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THE selection of grain drying and storage facilities is dependent upon many factors with three of the more important being harvest rate, harvest volume and drying method. Other considerations include the type of hauling vehicle, the hauling distance, the type of handling equipment, labor and the economic feasibility of grain storage. To incorporate the foregoing considerations, the design computer simulation CHASE (Corn Handling and Storage Evaluator) was developed by Bridges et al. (1976b).

OBJECTIVES

Producers often make storage and drying equipment selections without considering the overall grain production system. CHASE provides the capability for a producer to see the effects of his decisions on system selection applied to his operations. Of particular interest to a producer would be the influence of harvest rate in the selection of a drying technique. With this in mind, the purpose of this study was to use the design computer simulation CHASE to accomplish the following objectives:

1 To determine the least cost drying method as a function of harvest rate by varying the harvest volume and the number of harvest days.

2 To determine the influence of hauling vehicle, handling technique and market option on the selection of the least cost drying method.

3 To determine the effect of drying time on the least cost drying facility.

PROGRAM DESCRIPTION AND INPUT

CHASE utilizes selected producer inputs and presents a ranked order with regard to cost for alternative methods of hauling, handling, drying, and storage of grain. CHASE, along with other programs dealing with the design and economics of grain storage and drying (Benock et al., 1977; Loewer et al., 1975, 1976a), is currently being used by the Cooperative Extension Service at the University of Kentucky.

The flow network described by CHASE contains a total of 60 combinations of hauling, handling, drying and storage (Fig. 1). Each combination is a feasible system and is acceptable as an on-the-farm method of grain handling. Farm parameters that must be supplied to CHASE are: hectares (acres) or corn, expected yield per hectare in cubic meters (bushels per acre), row width in centimeters (inches), the number of days the harvester will operate, the length of the harvest day in hours, and the maximum distance from the field to the facility in kilometers (miles). Other producer inputs include the moisture content at the start of harvest (percent wet basis), the desired moisture contents (percent wet basis) for both storage and for selling at the elevator, and the length of the drying day utilized for portable drying. Producer inputs pertaining to local energy and labor costs include electricity rates (dollars per kilowatt-hour), gasoline and liquid propane fuel costs (dollars per liter) and a labor wage rate (dollars per hour).

CHASE utilizes the total expected yield and the number of days of combine operation to calculate a design harvest rate for each system. An inherent assumption of the model is that there are sufficient hauling vehicles such that the combine never waits to unload during the harvest day. After all systems are designed, the program incorporates list prices to calculate an investment and annual cost for each system and ranks these accordingly. CHASE also presents the equipment and labor required by each feasible system.

Economic Concepts

Purchase costs were determined through cost arrays and equations using manufacturer's suggested list prices of representative companies (Table 1). Annual costs were calculated using straight-line depreciation, an estimated life and rate of repair, and constant interest, tax and insurance rates (Loewer et al., 1976b).

Purchase costs for a given system include the cost of equipment (except the combine) plus that of construction. The annual cost for a particular system includes the charge for the equipment, gasoline, LP gas, electricity, labor and construction.

CHASE includes in the purchase cost of a particular system the cost of all vehicles required to sustain the harvesting operation. The annual cost for a system reflects only a percentage of the total fixed annual cost of tractors and trucks. This percentage was calculated as the number of harvest days divided by 365. As will be shown later, this factor does not influence the break point between drying techniques.

CHASE (Bridges et al., 1976c) is a deterministic model that allows the producer to see the consequences of his decisions. The model conducts a comparison of equipment systems relative to themselves without regard to potential economic return resulting from the sale of the grain. While it is recognized that the economic return to a system is of great importance, the model design criteria is that all sixty equipment systems will yield the same quality and quantity of grain. The effects of marketing and facility management upon economic return has been addressed in other studies including Loewer et al., 1978.

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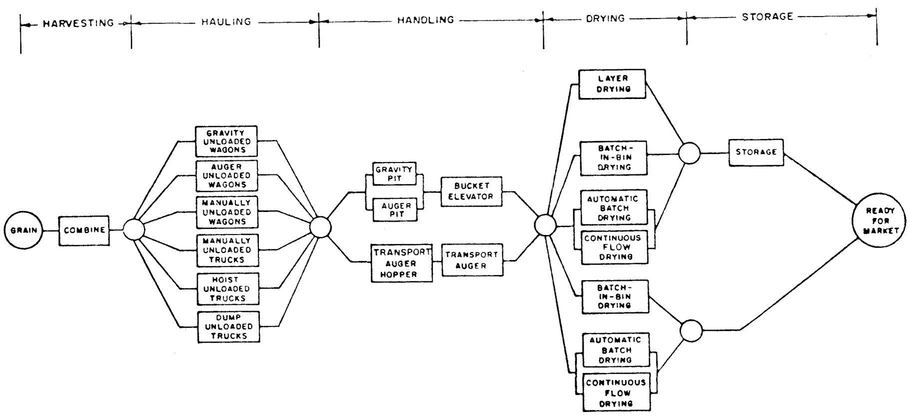

FIG. 1 The flow network of systems compared by CHASE.

DESIGN CONCEPTS

The computer design simulation CHASE was used to determine the investment and annual costs for various systems. Two specific input parameters to the model were varied:

1 Hectares (acres) of corn: 20.23(50), 40.47(100), 60.7(150), 80.94(200), 101.17(250), 121.41(300), 141.64 (350), 161.87(400), 182.11(450) and 202.34(500).

2 Harvest days: 1 through 30.

Other input parameters previously mentioned remained constant throughout the study and are listed in Table 2. The hectares of corn were multiplied by a constant yield of 8.71 m^3/ha (100 bu/acre) to obtain harvest volume increments. For this study the minimum and maximum harvest rates were 31.72 and 352.4 m^3 (900 and 10,000 bu) per day, respectively. Harvest rates above and below these limits were not considered.

In-bin drying systems (layer and batch-in-bin) were restricted to one fan per bin with a maximum size of 14,913.8 W (20 hp). There were two reasons for this: (a) commercially available drying fans usually do not exceed this power rating, and (b) CHASE was developed mainly for Kentucky farm situations where three-phase power is a rarity.

Table 3 shows an example of the data output for this study. Twenty-four such tables were developed (Bridges et al., 1976a), each representing the least cost drying method for a particular system combination of hauling vehicle, handling technique and market option.

Six types of hauling vehicles were considered: gravity wagons, auger wagons, manually unloaded wagons, manually unloaded trucks, hoist unloaded trucks and dump trucks.

TABLE 1. PRICE REFERENCES USED IN CHASE

	Item	Company	Effective date†
1.	Bin structure	Circle Steel Corp.	August 31, 1974
2.	Perforated floor*	Circle Steel Corp.	August 31, 1974
3.	Unloading auger, 6 in.*	Cardinal	November 1, 1974
4.	Electric motors	MFS	January 1, 1975
5.	Aeration fans	MFS	February 15, 1975
6.	Foundation ring	Circle Steel Corp.	August 31, 1974
7.	Aeration subfloor	Circle Steel Corp.	August 31, 1974
8.	Grain spreader	Circle Steel Corp.	August 31, 1974
9.	Humidistat	Circle Steel Corp.	August 31, 1974
10.	Thermostat	Circle Steel Corp.	August 31, 1974
11.	Pit auger and U-trough	Sweet Manufacturing Co.	January 31, 1974
12.	Bucket elevator*	Sweet Manufacturing Co.	January 31, 1975
13.	Cleaner	Clay Equipment Co.	December 15, 1974
14.	Transport auger	Hutchinson	January 1, 1975
15.	Fans with heaters*	Farm Fans, Inc.	January 1, 1974
16.	Portable batch dryers	Super B	February, 1975
17.	Continuous flow dryers	Butler	June, 1975
18.	Trucks	International	March, 1975
19.	Wagons	M & W and Cobey	January, 1975
20.	Combines and cornheads	Official guide from Ky. Power & Equipment Dealers Association	Fall, 1974
21.	Construction cost	Southern States	November, 1974

*Includes accessory equipment.
†All prices were obtained at the February, 1975 Farm Machinery Show in Louisville, KY.

TABLE 2. INPUT PARAMETERS TO CHASE

Yield = 8.71 m^3/ha (100 bu/acre)	LP gas = $0.106 per liter ($0.40/gal)
Row width = 91.44 cm (36 in.)	Electricity = $0.05 per kWh
Harvest day = 8 hours	Labor = 13.50 per hour
Distance = 1.61 km (1.0 mile)	Initial moisture content = 25.5 % wb
Portable drying time = 12 h/day	Selling moisture content = 15.5% wb
Gasoline = $0.13 per liter ($0.50/gal)	Storage moisture content = 14.0% wb

Table 3: LEAST COST DRYING METHOD.
INVESTMENT AND ANNUAL COST

Market Option 1 Hauling Vehicle Dump Truck Handling Technique T. A.

Harvest Cubic Meters (Bushels x 10^3)

Each cell: $ / $/Yr

Harvest Days	176(5)	352(10)	528(15)	705(20)	881(25)	1057(30)	1233(35)	1409(40)	1586(45)	1762(50)
1	53575 / 7851	72463 / 9750								
2	25508 / 2939	53575 / 8248	73501 / 4622	72463 / 10687						
3	21494 / 2493	32780 / 4297	53575 / 8711	72265 / 9557	80809 / 10942	81301 / 11678				
4	19753 / 2257	25508 / 3509	33120 / 4847	53573 / 9174	72265 / 10048	73501 / 10622	80809 / 11897	81301 / 12586		
5	19753 / 2260	22832 / 3124	32780 / 4801	33684 / 5475	53575 / 9637	55715 / 10301	57414 / 10875	73262 / 11473	80809 / 12844	81301 / 13494
6		21494 / 3040	25508 / 4080	32780 / 5302	33684 / 6106	53575 / 10100	55304 / 10662	57414 / 11329	73501 / 12048	80809 / 13326
7		20090 / 2904	32363 / 3986	28078 / 4899	32780 / 5802	33684 / 6642	53575 / 10563	55304 / 11125	57404 / 11784	57414 / 12235
8		19753 / 2888	22550 / 3611	25508 / 4650	32780 / 5806	33120 / 6362	63675 / 10821	53575 / 11026	55304 / 11588	57414 / 12238
9		27208 / 2917	21494 / 3587	32363 / 4557	28078 / 5451	32780 / 6307	33120 / 6864	53575 / 11030	53575 / 11489	55304 / 12051
10		27209 / 2920	21494 / 3590	22832 / 4225	25508 / 5220	32780 / 6310	32780 / 6806	33684 / 7522	53575 / 11493	53575 / 11952
11		19753 / 2899	20090 / 3517	21494 / 4130	32363 / 5125	28078 / 6003	32780 / 6809	32780 / 7306	33684 / 8034	53575 / 11956
12			19753 / 3519	21494 / 4134	32363 / 5132	25508 / 5791	32780 / 6813	32780 / 7310	33120 / 7875	33684 / 8785
13			27208 / 3558	21494 / 4137	22550 / 4699	32363 / 5696	28078 / 6554	32780 / 7314	32780 / 7810	33120 / 8379
14			27208 / 3510	20090 / 4127	21494 / 4677	32363 / 5703	25508 / 6359	28078 / 7102	32780 / 7814	32780 / 8311
15			27208 / 3515	20585 / 4182	21494 / 4681	22832 / 5327	32363 / 6265	26286 / 6858	32780 / 7818	32780 / 8315
16			19753 / 3534	19573 / 4150	21494 / 4684	22550 / 5246	32363 / 6272	25508 / 6930	28078 / 7655	32780 / 8318
17				27209 / 4200	21494 / 4688	21494 / 5224	22832 / 5873	32363 / 6836	26286 / 7405	32780 / 8322
18				27208 / 4206	20090 / 4729	21494 / 5219	22550 / 5773	32363 / 6840	25508 / 7487	28078 / 8188
19				19753 / 4162	20585 / 4786	21494 / 5231	22550 / 5790	25508 / 6941	25508 / 7504	26286 / 7951
20				27208 / 4214	19753 / 4781	21494 / 5235	21494 / 5771	22832 / 6426	32363 / 7411	25508 / 8070
21				19753 / 4169	19753 / 4785	20090 / 5350	21494 / 5779	22550 / 6333	32363 / 7418	25908 / 8074
22				19753 / 4173	27208 / 4847	20090 / 5354	21494 / 5778	21494 / 6315	22832 / 6975	32363 / 7982
23					27208 / 4854	20585 / 5391	21494 / 5782	21494 / 6318	22550 / 6875	32363 / 7989
24					27208 / 4861	19573 / 5413	21494 / 5785	21494 / 6322	22550 / 6879	24607 / 7994
25					19452 / 4866	19573 / 5416	20090 / 5961	21494 / 6325	21494 / 6862	22832 / 7527
26					19753 / 4804	19452 / 5482	20090 / 5965	21494 / 6329	21494 / 6865	22832 / 7531
27					19753 / 4808	19452 / 5486	20585 / 5994	21494 / 6332	21494 / 6869	22832 / 7535
28						19452 / 5489	19753 / 6042	20090 / 6570	21494 / 6872	21494 / 7409
29						19452 / 5493	19753 / 6046	20090 / 6574	21494 / 6876	21494 / 7412
30						19452 / 5496	19452 / 6109	20585 / 6594	21494 / 6879	21494 / 7416

Continuous Flow Drying

Batch-In-Bin Drying

TABLE 4. COST COMPARISON OF BATCH IN BIN AND CONTINUOUS FOLW DRYING*

Harvest days	Harvest volume m³ (bu)	Drying method	Drying time h/day	Investment cost, $	Annual cost, $
4	528.6 (15000)	B-I-B†	17	33120	4847
4	528.6 (15000)	CF‡	12	37046	5813
4	528.6 (15000)	CF	19	33289	5183
4	528.6 (15000)	CF	24	32375	5014
4	1057.2 (30000)	B-I-B	17	66394	9253
4	1057.2 (30000)	CF	12	73501	10622
4	1057.2 (30000)	CF	19	60139	8307
4	1057.2 (30000)	CF	24	57830	7920

*Cost comparison is for the system combination including dumptrucks, transport auger and market option 1.
†Batch-in-bin drying technique.
‡Continuous flow drying technique.

Two separate handling techniques (transport auger (T.A.) and bucket elevator (B.E.)) and two types of market options (Market Option 1: Selling to elevator immediately after drying, and Market Option 2: On-the-farm storage after drying) were studied. The market options were compared only with regard to equipment system costs with no consideration being given to potential net return.

Three drying methods were considered in conjunction with the on-the-farm storage marketing option: layer drying, batch-in-bin drying and portable drying. A cost comparison between automatic batch and continuous-flow drying is conducted within CHASE to determine which portable drying method is least costly for the particular set of inputs. However, the two methods are competitive in price for most systems. In as much as layer drying systems would involve the same costs regardless of marketing option, only batch-in-bin and portable drying methods were studied in combination with selling immediately after drying.

RESULTS

Selection of a particular drying method for a given system combination such as that shown in Table 3 was based on least annual cost. The first number in each cell represents the investment cost of the system containing the least cost drying method. Listed below the larger number is the annual cost for that particular system. The heavy line represents the drying method break-point or the place in the table where the least cost system changes drying technique. It should be noted that the only two drying techniques appearing were batch-in-bin and continuous-flow drying.

The 24 system combinations were arranged by market option and handling technique in groups of six representing the six types of hauling vehicles. It was noted that within a grouping of six the break-point between drying techniques was the same, indicating that type of hauling vehicle has little or no effect upon the selection of drying method at a fixed distance.

A comparison of system combinations with like market options but different handling techniques also showed no difference in the break-point line. This indicates that the type of handling technique, portable auger or bucket elevator, has no effect upon the selection of the least-cost drying method as long as sufficient handling capacity is available.

Contrasting system combinations with the same handling technique but different market options found that there were significant differences in the break-point line. Generally, for Market Option 2 (on-the-farm storage after drying), and a given number of harvest days the break-point appears sooner across the range of harvest volumes than for Market Option 1. A contributing factor to this is the additional moisture that must be removed when the grain is stored as opposed to selling it immediately after drying (Table 2).

Due to discrete intervals in harvest volumes, no attempt was made to pinpoint the exact the exact harvest rate at which the break-point between drying methods occurred. The break-point for systems containing Market Option 1 was generally found to be in a range of 132.1 to 151.5 m³ (3750 to 4300 bu) per day. The break-point for systems containing Market Option 2 was somewhat less, generally falling in a range of 116.3 to 133.9 m³ (3300 to 3800 bu) per day. As stated previously, Market Option 2 requires storage, therefore, requiring more moisture to be removed and hence increasing the required drying capacity.

For harvest rates above the minimum up to the break-point line, this study concluded that batch-in-bin drying was the least cost drying method of those considered regardless of system combination. Above the break-point line, up to the maximum harvest rate, continuous-flow drying became the least cost drying method of those considered. It should be noted that within the ranges mentioned above, the two drying techniques are competitive in both price and capacity.

Facility Cost and Drying Time

In crossing the break-point line from batch-in-bin drying to continuous-flow drying (Table 3), investment and annual cost significantly increase for a given number of harvest days. This indicates that the break-point line is due to the power limitation on the in-bin drying system fans.

One factor that contributed to this cost increase was that the portable drying time was limited to 12 h/day while that of batch-in-bin was 17 h/day. In comparison, both drying times are typical values, but the continuous-flow system has more flexibility with regard to increasing the total quantity of grain that may be dried in 1 day.

Further inspection of Table 3 shows some interesting system costs. An example of these occur for harvest volumes of 528.6 and 1057.2 m³ (15,000 and 30,000 bu) and 4 harvest days. Both the investment and annual cost for the continuous-flow drying system are more than double that of the batch-in-bin drying system. This indicates for the range of parameters of the simulation (Table 2), that two batch-in-bin drying systems for a 528.6 m³ (15,000 bu) harvest volume would be less expensive than one continuous flow system for 1057.2 m³ (30,000 bu). This cost difference is a function of drying time.

Table 4 shows a comparison of the two drying methods at different harvest rates and drying times. It can be seen that as the continuous-flow drying time increased from 12 to 24 h both the investment and annual cost of the respective systems decreased and that the continuous-flow system became competitive in price with the batch-in-bin system at 19 h.

While the study rendered the batch-in-bin system at 1057.2 m³ (30,000 bu) infeasible (larger than maximum fan size), it can be seen that the continuous-flow system at 19 h was cheaper both in investment cost and annual cost. The data in Table 4 indicate that had the study been conducted with a portable drying time of 19 h, as opposed to 12 h, and no fan limitation on the in-bin drying systems, continuous-flow drying would appear in the tables as a least cost drying method and that the system cost increase across the break-point line would be more uniform. Table 4 also shows that for 19 h drying time the continuous-flow system for 1057.2 m^3 (30,000 bu) is no longer twice as expensive as the batch-in-bin system for 528.6 m^3 (15,000 bu).

SUMMARY AND CONCLUSIONS

The design computer simulation CHASE was used to determine comparative purchase and annual costs of selected systems. The design inputs of crop area and harvest days were varied over a range of values and the least cost drying method was determined. The system combinations were grouped by market option and handling technique with each group including all vehicle types specified by CHASE.

Over the range of input parameters it was found that:

1 Within market options, there was no influence upon the break-point line due to hauling vehicles and handling techniques.

2 For Market Option 1 (Selling immediately after drying), the break-point line was generally in the range of 132.1 to 151.5 m^3 (3750 to 4300 bu) per day.

3 For Market Option 2 (On-the-farm storage after drying), the break-point line was generally in the range of 116.3 to 133.9 m^3 (3300 to 3800 bu) per day.

4 For harvest rates below the break-point, batch-in-bin drying was the least cost drying method and for rates above the break-point continuous-flow drying became the least expensive method.

5 The amount of time assigned for portable drying is an important factor in system costs comparisons.

The results shown in this paper are an evaluation of drying methods for the particular set of input conditions listed in Table 2. While the model includes only those drying methods discussed, there may be other drying methods (batch-in-bin with multiple fans or continuous-flow drying using dryeration) that are more suitable to the producer's needs. There may also be other factors such as labor or convenience that influence his selection of a drying facility. This study is an attempt to show an application of the model CHASE where the producer might vary input parameters to determine economic break-points and the influence of drying time for his own set of farm conditions.

CHASE designs 60 different systems for each particular situation. List prices were incorporated to reflect as true an investment and annual cost as possible. However, the real value of these data lies in the relative comparison of costs rather than the actual costs themselves.

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