corn drying and storage facilities as influenced by the calendar days required for harvesting if on-the-farm grain drying and storage facilities are not available.

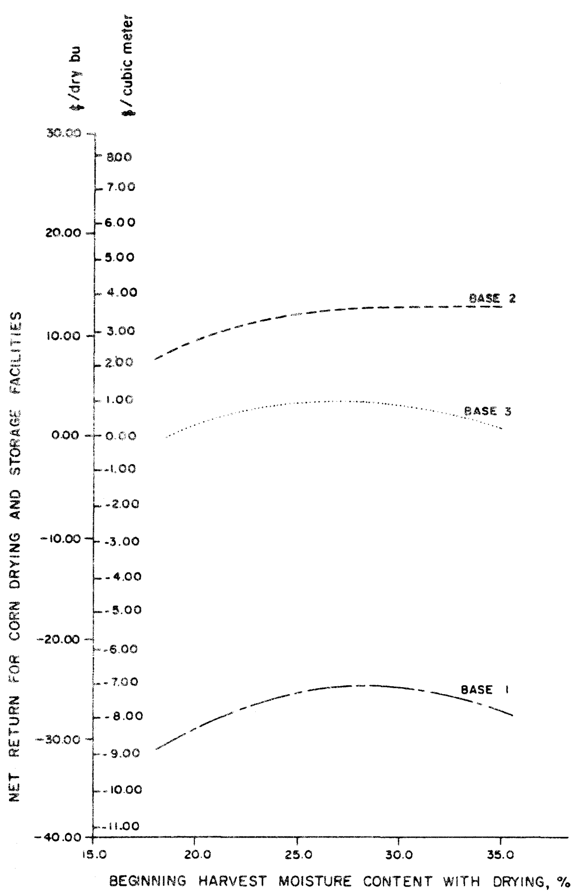

FIG. 5 Net return for on-the-farm corn drying and storage facilities as influenced by the calendar days required for harvesting if on-the-farm grain drying and storage facilities are available.

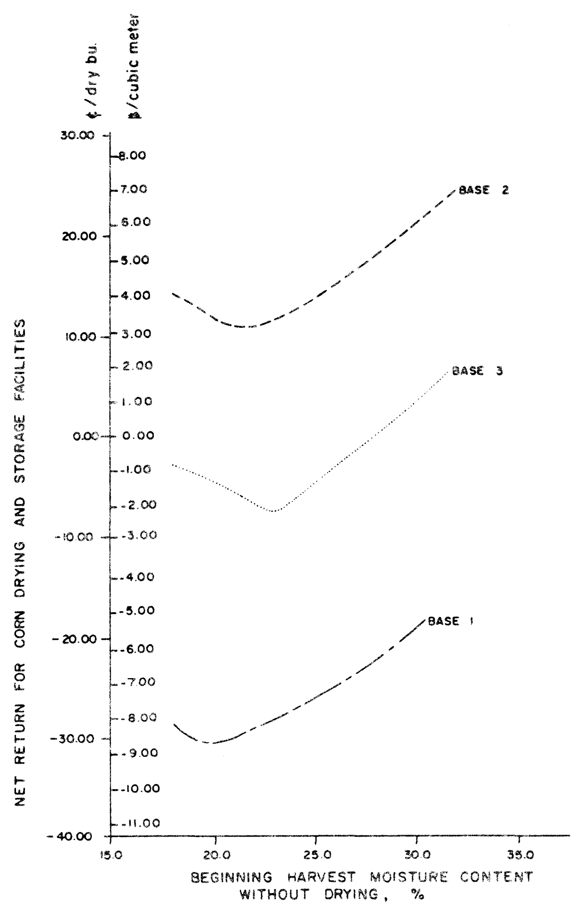

FIG. 6 Net return for on-the-farm corn drying and storage facilities as influenced by the moisture content at which harvest begins if on-the-farm grain drying and storage facilities are not available.

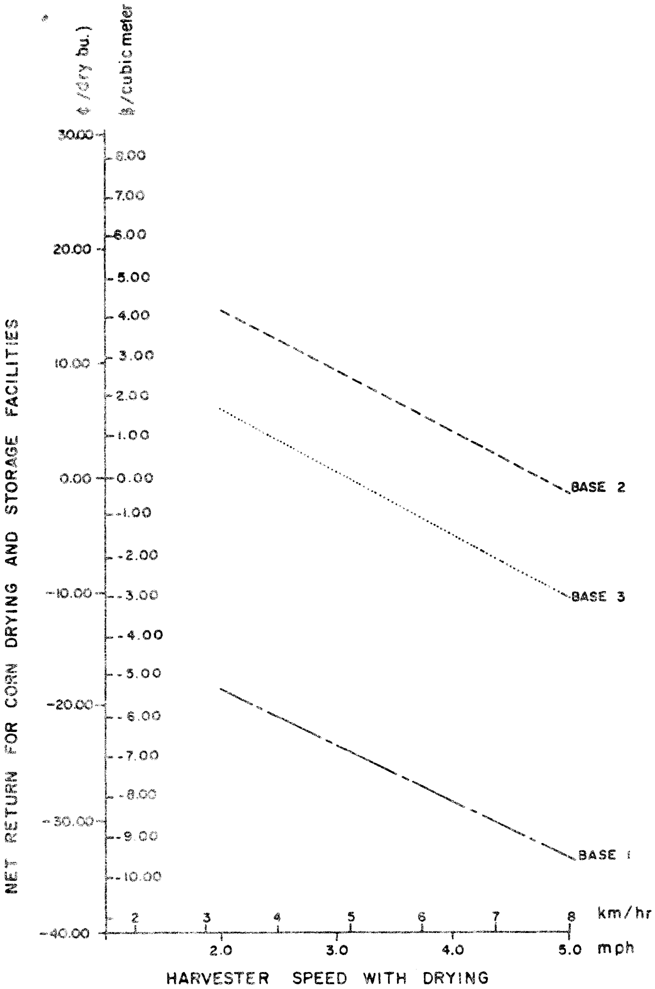

FIG. 7 Net return for on-the-farm grain drying and storage as influenced by the average operating speed of the harvester if on-the-farm grain drying and storage facilities are available.

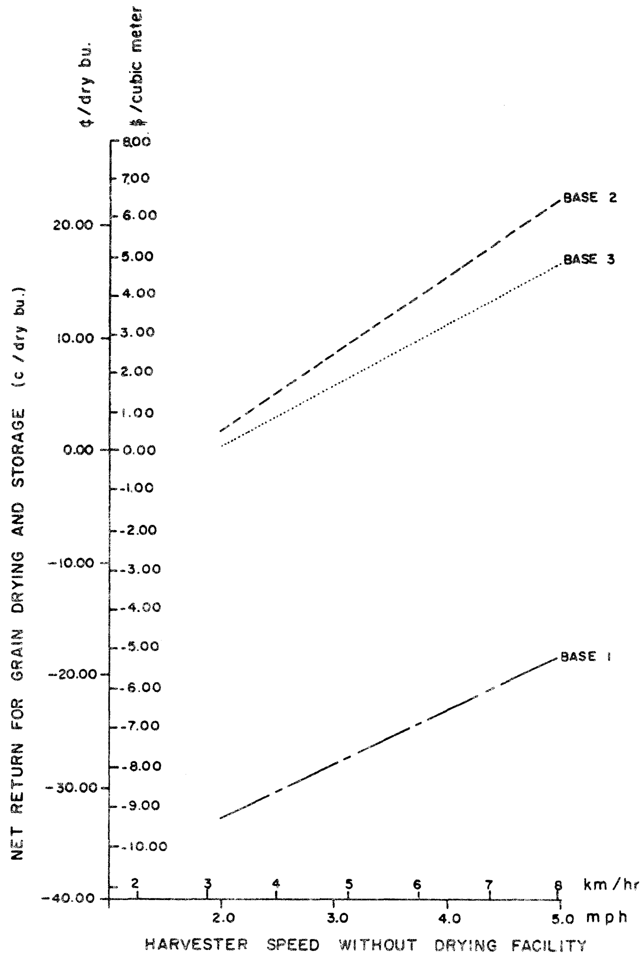

FIG. 8 Net return for on-the-farm corn drying and storage facilities as influenced by the operating speed of the harvester if on-the-farm grain drying and storage facilities are not available.

harvest losses decrease but the dockage increases. The trade-off between these relationships in terms of net profit is shown in Fig. 6. This would indicate that if the farmer has no grain storage system and has traditionally begun his harvest in the 21 to 23 percent moisture content range, he will receive relatively less benefit from the addition of a grain facility.

Harvest Speed with Drying: The relationship between harvest speed, when having a drying and storage system, and net economic return is shown in Fig. 7. As speed increases in the "with drying" option, harvest losses also increase which accounts for the reduction in net profit, the rate being approximately -$1.467/m³/km/h (-5.168 cents/bu/mph) increase in harvest speed. This assumes that the increase in harvester speed will not reduce overall harvesting time in terms of calendar days.

Harvester Speed without Drying: As harvesting speed increases when farm storage is not available, harvest losses also increase, resulting in a more favorable expected economic return to the "with drying" option (Fig. 8). The rate of return is approximately $1.603/m³/ km/h (5.649 cents/bushel for each additonal mph) in harvest speed.

Facility Management Practices

Once the farmer has committed himself to the storage of his grain, he must then make decisions concerning the management of his drying and storage system.

Interest, Taxes and Insurance: If grain were sold at harvest time, the money from this sale could be used to repay loans or placed in a savings account. Regardless, the interest charge to stored grain must be viewed as an opportunity cost. Likewise, taxes and insurance charges are a function of the value placed on the stored grain. The effects of a composite interest, taxes and insurance charge on expected net return are shown in Fig. 9. Note that the slopes for the three base conditions are not parallel due to the differences in storage time and the value of the stored material. For purposes of this study, the effective percentage charged was based on the average value of the grain over the storage period. The interest cost on stored grain may be the single largest cost in many grain storage systems.

Number of Months that Grain is to be Stored: The number of months that grain is to be stored is one of the critical factors in determining the effects of interest, taxes and insurance on expected net return to grain storage (Fig. 10). The variation in slopes of the three base conditions is due to different charges for interest taxes and insurance, and a difference in the average value of the stored grain over the storage period.

Moisture Content of Stored Corn: The moisture content of grain to be placed in storage depends on the expected temperatures during the storage period and the risk that the manager is willing to assume (Ross et al., 1973). Corn that is to be stored in the Mid-west only during the winter months may retain its quality with a 15.5

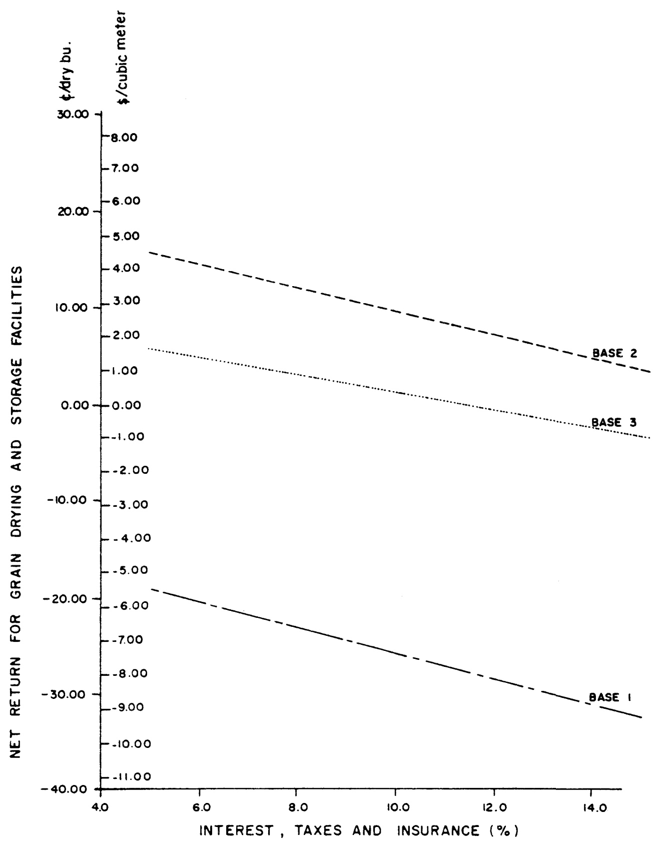

FIG. 9 Net return for on-the-farm drying and storage facilities as influenced by the cumulative interest, tax and insurance charges for the average value of the stored grain.

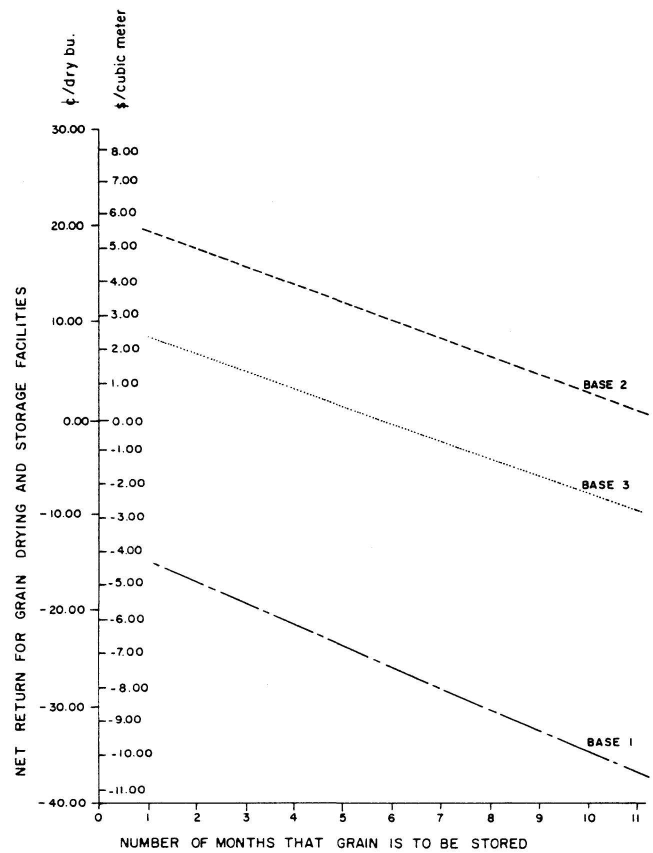

FIG. 10 Net return for on-the-farm corn drying and storage facilities as influenced by the average number of months that the grain will be stored assuming the same price will be received regardless of storage time.

percent storage moisture content assuming the manager is willing to assume some risk. This would be contrasted with a 12 percent storage moisture content in the South for the manager who plans to store his grain until midsummer.

A storage moisture content below the 15.5 base moisture standard for No. 2 corn results in economic loss to the farmer by (1) reducing the quantity of product the farmer has available for sale and (2) increasing the cost of drying because of the extra moisture that must be removed. The effects of storage moisture content on expected net return is shown in Fig. 11.

If the grain is to be fed on the farm (a situation not presented in the study) the "overdrying" is less important in that the dry matter content of the corn remains essentially the same regardless of moisture content. Also, overdrying may be necessary for safe storage of the grain and, if so, it should be viewed as an essential cost of grain storage.

Market Conditions

One of the primary considerations in the purchase of grain drying and storage equipment is the expected economic benefits to be gained from holding the grain for future sale. Although it is impossible to predict the exact prices at a given point in time, the net return can be computed based on given market expectations.

Price of Corn at Harvest: The price of corn at harvest affects the profitability of on-the-farm grain storage in several ways. As the price increases, the absolute increase in price over the storage period also increases for a constant percentage expected increase in value. In other

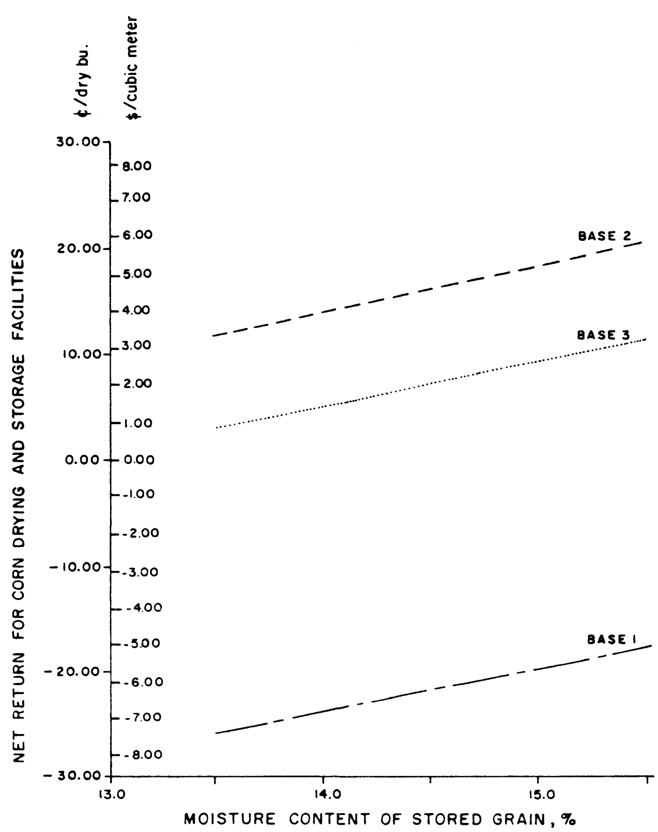

FIG. 11 Net return for on-the-farm corn drying and storage facilities as influenced by the moisture content at which the grain will be stored assuming no-in-storage losses related to excess moisture in the grain.

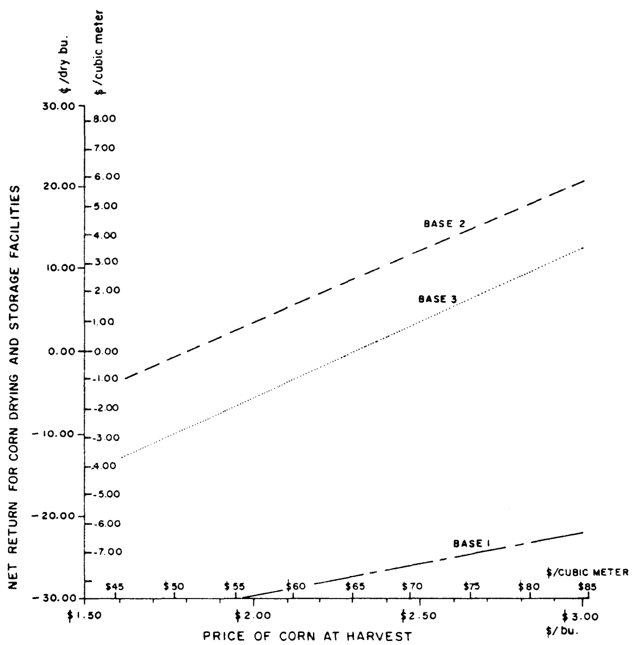

FIG. 12 Net return for on-the-farm corn drying and storage facilities as influenced by the average price of corn at harvest.

words, if the farmer expects a 10 percent increase in the price of corn over the storage period, $2.00/bu corn will increase by $0.20/bu, while $3.00/bu corn increases $0.30/bu, a difference of $0.10/bu for the same expected percentage increase in value.

Based on the same approach, higher prices of corn at harvest will reduce profitability somewhat because of an increased cost for interest, taxes and insurance.

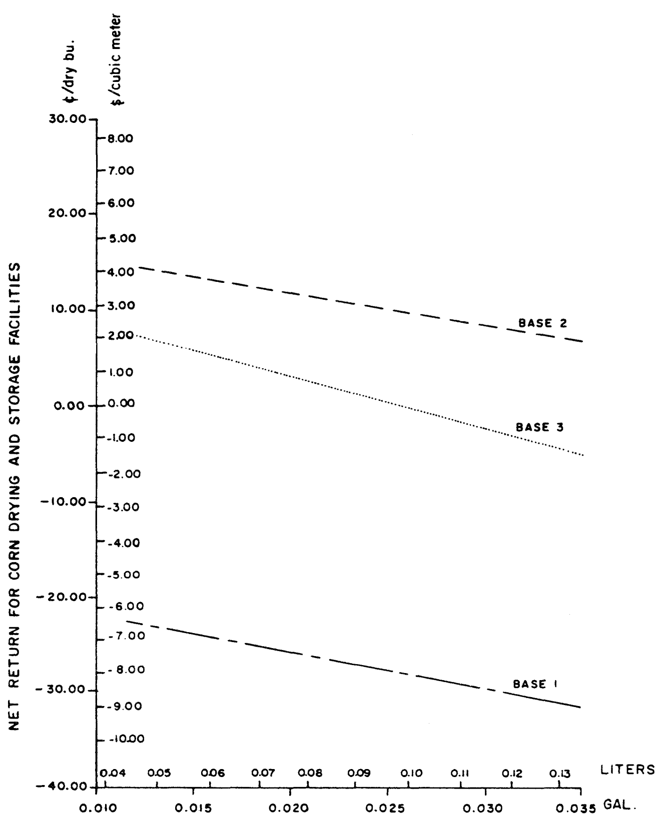

FIG. 14 Net return for on-the-farm corn drying and storage facilities as influenced by the quantity of LP gas burned per point of moisture removed from the corn.

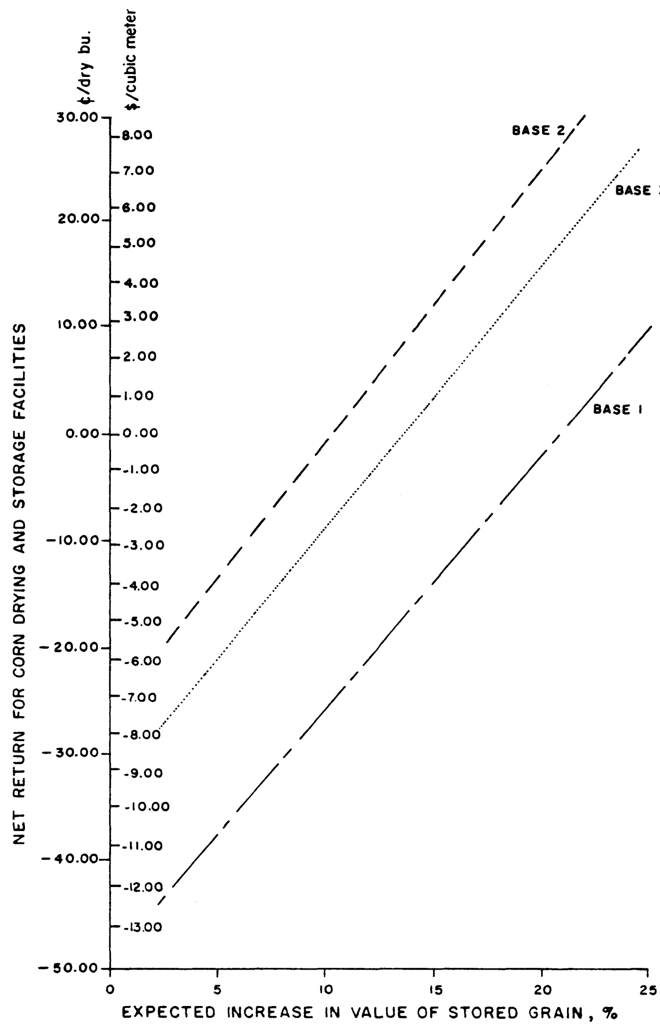

FIG. 13 Net return for on-the-farm corn drying and storage facilities as influenced by the percentage increase in value of the stored corn over a given storage period.

Likewise, the cost of overdrying, owing to a reduction of salable product, also increases with an increase in the price of corn.

Probably the most significant factor of the increase in corn prices is related to harvest losses. The value of each unit lost due to the factors discussed in the section "Harvesting Strategy Factors" increases directly with price. The net effects of these factors is shown in Fig. 12.

Expected Increase in the Value of Stored Grain: This is probably the single most important factor in determining expected net return to grain storage. If the expected increase in the value of stored grain is large enough, any grain system will be profitable. Likewise, it is difficult (but not impossible) for a system to show a profit if the expected increase in the value of the stored grain approaches zero.

As the expected increase in value becomes larger, the average value of the grain also increases. This reduces the profitability in the same way as discussed in the previous section, "Price of Corn at Harvest". The net effect of these factors is shown in Fig. 13.

Energy Considerations

As energy becomes less available and more expensive, increasing attention will be given to fuel efficiency. Likewise, many studies are being directed toward the use

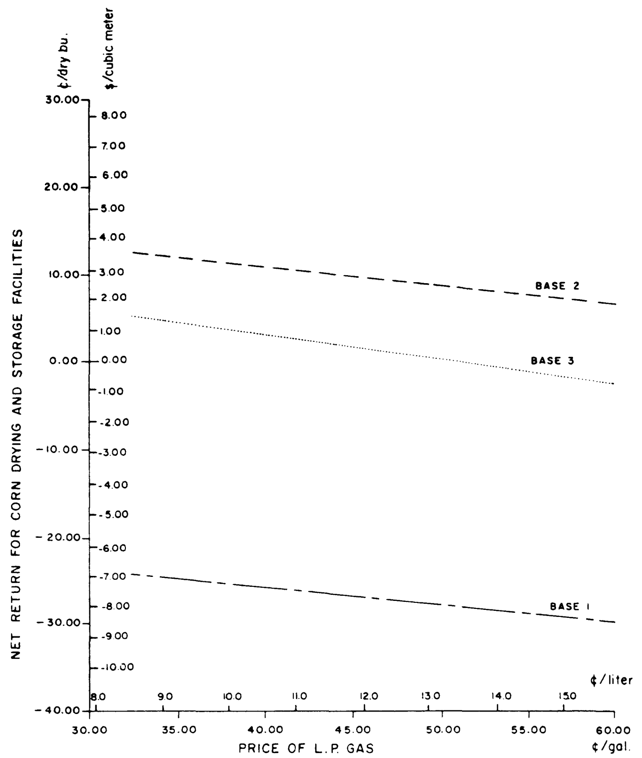

FIG. 15 Net return for on-the-farm corn drying and storage facilities as influenced by the price of LP gas for drying.

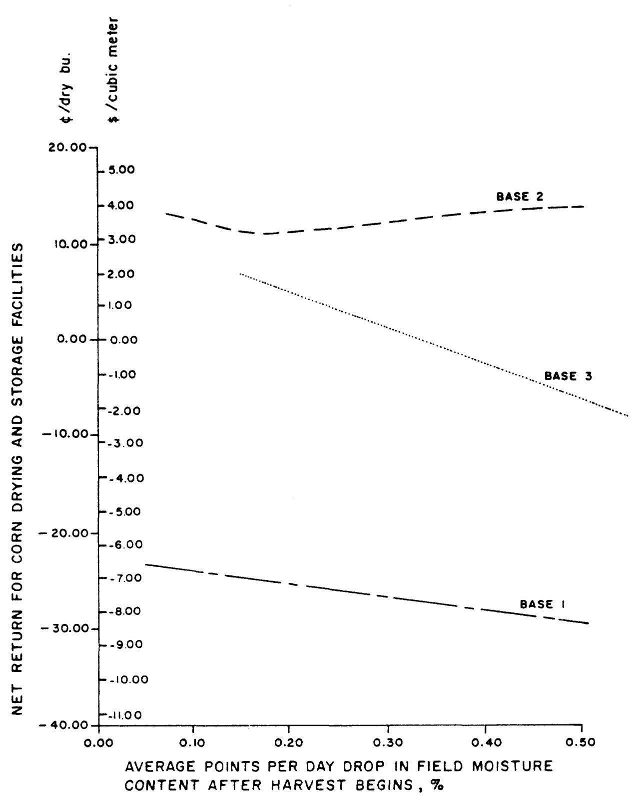

FIG. 16 Net return for on-the-farm corn drying and storage facilities as influenced by the average point per day drop in field moisture content after harvest begins.

of alternate fuels. Typically, the alternate sources of energy are considerably more expensive than LP gas and are not considered to be economically competitive in a direct substitution analysis.

Amount of Fuel/Point of Moisture Removal: The grain system manager does have some flexability in his utilization of LP gas for drying. For example, using higher temperatures for drying or adopting the dryeration process may result in an energy savings (McKenzie et al.)

Theoretically, it takes approximately 0.03 L (0.008 gallon) of LP gas/point of moisture removed. Conversion of LP gas to usable heat, when coupled with the drying process, increases this quantity by a factor of approximately 2 to 3 times. Fig. 14 relates the effects of energy utilization on the expected net return to grain drying and storage systems. Results indicate that although energy utilization is important, only a relatively large change in drying and burning efficiencies would significantly alter expected net return.

Price of Fuel: The price of fuel for drying affects the expected net return to storage in much the same way as drying efficiency (Fig. 15). Again, the cost of fuel is important, but if the expected net return to grain storage is sufficiently large, as with the Base Condition 2, fuel prices alone will not be the deciding factor in the economic feasibility of on-the-farm grain storage in the near future. This point is very important in the evaluation of alternate sources of fuel for drying such as biomass conversion or solar. It may be possible to utilize these energy sources for drying at a much higher cost than the present cost of LP gas and still have a profitable total drying and storage system.

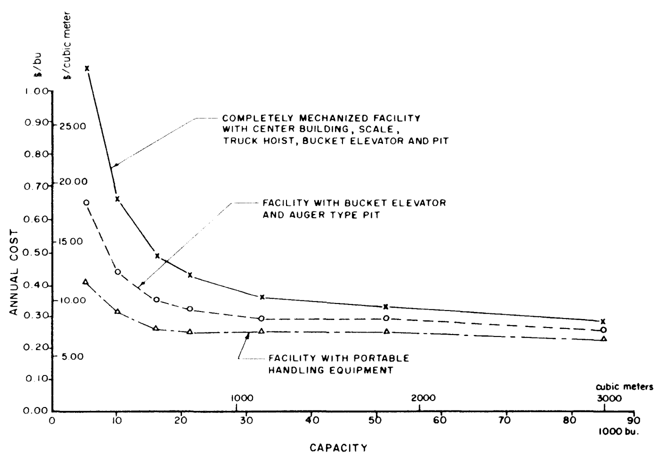

FIG. 17 Annual cost for layer drying facility, 20 day harvest time. (Loewer et al., 1976c, 1976d)

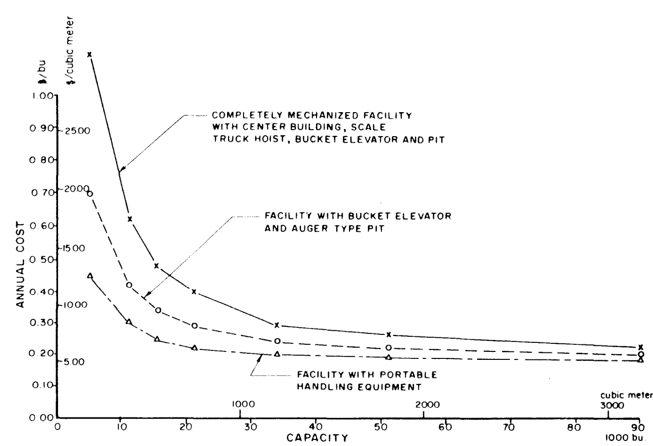

FIG. 18 Annual cost for batch-in-bin drying facility, 20 day harvest time. (Loewer et al., 1976c, 1976d)

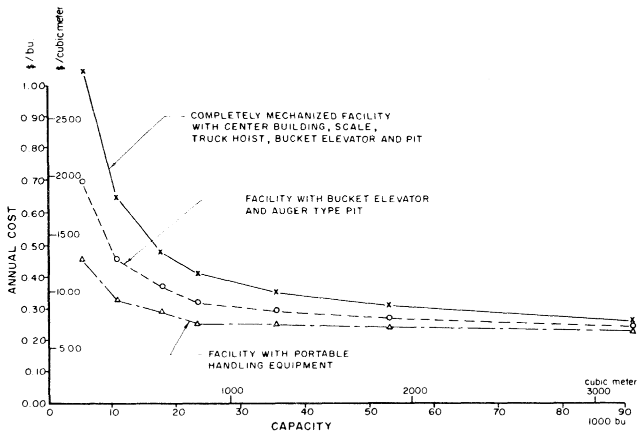

FIG. 19 Annual cost for a portable drying facility, 20 day harvest time. (Loewer et al., 1976c, 1976d)

Moisture Drop per Day in Field Moisture Content after Harvesting Begins: The effects of varying this term are rather inconsistent indicating a significant interaction among the associated input parameters (Fig. 16). As the moisture content drops more rapidly in the field, the fuel required for on-the-farm drying decreases, but the benefits of the 2 percent dockage system favor the no-drying option. The CACHE model does not allow the average moisture content during the total harvesting season to fall below 18 percent, thus, somewhat modifying the effects of relatively high rates of moisture drop in terms of expected net return.

Facility Component Costs

The cost of grain facility equipment on a per unit volume basis is largely a function of capacity, drying method, drying rate, and degree of mechanization. The effects of these parameters, not considering tax savings associated with depreciation and investment credit, are shown in Figs. 17 to 19 (Loewer et al., 1976c, 1876d). The following relationships indicate the degree to which facility size influences expected net return.

Potential Yield (m^3/ha, bu/acre): Potential yield is defined as the yield if no harvest losses were encountered. As the potential yield increases, the required storage space also increases for the same harvesting strategy. The magnitude of harvest losses becomes more pronounced as do expenses and returns for drying. The effect of potential yield on expected net return is shown in Fig. 20.

Area of Corn to be Dried (hectares or acres): All the harvested corn in this study was dried, stored and marketed. The influence of this parameter is similar to potential yield although much more pronounced. Notice that the effect of acreage on expected net return (Fig. 21) is very closely related to the curves presented in Figs. 17 to 19, indicating that much of the benefit of increased acreage is associated with reduced cost per bushel for storage facilities.

SUMMARY

Expected net return to grain storage is a function of many parameters. A summary of the effects of several of these factors is shown in Table 2.

Generally, if on-the-farm storage is available, expected net return can be increased by reducing travel

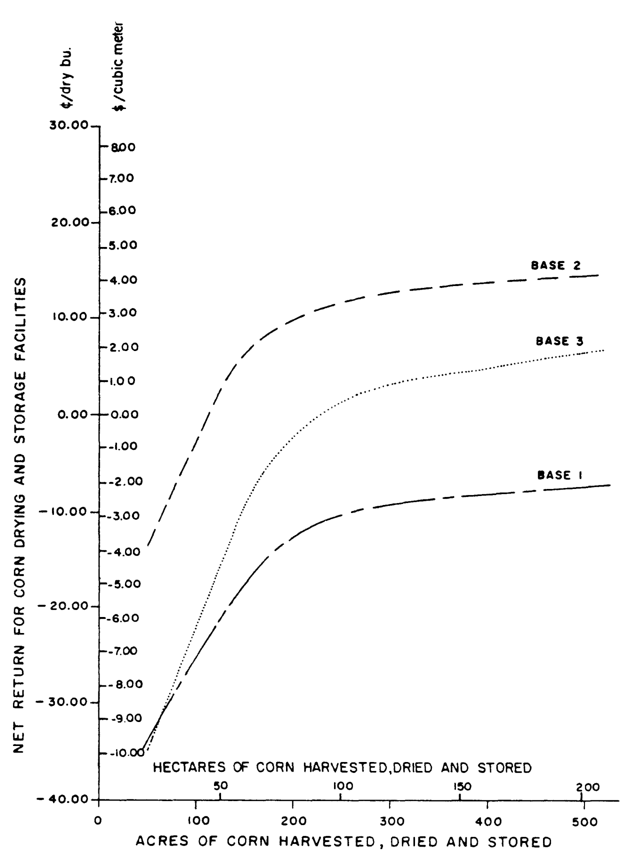

FIG. 20 Net return for on-the-farm corn drying and storage facilities as influenced by the potential corn yield. Potential yield is the quantity of grain that would be harvested if there were no harvest losses.

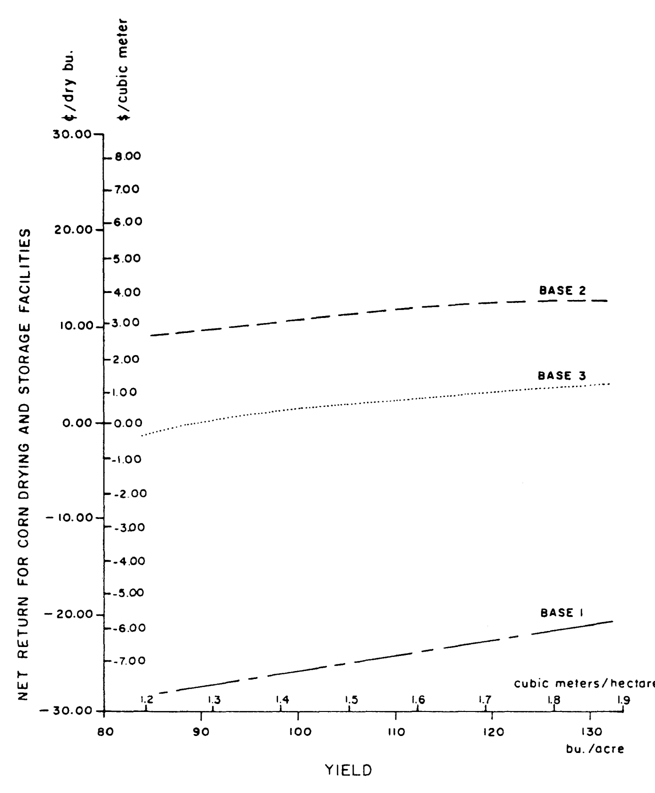

FIG. 21 Net return for on-the-farm corn drying and storage facilities as influenced by the area of corn that is to be harvested, dried, and stored.

speed of the combine while keeping total harvesting time as short as possible. However, well designed facilities free of bottlenecks may allow the farmer to accomplish both objectives (Benock et al., 1977). Regardless, the beginning moisture content for harvesting should be approximately 28 percent.

On-the-farm storage is relatively less beneficial to the farmer who would not reduce his total harvest time or combine speed if he were to purchase grain storage facilities, and is presently beginning his harvest when the grain reaches approximately 22 percent.

Expected net return to on-the-farm storage decreases with increases in interest, tax and insurance charges; storage time for the same expected rate of return; drying fuel usage and cost; and field drying rate.

Expected net return to on-the-farm storage increases with increases in moisture content of stored grain so long as no damage occurs; price of corn at harvest; expected increase in the value of corn over the storage period; yield per acre; and total acres to be placed in storage.

The key to economic success, so far as a grain storage system is concerned, is to make the management decisions necessary to adjust from a no-storage to an on-the-farm storage situation. Primarily, this involves keeping harvest losses to a minimum with existing harvesting and delivery equipment, being aware of interest charges, building economical drying and storage facilities, and following correct marketing practices. Allowing the corn to dry in the field rather than spend money for drying will be false economy in most years. Holding corn for future sales must be justified with regard to interest charges on the stored grain.

(Continued on page 480)

TABLE 2. CHANGE IN EXPECTED NET RETURN PER UNIT VOLUME AS INFLUENCED BY AN INCREASE IN THE STATED SYSTEM PARAMETER ASSUMING A LINEAR RELATIONSHIP OVER THE RANGE TESTED

		Change per unit increase $/m³ (¢ /dry bu)			
System parameter	Unit	Base 1	Base 2	Base 3	Average
I. Harvesting strategies					
A. If on-the-farm grain drying and storage is not available					
1. Calendar days required for harvesting					
10-31 days	Days	0.024	0.043	0.014	0.027
		(0.084)	(0.152)	(0.048)	(0.095)
31-46 days	Days	- 0.014	0.060	- 0.016	0.010
		(- 0.050)	(0.211)	(- 0.055)	(0.035)
2. Moisture content at which harvest begins					
18-21 percent	Percent	- 0.301	- 0.329	- 0.261	- 0.297
		(- 1.060	(- 1.158)	(- 0.920)	(- 1.046)
21-30 percent	Percent	0.345	0.351	0.442	0.379
		(1.214)	(1.237)	(1.557)	(1.336)
3. Speed of corn harvester	km/h	1.303	1.933	1.575	1.603
	(mph)	(4.590)	(6.810)	(5.548)	(5.649)
B. If on-the-farm grain drying and storage is available					
1. Calendar days required for harvesting	Days	- 0.085	- 0.070	- 0.064	- 0.073
		(- 0.300)	(- 0.248)	(- 0.226)	(- 0.258)
2. Moisture content at which harvest begins					
18-28 percent	Percent	0.188	0.138	0.102	0.143
		(0.664)	(0.488)	(0.358)	(0.503)
28-35 percent	Percent	- 0.112	- 0.034	- 0.094	- 0.080
		(0.396)	(- 0.120)	(- 0.330)	(- 0.282)
3. Speed of corn harvester	km/h	- 1.410	- 1.518	- 1.471	- 1.467
	(mph)	(- 4.970)	(-5.350)	(- 5.183)	(- 5.168)
II. Facility management strategies					
A. Interest, taxes and insurance charge	Percent	- 0.373	- 0.338	- 0.257	- 0.322
		(- 1.313)	(- 1.190)	(- 0.906)	(- 1.136)
B. Average number of months grain is to be stored	Months	- 0.621	- 0.540	- 0.513	- 0.558
		(- 2.187)	(- 1.903)	(- 1.808)	(- 1.966)
C. Moisture content of stored grain	Percent	1.147	1.232	1.209	1.196
		(4.042)	(4.340)	(4.260)	(4.214)
III. Market conditions					
A. Price of corn at harvest	$/m³	2.224	4.709	5.151	4.028
	($/bu)	(7.840)	(16.593)	(18.150)	(14.194)
B. Percentage increase in the value of stored corn	Percent	0.672	0.720	0.688	0.693
		(2.367)	(2.536)	(2.423)	(2.442)
IV. Energy considerations					
A. LP gas used per point of moisture removed	liter	- 111.392	- 103.47	- 158.190	- 124.352
	(gal.)	(- 392.500)	(- 364.600)	(- 557.400)	(- 438.167)
B. Price of LP gas	$/L	- 5.571	- 5.912	- 7.907	- 6.464
	($/gal.)	(- 19.630)	(- 20.833)	(- 27.862)	(- 22.775)
C. Average drop per day in field moisture content	Percent	- 4.186	- 2.995	- 10.205	- 5.796
		(- 14.750)	(- 10.555)	(- 35.960)	(- 20.442)
V. Facility design					
A. Potential yield	m³/ha	0.049	0.023	0.025	0.032
	(Bu/acre)	(0.172)	(0.080)	(0.088)	(0.113)
B. Area of corn to be dried and stored					
50-100 acres	Hectares	0.043	0.046	0.072	0.053
	(Acres)	(0.150)	(0.161)	(0.253)	(0.188)
100-300 acres	Hectares	0.010	0.009	0.015	0.011
	(Acres)	(0.035)	(0.031)	(0.053)	(0.040)
300-500 acres	Hectares	0.002	0.002	0.005	0.003
	(Acres)	(0.008)	(0.008)	(0.018)	(0.011)

Feasibility of Farm Grain Drying

(Continued from page 476)

The successful manager will be aware of the many trade-offs involved in grain facility management. This study provides some of the information needed to make correct decisions.

References

1 Benock, G., O. J. Loewer, Jerry Bowden, Y. Miyake, T. C. Bridges and D. G. Overhults. 1977. Determination of grain-flow restrictions in the harvesting-delivery-drying system interface. ASAE Paper No. 77-1506. ASAE, St. Joseph, MI 49085.

2 Johnson, W. H. and B. J. Lamp. 1966. Corn harvesting. AVI Publishing Company, Inc., Westport, CT.

3 Loewer, O. J. and H. E. Hamilton. 1974. Economics of corn drying: two percent of selling price dockage rate. Cooperative Extension Publication AEN-29, University of Kentucky, Lexington.

4 Loewer, O. J., T. C. Bridges and D. G. Overhults. 1975a. Compuer analysis of the economics of corn harvesting and processing systems. Presented at the 1975 Southeast Region Meeting of ASAE, New Orleans, LA.

5 Loewer, O. J., G. M. White and D. G. Overhults. 1975b. Economics of drying storage and feed processing: Part I, operational considerations. Cooperative Extension Publication AEN-33, University of Kentucky, Lexington.

6 Loewer, O. J., G. M. White and D. G. Overhults. 1975c. Economics of drying storage and feed processing: Part II, drying. Cooperative Extension Publication ASN-34, University of Kentucky, Lexington.

7 Loewer, O. J., G. M. White and D. G. Overhults. 1975d. Economics of drying storage and feed processing: Part III, storage considerations. Cooperative Extension Publication AEN-35, University of Kentucky, Lexington.

8 Loewer, O. J., T. C. Bridges and D. G. Overhults. 1976a. CACHE: computer model for the analysis of the economics of corn harvesting and processing systems. University of Kentucky Agricultural Engineering Technical Series No. 10, Lexington.

9 Loewer, O. J., G. M. White and D. G. Overhults. 1976b. Economics of drying storage and feed processing: Part IV, feed processing. Cooperative Extension Publication AEN-41, University of Kentucky, Lexington.

10 Loewer, O. J., T. C. Bridges and D. G. Overhults. 1976c. Facility costs of centralized grain storage systems utilizing computer design. TRANSACTIONS of the ASAE 19(6):1163-1168.

11 Loewer, O. J., T. C. Bridges and D. G. Overhults. 1976d. Computer layout and design of grain storage facilities. TRANSACTIONS of the ASAE 19(6):1130-1137.

12 Loewer, O. J., T. C. Bridges and D. G. Overhults. 1977. Using the computer to analyze grain storage facilities. Agricultural Engineering 58(1):42-43.

13 McKenzie, B. A., G. H. Foster, R. T. Noyes and R. A. Thompson. Dryeration—better corn quality with high speed drying. Extension Publication AE-72, Purdue University, West Lafayette, IN.

14 Ross, I. J., H. E. Hamilton and G. M. White. 1973. Principles of grain storage. Cooperative Extension Publication AEN-20, University of Kentucky, Lexington.