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# An Economic Evaluation Of Liquid Manure Disposal From Confinement Finishing Hogs

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UNIVERSITY OF ILLINOIS COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION BULLETIN 722

Urbana, Illinois | December, 1966

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station.

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# AN ECONOMIC EVALUATION OF LIQUID MANURE DISPOSAL FROM CONFINEMENT FINISHING HOGS

R. P. KESLER and R. A. HINTON[1]

Manure is a valuable byproduct of the hog industry. When applied to cropland, it improves the chemical, physical, and biological properties of the soil. At 1964 fertilizer prices, the replacement cost of the major plant nutrients in the manure from the 12,881,000 hogs produced in Illinois was approximately 27 million dollars.

Animal wastes must be removed from confinement livestock buildings if production is to continue. Among the reasons for removing manure from livestock buildings are animal health, improvement in feed efficiency, and control of odors and fly breeding.

Three alternative methods of manure disposal are analyzed in this study. The purpose is to make an economic evaluation of the alternatives as a guide to farmers in choosing the method that will permit them to dispose of manure at either a maximum return or a minimum cost to their total farming operation.

## ALTERNATIVE METHODS OF MANURE DISPOSAL

### Total hauling and spreading (Method A)

In this method, the total hog waste is loaded, hauled, and spread throughout the entire year. During the four months from June 15 to October 15, the manure is spread on noncrop land where little fertility value is derived by growing crops. Fertility benefits from manure spread on noncrop land are considered to be zero in this study.

### Total lagooning (Method B)

Total lagooning involves the discharge of the total hog waste into a lagoon throughout the entire year. No economic value is derived from manure disposed of in this way.

### Partial hauling and spreading and lagooning (Method C)

Method C uses both hauling and spreading and a lagoon to dispose of the manure. During the four months from June 15 to October 15, the manure is discharged into a lagoon. During the other eight months, the manure is loaded, hauled, and spread on land to be used for corn and soybean production.

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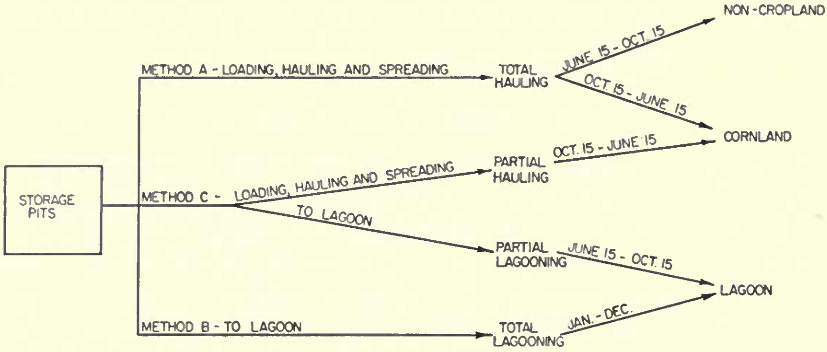



**A schematic diagram of the alternative methods of manure disposal. (Fig. 1)**

## METHOD OF ANALYSIS

The analysis of the costs, returns, and other factors associated with the disposal of liquid hog manure consists of two parts. The first is a description of the resources used and practices followed in the disposal of liquid manure on 13 of the 49 hog farms enrolled in the 1964 detailed cost study conducted by the Department of Agricultural Economics. The second is a budgeting analysis of the costs and returns for the three methods of liquid manure disposal in three sizes of hog operations. The farm performance data generated by the study of the sample of farms provided the data for this analysis.

## STUDY OF THIRTEEN FARM LIQUID-MANURE DISPOSAL SYSTEMS

Thirteen farms were selected for intensive study of their hog manure disposal practices. These farms were located in central and west-central Illinois. Totally enclosed, partially slotted-floor confinement finishing facilities were in operation on each of these farms. Multiple farrowing systems were followed on all farms with farrowing frequencies ranging from 4 to 12 times per year.

The data in Table 1 show selected characteristics of all 13 sample farms and the average of farms classified by method of manure disposal. Seven of these farms disposed of their liquid hog manure by hauling and spreading it throughout the year (Method A). Three farms used total lagooning (Method B), while three others used partial hauling and lagooning (Method C).

The supply of available labor on the sample farms was 24.7 months or approximately two men. Farms using Methods A and C for manure

**Table 1. — Selected Characteristics of 13 Hog Farms Using Liquid Manure Disposal Systems, 1964**

| Characteristics of farm | All farms | Method of manure disposal | | |
|---|---|---|---|---|
| | | Farms using Method A | Farms using Method B | Farms using Method C |
| Number of farms | 13 | 7 | 3 | 3 |
| Total acres per farm | 362 | 469 | 237 | 239 |
| Tillage acres per farm | 314 | 411 | 187 | 215 |
| Litters of hogs produced per farm | 186 | 162 | 138 | 291 |
| Hogs produced per farm | 1,431 | 1,292 | 1,117 | 2,069 |
| Months of available labor | 24.7 | 25.7 | 21.2 | 25.7 |

disposal had an available labor force of 25.7 months while those using Method B, total lagooning, had 21.2 months of available labor.

Farms using Method A for manure disposal were approximately 100 acres larger than the sample as a whole. Farms using Method B, total lagooning, for manure disposal had less than 50 percent as many tillable acres as those using Method A and were slightly smaller than those farms using Method C. However, there was adequate cropland on all the farms on which to spread the manure.

The 13 sample farms produced an average of 1,431 hogs or 186 litters per farm in 1964. The farms using Methods A and B for manure disposal produced about the same number of hogs per farm. However, on farms using Method C, partial hauling and lagooning, the hog enterprise was considerably larger. The farms using Method C produced 2,069 hogs while those using Methods A and B produced an average of 1,292 and 1,117 hogs per farm, respectively. The farms with the larger hog enterprises elected to use a combination of manure disposal methods. Two reasons support the choice made on these farms. First, on the farms with the larger hog enterprises, there was less tillable land per unit of hog production on which to spread the manure as a replacement for commercial fertilizer. Second, competition for labor perhaps made it difficult to be as timely with the manure hauling operation. Thus Method C was used for a more uniform distribution of the labor load throughout the year.

## Quantity of liquid manure hauled per unit of hog production

Data were collected on the quantity of liquid hog manure hauled from the finishing house and on the average daily liveweight of hogs in the finishing house throughout the year. The estimate of manure production does not include bedding, but does take into account evap-

**Table 2. — Quantity of Liquid Manure and Pounds of Manure Hauled per Day per 1,000 Pounds of Liveweight of Hogs on Seven Farms Using Method A for Manure Disposal, 1964**

| Farm No. | Quantity of manure hauled | | | Average daily liveweight of hogs in house | Manure hauled per day per 1,000 pounds of liveweight[a] | Daily manure hauled as a percentage of liveweight[b] |
|---|---|---|---|---|---|---|
| | (loads) | (gallons) | (pounds) | (pounds) | (pounds) | (percent) |
| 15........ | 273 | 218,400 | 1,747,200 | 21,311 | 225[c] | 22.5[c] |
| 19........ | 171 | 119,700 | 957,600 | Data not available | | |
| 23........ | 313 | 219,000 | 1,752,000 | 44,272 | 110 | 11.0 |
| 33........ | 321 | 224,700 | 1,797,600 | 42,000 | 117 | 11.7 |
| 35........ | 334 | 300,600 | 2,404,800 | 88,330 | 75 | 7.5 |
| 36........ | 210 | 189,000 | 1,512,000 | 46,000 | 90 | 9.0 |
| 45........ | 228 | 205,200 | 1,641,600 | 62,900 | 72 | 7.2 |
| Average... | 264 | 210,957 | 1,687,656 | 56,700 | 93 | 9.3 |

[a] With Method A, total hauling and spreading, the amount of manure hauled per 1,000 pounds of liveweight is equal to the amount of manure produced per 1,000 pounds of liveweight.
[b] Equal to the daily manure production as a percentage of liveweight.
[c] Not included in average because of excessive dilution from waterer overflow and surface water.

oration and dilution from waterer overflow. These data were used to calculate the manure hauled per day per 1,000 pounds of liveweight. These calculations, expressed as a percentage of the liveweight of hogs in the building, are shown in Tables 2 and 3, together with the amount of manure hauled per day.

On farms using Method A, the average amount of manure hauled per day per 1,000 pounds of liveweight of hogs was 93 pounds, or 9.3

**Table 3. — Quantity of Liquid Manure and Pounds of Manure Hauled per Day per 1,000 Pounds of Liveweight of Hogs on Three Farms Using Method C for Manure Disposal, 1964**

| Farm No. | Quantity of manure hauled | | | Average daily liveweight of hogs in house | Manure hauled per day per 1,000 pounds of liveweight | Daily manure hauled as a percentage of liveweight |
|---|---|---|---|---|---|---|
| | (loads) | (gallons) | (pounds) | (pounds) | (pounds) | (percent) |
| 1......... | 103 | 72,100 | 576,800 | 42,740 | 37 | 3.7 |
| 7......... | 279 | 265,050 | 2,120,400 | 169,057 | 34 | 3.4 |
| 24........ | 297 | 356,400 | 2,851,200 | 137,610 | 52 | 5.2 |
| Average... | 226 | 231,183 | 1,849,464 | 116,469 | 41 | 4.1 |

**Table 4. — Average Daily Manure Production per 1,000 Pounds of Liveweight for Hogs, Selected Studies**

| Source (see page 28) | Average daily manure production per 1,000 pounds of liveweight |
|---|---|
| | (pounds) |
| Hazen | 99 |
| Davis | 98 |
| Salter and Schollenberger | 98 |
| Hart | 86 |
| Robinson | 100 |
| Taiganides | 70 |
| This study | 93 |

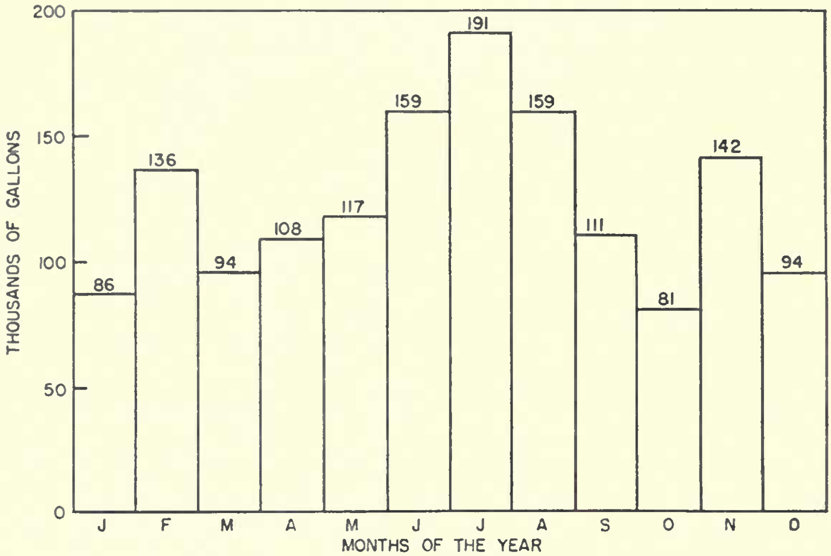
percent of the liveweight. This amount is equal to the total manure produced on these farms because, in Method A, the total manure was hauled and spread throughout the year. The range was 72 to 117 pounds of manure per day per 1,000 pounds of liveweight excluding Farm No. 15. This farm was excluded because of excessive dilution from waterer overflow and from surface water entering the manure pits.

These data agree closely with the results of research conducted elsewhere. The summary in Table 4 shows the daily manure production per 1,000 pounds of liveweight of hogs reported by six other workers.

## Seasonal hauling of liquid manure

The quantities of manure hauled, by months, on seven farms using Method A for manure disposal are shown in Fig. 2. The farmers in this group generally hauled the manure monthly as it was produced. During the first five months of the year, January through May, they hauled a total of 108,000 gallons per month and in the four-month period September through December they hauled 107,000 gallons per month. During the summer months, June through August, they hauled 170,000 gallons per month. These data would agree with an observation made by one farmer that the manure production in his finishing house during each summer month was 1½ times that during each of the cooler months of the year.

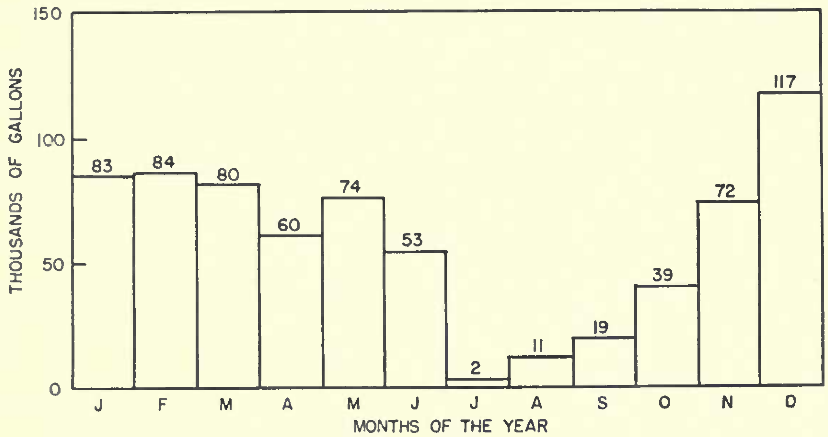
A smaller volume of manure was hauled during the months of January and October than during the other months of the year. Apparently, unfavorable weather and field conditions accounted for the light hauling in January while the high labor requirements for corn harvesting competed with manure hauling in October.




**Total quantities of manure hauled by months during 1964 from confinement buildings on seven farms using Method A for manure disposal. (Fig. 2)**

The quantity of manure hauled, by months, on three farms using Method C for manure disposal is shown in Fig. 3. During eight months of the year the monthly quantity of manure hauled on this group of farms followed very closely that of the farms using Method A for manure disposal. They hauled a fairly constant volume of manure for the eight-month period (January through June, November, and December) averaging 78,000 gallons per month. However, during the other four months of the year, July through October, they hauled an average of only 18,000 gallons per month. Assuming the manure production rate for this period would increase to 1½ times that of the rest of the year, this would indicate that, on farms using Method C for manure disposal, the lagoon was used for the disposal of about 85 percent of the manure during this period.

The farms using Method C for manure disposal had little cropland area available on which to spread manure during the four-month summer period. An average of 97 percent of their tillable land was in row crops. Observations indicated that farmers delayed the planting of a small acreage of corn so that the manure pits could be emptied during the early part of June. Part of this manure was applied before planting while part of it was applied as a sidedress application on corn in the




**Total quantities of manure hauled by months during 1964 from confinement buildings on three farms using Method C for manure disposal. (Fig. 3)**

early stages of growth. The hauling of manure was started again in late October after at least part of the harvest had been completed and prior to fall plowing.

To a lesser extent, the farms using Method A had a similar problem. These farms had an average of 79 percent of their tillable land in row crops. During the four-month period, June 15 through October 15, little cropland area was available on which the manure could be utilized as a replacement for commercial fertilizer.

## Labor and tractor time for hauling liquid manure

**Total labor and tractor time.** The percentages of total direct hog labor used for hauling and spreading manure on the sample farms were 7.5, 1.7, and 5.4 for Methods A, B, and C, respectively. These figures show that the labor required for manure hauling and spreading is a relatively small proportion of the total labor required by the hog enterprise.

The total hours of labor and tractor time per farm for hauling and spreading liquid manure are given in Table 5. These data indicate the magnitude of the total labor and tractor time utilized per farm in hauling and spreading liquid manure. The average requirements per farm were approximately 110 hours of labor and 90 hours of tractor time. The total labor and tractor time is a function of the size of the hog enterprise, distance hauled, and type of equipment used to load, haul, and spread the manure.

Table 5. — Total Labor and Tractor Time and Labor and Tractor Time per 1,000 Gallons of Liquid Manure Hauled From Finishing Buildings on 10 Farms, 1964

| Farm No. | Quantity of manure hauled | Total labor | Labor per 1,000 gallons hauled | Total tractor time | Tractor time per 1,000 gallons hauled |
|---|---|---|---|---|---|
| | (gallons) | (hours) | (hours) | (hours) | (hours) |
| 1 | 72,100 | 71.00 | .985 | 46.75 | .648 |
| 7 | 265,050 | 149.25 | .563 | 132.50 | .500 |
| 15 | 218,400 | 163.25 | .747 | 91.50 | .419 |
| 19 | 119,700 | 82.50 | .689 | 77.50 | .647 |
| 23 | 219,100 | 107.50 | .491 | 120.50 | .550 |
| 24 | 356,400 | 152.75 | .428 | 111.75 | .314 |
| 33 | 224,700 | 92.75 | .413 | 92.75 | .413 |
| 35 | 300,600 | 129.50 | .431 | 105.50 | .351 |
| 36 | 189,000 | 82.50 | .436 | 63.75 | .337 |
| 45 | 205,200 | 69.75 | .340 | 54.50 | .266 |
| Average | 217,025 | 110.07 | .507 | 89.70 | .413 |

**Labor and tractor time per 1,000 gallons of liquid manure hauled.** The data in Table 5 also show the labor and tractor time per 1,000 gallons of liquid manure hauled. These figures are a function of the distance hauled and the type of equipment used to load, haul, and spread the manure. The sample farms used an average of 0.507 hour, or about 30 minutes, of labor and 0.413 hour, or about 25 minutes, of tractor time per 1,000 gallons of liquid manure hauled.

## Equipment used to load, haul, and spread liquid manure

Table 6 lists the equipment used for loading, hauling, and spreading liquid hog manure on the 10 farms using Methods A and C for manure disposal.

The spreading equipment on five of the farms was custom built either by the farmer or by a local machine shop. All of the farms used a pump for loading the liquid manure. With six of the tanks a vacuum pump was used to reduce pressure in the tank, causing the liquid manure to flow into the tank through a suction hose. With this equipment it was possible to reverse the pump and use pressure to force the manure out of the spreading tank. This type of pump facilitated more even distribution of the manure than was possible with gravity discharge alone. The other four pumps were of the impeller-irrigation type. Although they were high-capacity pumps, the manure had to be discharged from the spreading tank by gravity.

The average capacity of spreader tanks used on the 10 farms was

Table 6. — Description of Equipment Used for Loading, Hauling, and Spreading Liquid Hog Manure on 10 Farms

| Farm No. | Type of pump | Size of tank (gallons) | Tractor size most frequently used | Initial investment in equipment |
|---|---|---|---|---|
| 1 | Vacuum | 775 | 4-Plow | $ 962 |
| 7 | Impeller | 1,100 | 2–3-Plow | 1,274 |
| 15 | Vacuum | 900 | 3–4-Plow | 500[a] |
| 19 | Vacuum | 775 | 4-Plow | 832 |
| 23 | Vacuum | 775 | 3–4-Plow | 1,028 |
| 24 | Impeller | 1,400 | 5-Plow | 1,814 |
| 33 | Vacuum | 775 | 4-Plow | 1,130 |
| 35 | Impeller | 1,000 | 4-Plow | 1,552 |
| 36 | Vacuum | 950 | 4-Plow | 1,045 |
| 45 | Impeller | 1,000 | 4-Plow | 1,172 |
| Average | ....... | 945 | | $1,131[b] |

[a] The farmer on Farm No. 15 stated that his present equipment was unsatisfactory, and at the end of the year he replaced it with a commercial spreader and pump.
[b] Without Farm No. 15, the average equipment cost was $1,209.

945 gallons. The largest tank held 1,400 gallons, while the smallest held 775 gallons. Due to foaming during pumping and the danger of overfilling, the average load was kept to about 90 percent of the tank capacity.

A 4-plow tractor was most frequently used for hauling and spreading liquid manure on the 10 sample farms. The average load of manure weighed approximately 3.78 tons. The weight of the manure plus the weight of the spreader wagon made the gross weight commonly exceed 4.5 tons.

### Initial investment in hauling and spreading equipment

The average initial investment in equipment used for handling liquid manure on the 10 farms was $1,131 per farm. However, on Farm 15 the operator considered the equipment to be unsatisfactory. The average cost of equipment used for handling liquid manure on the other 9 farms was $1,209 per farm. The equipment investment for handling liquid manure on the 9 farms ranged from $832 to $1,814.

## COMPARISON OF COSTS AND RETURNS FOR THREE SIZES OF HOG OPERATIONS

The standardized costs and returns for the three methods of liquid manure disposal were examined in relation to three sizes of hog operations: 500, 1,500, and 2,500 hogs per year. This is equivalent to approximately 65, 200, and 325 litters produced annually. Only the growing-finishing phase of the production system is considered in this analysis. A totally enclosed, partially slotted-floor confinement building is used in which manure storage is provided in pits under the slotted-floor area for a period of 3 to 6 weeks. The hogs are assumed to be housed in this building for a period of 120 days. The average weight per hog during this period is considered to be 130 pounds.

The sample farm data provide most of the budgeting information needed for the analysis. Engineering data are used to determine the costs of a manure lagoon as these data are not available from the sample farms.

## Total quantity of manure hauled

The data in Table 7 show the total gallons of manure hauled for three selected sizes of hog operations using Methods A and C. For Method A, the quantity of manure hauled is based on a 120-day growing-finishing period, a 130-pound average weight per hog, and manure production equal to 9.3 percent of body weight per day. The average manure production per hog is 180 gallons during the growing-finishing period.

For Method C, the quantity of manure hauled is 57 percent of the total manure produced and hauled by Method A. During the four-month period June 15 to October 15, the manure is disposed of in a lagoon. On the basis of farm observations, it is assumed that 1½ times as much manure is produced per unit of time during this period than during the other eight months of the year.

## Resources required for disposing of liquid manure by alternative methods

The resources required for disposing of liquid manure by alternative methods for three selected sizes of hog operations are shown in Table 8. The investment in the tank spreader and manure pump is $1,200 for each size of operation. It is assumed that a tractor is available on the farm to pull the applicator tank. The tractor and labor hours vary with the amount of manure hauled and spread.

The investment costs of lagoons vary with the size of lagoon needed to dispose of wastes. The necessary size of a lagoon varies with number of hogs and proportion of manure lagooned. The initial total investment costs include the cost of moving earth to provide a lagoon with a depth of about 6 feet and a water depth of 4 to 5 feet; the cost of a fence around the perimeter of the lagoon; and the cost of a tile line to carry the liquid manure from the finishing build-

Table 7. — Quantity of Manure Hauled by Methods A and C for Three Sizes of Hog Operations

| Number of hogs produced annually | Quantity of manure hauled | |
|---|---|---|
| | Method A[a] | Method C[b] |
| | (gallons) | |
| 500 | 90,000 | 51,000 |
| 1,500 | 270,000 | 154,000 |
| 2,500 | 450,000 | 256,000 |

[a] Equal to total manure production during 120-day growing-finishing period (40 pounds to 220 pounds). Based on manure production of 9.3 percent of body weight per day and average weight of 130 pounds per hog (see Table 2).
[b] Fifty-seven percent of total manure produced is hauled when Method C is used.

Table 8. — Resources Required for Alternative Methods of Manure Disposal by Three Sizes of Hog Operations

| Method | Total requirement for annual production of | | |
|---|---|---|---|
| | 500 hogs | 1,500 hogs | 2,500 hogs |
| **Total hauling and spreading (Method A)** | | | |
| Tank spreader and pump | $1,200 | $1,200 | $1,200 |
| Tractor (hours)[a] | 37 | 111 | 184 |
| Labor (hours)[b] | 45 | 135 | 225 |
| **Total lagooning (Method B)** | | | |
| Lagoon[c] | | | |
| Moving earth[d] | $ 889 | $2,667 | $4,445 |
| Fencing[e] | 137 | 219 | 277 |
| Tile[f] | 120 | 120 | 240 |
| Total lagoon costs | $1,146 | $3,006 | $4,962 |
| **Partial lagoon and hauling (Method C)** | | | |
| Lagoon[g] | | | |
| Moving earth[d] | $ 445 | $1,334 | $2,223 |
| Fencing[e] | 104 | 162 | 202 |
| Tile[f] | 120 | 120 | 240 |
| Total lagoon costs | $ 669 | $1,616 | $2,665 |
| Tank spreader and pump | $1,200 | $1,200 | $1,200 |
| Tractor (hours)[a] | 21 | 63 | 105 |
| Labor (hours)[b] | 25 | 77 | 128 |

[a] Based on .41 tractor hour per 1,000 gallons hauled.
[b] Based on .50 hour of labor per 1,000 gallons hauled.
[c] Based on 100 square feet per hog on hand. Number on hand equals 40 percent of annual production.
[d] An average of 4 feet of earth removed at a cost of 30 cents per cubic yard.
[e] Costs 20 cents per foot of fence.
[f] 100 feet of 8-inch tile. Two tile lines required for 2,500-hog annual production.
[g] Based on 50 square feet per hog on hand. Number on hand equals 40 percent of annual production.

ing to the lagoon. No tractor time or labor is required when manure is disposed of through the lagoon. Actually, a small amount of labor is required periodically to pull the plug in the manure pit and allow the manure to flow into the lagoon. However, it is assumed that this labor is part of the regular inspection chores and is not charged against the manure disposal operation.

Experimental trials with lagoons at the University of Illinois swine farm indicate that early recommendations of 20 to 60 square feet of surface area per hog were not adequate for complete waste disposal. In this study, when the entire amount of hog wastes is disposed of in a lagoon (Method B), it is assumed that a lagoon surface area of 100 square feet per hog is needed for the maximum number of hogs on hand at one time. When a combination of lagooning and hauling is used (Method C), an area of 50 square feet per hog is assumed to be adequate.

## Annual costs of disposing of liquid manure by alternative methods

The annual costs of disposing of liquid manure by the alternative methods for three selected sizes of hog operations are shown in Table 9. These costs are determined in the following manner for the various resources used.

**Table 9. — Annual Cost of Disposing of Liquid Manure by Alternative Methods for Three Sizes of Hog Operations**

| Method | Number of hogs produced annually | | |
|---|---|---|---|
| | 500 | 1,500 | 2,500 |
| Total hauling and spreading (Method A) | | | |
| Tank spreader and pump[a] | $240 | $240 | $240 |
| Tractor[b] | 35 | 106 | 177 |
| Labor[c] | 69 | 207 | 344 |
| Total annual costs | $344 | $553 | $761 |
| Total lagooning (Method B) | | | |
| Total annual costs of lagoon[d] | $160 | $421 | $695 |
| Partial lagooning and hauling (Method C) | | | |
| Lagoon[d] | $ 94 | $226 | $373 |
| Tank spreader and pump[a] | 240 | 240 | 240 |
| Tractor[b] | 20 | 61 | 101 |
| Labor[c] | 39 | 118 | 196 |
| Total annual costs | $393 | $645 | $910 |

[a] Twenty percent of initial investment to cover annual costs of depreciation, interest, taxes, insurance, maintenance, and repairs.
[b] Based on a rate of 96 cents per tractor hour for fuel and repair.
[c] Based on a wage rate of $1.53 per hour.
[d] Fourteen percent initial investment to cover annual costs of depreciation, interest, maintenance, and repairs.

Twenty percent of the initial investment is used as an estimate of the annual cost of the tank spreader and pump. Twelve and one-half percent was allowed for depreciation (8-year life), 3 percent for interest on investment, and 4½ percent for maintenance, repairs, taxes, and insurance. The interest charge assumes a 6-percent interest rate on the average unrecovered cost of the equipment.

Only the tractor operating costs (fuel and repairs) are charged against the manure disposal operation, as it is assumed that a tractor is available on the farm to pull the tank spreader. According to the farm observations (Table 6) a 4-plow tractor was most frequently used for hauling and spreading liquid manure. The cost of operating a tractor of this size on the sample farms was 96 cents per hour in 1964.

The labor used for hauling and spreading liquid manure is charged at the average hired wage rate paid by the sample farms. This rate was $1.53 per hour in 1964.

The annual cost of the lagoon is 14 percent of the initial investment. This estimate allows 10 percent for depreciation (10-year life), 3 percent for interest on the investment, and 1 percent for maintenance and repairs. Because of limited farm experience with manure lagoons, the period during which the initial investment should be recovered is difficult to estimate. A lagoon may have a useful life of more than 10 years, but some observations indicate that extensive cleaning may be necessary after this period.

## A comparison of the annual costs of disposing of liquid manure by alternative methods

The total annual cost of resources, per hog and per 1,000 gallons disposed, for disposing of liquid manure for three selected sizes of hog operations by the alternative methods of disposal is shown in Table 10. For all three methods of manure disposal, spreading the costs of the lagoon and manure handling equipment over more units of output causes the cost per hog and per 1,000 gallons of manure disposed to decrease as size of operation increases.

When no consideration is given to the salvage value of manure, the lowest total cost method of disposing of liquid manure is Method B. When 500 hogs are produced annually, the cost per hog is 32 cents compared with 69 and 79 cents for Methods A and C. When the size of the hog operation is increased to 2,500 hogs per year, the difference in costs between the methods of manure disposal decreases considerably. At this level of production, the cost is 28 cents per hog for Method B, and 30 and 36 cents for Methods A and C respectively.

Table 10. — A Comparison of the Annual Cost of Resources for Disposing of Liquid Manure by Alternative Methods, for Three Sizes of Hog Operations

| Number of hogs produced annually | Total annual cost of manure disposal | | | | | |
|---|---|---|---|---|---|---|
| | Method A | | Method B | | Method C | |
| | Per hog | Per 1,000 gallons | Per hog | Per 1,000 gallons | Per hog | Per 1,000 gallons |
| 500 | $.69 | $3.82 | $.32 | $1.78 | $.79 | $4.37 |
| 1,500 | .37 | 2.05 | .28 | 1.56 | .43 | 2.39 |
| 2,500 | .30 | 1.69 | .28 | 1.54 | .36 | 2.02 |

In choosing a manure disposal method, one must consider the salvage value of the manure. This problem is discussed in the following section.

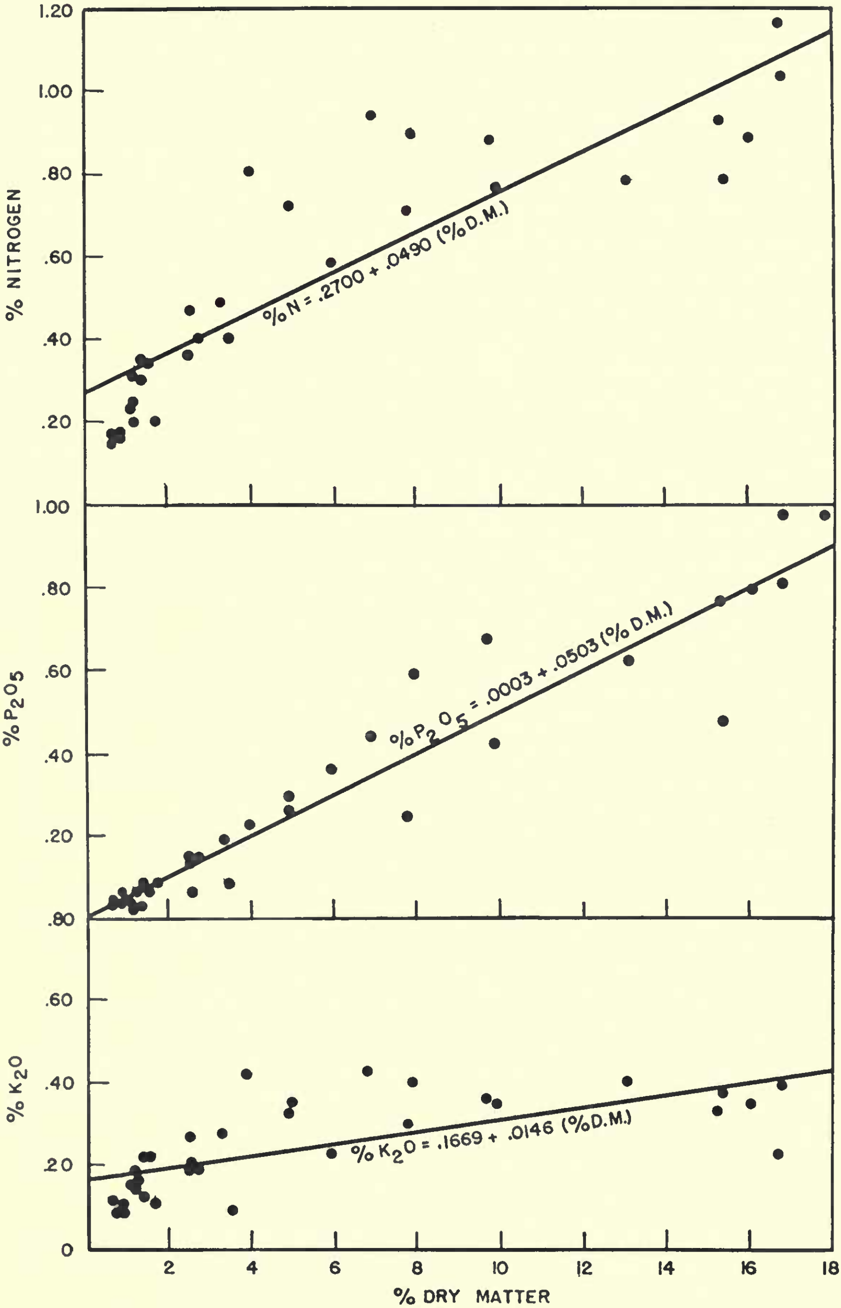
## Value of liquid hog manure

**Chemical analysis of liquid manure samples.** In this study the value of manure is based upon the quantities of fertilizer nutrients in the liquid manure that is being hauled from storage beneath the slotted floor. Thirty-four samples of liquid hog manure were obtained from totally enclosed finishing buildings on February 4 and 23, 1965. Analysis[1] showed a wide variation in dry matter and the fertilizer elements of nitrogen, phosphorus, and potassium. However, when the N, $P_2O_5$, and $K_2O$ contents of the samples are related to dry matter content, a high degree of linear correlation is found to exist (see Fig. 4). For all three nutrients the correlation is significant at a level of .001.

The relation between dry matter content and N, $P_2O_5$, and $K_2O$ content is shown in Fig. 4. The mean dry matter content of the 34 samples was 6 percent by weight. At this dry matter content, the average analysis of the manure was N, 0.56 percent; $P_2O_5$, 0.30 percent; and $K_2O$, 0.25 percent. The fertilizer nutrient content of the manure samples analyzed agrees closely with the results reported by T. W. Robinson and E. P. Taiganides (see page 28).

**Recovery rate of major fertilizer nutrients.** The value of the manure spread on cropland depends not only upon the amounts of the fertilizer nutrients spread but also upon the extent of the actual recovery of these nutrients by subsequent growing crops. This recovery rate depends both upon physical losses of fertility nutrients and upon the rate

[1] The analyses were made under the supervision of Richard M. Forbes, Professor of Nutritional Biochemistry.




Relationship of nitrogen, $P_2O_5$, and $K_2O$ content to dry matter content of 34 liquid manure samples in the winter of 1964-65. (Fig. 4) of availability of these nutrients after they are applied to the soil. The estimate of the quantities of fertilizer nutrients spread already allows for the losses occurring during storage.

Not all of the potential amount of fertilizer nutrients may be recovered because some of the manure may be spread on noncrop land. Some of the nitrogen may be lost through volatilization of ammonia and evolution of nitrogen gas if land is not plowed immediately after spreading. There are no similar physical losses of either phosphorus or potassium after spreading. However, if manure is spread on sloping land, runoff losses of all nutrients may be appreciable, especially if the soil is frozen.

Evidence suggests that the fertilizer nutrients, phosphorus and potassium, are as effective in manure as in mineral fertilizer; however, this is not true of the nitrogen in manure. The nitrogen in the urine is just as effective as that in commercial fertilizer; but much of the nitrogen in dung is in an organic form, which is either unavailable to crops or only slowly available, sometimes requiring years for total conversion into available forms. Illinois agronomists suggest that about 40 percent of the nitrogen in manure is available the first year and 30, 20, and 10 percent are available in each of the succeeding years.

The data in Table 11 show the quantities of N, $P_2O_5$, and $K_2O$ in the manure produced by three sizes of hog operations at selected recovery rates. The 100-percent recovery rate assumes that all of the manure as it comes from the pits is spread on cropland during the entire year. The 67-percent recovery rate assumes that the manure is spread on cropland only during eight months of the year. This rate of recovery may be applicable to Methods A and C. With Method A, it is assumed that during four months of the year (June 15 to October 15) no cropland is available on which to spread the manure as a replacement for commercial fertilizer. When Method C is used, the manure is disposed of in a lagoon during the same four months.

Lastly, the mineral fertilizer replacement quantities of N, $P_2O_5$, and $K_2O$ at a variable recovery rate are shown. The variable recovery rate assumes that the N in manure is 40 percent as effective as the N in mineral fertilizer and the $P_2O_5$ and $K_2O$ are 100 percent as effective. Since the manure is spread on cropland only eight months of the year, this gives an annual recovery rate of 27 percent of the total N, and 67 percent of the total $P_2O_5$ and $K_2O$. The N recovery rate is reduced to allow for its low availability in the year of application and the physical losses in nitrogen after manure is spread. No allowance is made for the residual value of manure. It is common, on farms where manure has

**Table 11. — Mineral Fertilizer Replacement Nutrients in Manure Produced by Three Sizes of Hog Operations, for Selected Recovery Rates**

| Number of hogs produced annually | Pounds of nutrients[a] | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| | (100-percent recovery rate)[b] | | |
| 500 | 4,032 | 2,160 | 1,800 |
| 1,500 | 12,096 | 6,480 | 5,400 |
| 2,500 | 20,160 | 10,800 | 9,000 |
| | (67-percent recovery rate)[c] | | |
| 500 | 2,689 | 1,441 | 1,200 |
| 1,500 | 8,068 | 4,322 | 3,600 |
| 2,500 | 13,447 | 7,204 | 6,000 |
| | (Variable recovery rate)[d] | | |
| 500 | 1,076 | 1,441 | 1,200 |
| 1,500 | 3,227 | 4,322 | 3,600 |
| 2,500 | 5,379 | 7,204 | 6,000 |

[a] Based on gallons of manure produced from Table 7 at 8 pounds per gallon and an average analysis of .56 percent N, .30 percent $P_2O_5$, and .25 percent $K_2O$.
[b] Assumes that manure is spread on cropland twelve months of the year and that nutrients in manure are as effective as those in mineral fertilizer.
[c] Assumes that manure is spread on cropland eight months of the year.
[d] Assumes that manure is spread on cropland eight months of the year and that N in manure is only 40 percent as effective as in mineral fertilizer.

been applied, to observe the beneficial effects of the manure on crops grown for a period of several years.

The variable recovery rate of the nutrients in manure is used as the basis for valuing manure in the cost and return summary. At this rate, the ratio of N, $P_2O_5$, and $K_2O$ in the manure is approximately 1-1.3-1. Recommended corn fertilization practices suggest a ratio between 2-1-1 and 3-1-1. If manure is applied to cornland to provide 60 pounds of N, $P_2O_5$, and $K_2O$ per acre, additional N will be required to make a complete corn fertilizer. The additional N may be easily applied as a preplant or sidedress application.

If the manure is applied to cornland as described above, approximately 20 acres is required on which to spread the manure produced by 500 hogs annually. Sixty and 100 acres will be required for operations of 1,500 and 2,500 hogs per year. Thus it is reasonable to assume that the manure from hog operations as large as 2,500 head per year can be used to replace commercial fertilizer on most Illinois farms.

**Replacement cost of major fertilizer nutrients in liquid manure.** The fertilizer nutrients in manure are valued at the prices farmers paid for commercial fertilizers. In the 1964 University of Illinois Detailed Cost Study, these prices, which include the cost of application, were as

Table 12. — Replacement Cost of the Fertilizer Nutrients in the Manure Produced, for Three Sizes of Hog Operations at Specified Rates of Recovery

| | Replacement cost of fertility nutrients by recovery rate[a] | | |
|---|---|---|---|
| | 100-percent[b] | 67-percent[c] | Variable rate[d] |
| Total for | | | |
| 500 head | $ 639.50 | $ 426.55 | $ 286.18 |
| 1,500 head | 1,918.51 | 1,279.64 | 858.37 |
| 2,500 head | 3,197.52 | 2,132.75 | 1,430.74 |
| Average per 1,000 gallons | 7.10 | 4.74 | 3.18 |
| Average per hog | 1.28 | .85 | .57 |

[a] Based on prices paid by farmers cooperating in the University of Illinois Detailed Cost Study, 1964, for fertilizer custom applied: N, 8.7 cents; $P_2O_5$, 9.2 cents; and $K_2O$, 5.0 cents per pound.
[b] Assumes that manure is spread on cropland twelve months of the year and that nutrients in manure are as effective as those in mineral fertilizer.
[c] Assumes that manure is spread on cropland eight months of the year.
[d] Assumes that manure is spread on cropland eight months of the year and that N in manure is only 40 percent as effective as in mineral fertilizer.

follows: N, 8.7 cents; $P_2O_5$, 9.2 cents; and $K_2O$, 5 cents per pound. The cost of replacing the fertilizer nutrients contained in manure produced by three selected sizes of hog operations at specified recovery rates is shown in Table 12. Also, the replacement cost of the nutrients per 1,000 gallons of manure and per hog is shown. With the variable rate of recovery, the cost of replacing the nutrients contained in 1,000 gallons of liquid manure was $3.18 and the cost of the nutrients in the manure produced by one hog was 57 cents.

## ANALYSIS OF FINDINGS

The data in Table 13 compare the value of the manure spread, using the variable recovery rate with the costs of the three manure disposal methods. When 500 head of hogs are produced annually, the value of the manure spread does not cover the total costs of any of the manure disposal methods. This situation holds for Method B (total lagooning) at any level of hog production, since no fertility value is recovered from manure disposal in a lagoon. With only 500 hogs produced annually, Method A (total hauling and spreading) has a net cost of $58 per year, the lowest of the three methods.

Similar comparisons of data on 1,500- and 2,500-head hog operations also indicate that Method A shows the greatest net return above total disposal costs. For the 1,500-head hog operation Method A shows a net return of $305, Method B a net cost of $421, and Method C a net return of $213. For a 2,500-head operation, Method A shows a net re-

Table 13. — Summary of Costs and Returns of Disposing of Liquid Manure by Alternative Disposal Systems for Three Sizes of Hog Operation

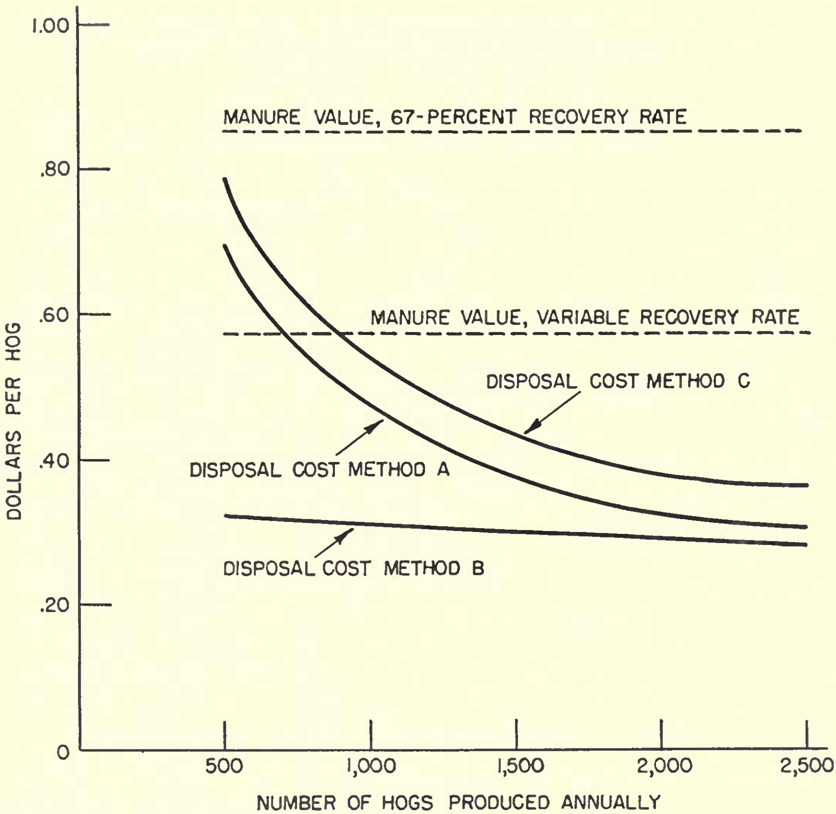
| Items | Annual costs and returns for method | | |
| --- | --- | --- | --- |
| | A | B | C |
| | (500 head produced annually) | | |
| Value of salvaged manure[a] | $ 286 | ... | $ 286 |
| Disposal costs[b] | | | |
| Labor | 69 | ... | 39 |
| Tractor | 35 | ... | 20 |
| Tank spreader and pump | 240 | ... | 240 |
| Lagoon | ... | 160 | 94 |
| Total | $ 344 | $ 160 | $ 393 |
| Returns above total disposal costs | $ −58 | $−160 | $−107 |
| | (1,500 head produced annually) | | |
| Value of salvaged manure[a] | $ 858 | ... | $ 858 |
| Disposal costs[b] | | | |
| Labor | 207 | ... | 118 |
| Tractor | 106 | ... | 61 |
| Tank spreader and pump | 240 | ... | 240 |
| Lagoon | ... | 421 | 226 |
| Total | $ 553 | $ 421 | $ 645 |
| Return above total disposal costs | $ 305 | $−421 | $ 213 |
| | (2,500 head produced annually) | | |
| Value of salvaged manure[a] | $1,431 | ... | $1,431 |
| Disposal costs[b] | | | |
| Labor | 344 | ... | 196 |
| Tractor | 177 | ... | 101 |
| Tank spreader and pump | 240 | ... | 240 |
| Lagoon | ... | 695 | 373 |
| Total | $ 761 | $ 695 | $ 910 |
| Return above total disposal costs | $ 670 | $−695 | $ 521 |

[a] Manure valued at variable recovery rate. Data from Table 12.
[b] Data from Table 9.

turn of $670, Method B a net cost of $695, and Method C a net return of $521.

## Effect of size of hog operation

The net return above total disposal costs increases per unit for all methods of manure disposal. The total costs per hog decreased for all three methods of manure disposal as the size of hog operation increased. The effect of size was greatest for Methods A and C because the initial investment in a tank spreader and pump are constant for all sizes of operation, whereas in Method B the amount of investment in the lagoon depends almost entirely on the number of hogs produced. When the size of operation increased from 500 to 2,500 head per year,




**Manure value for two recovery rates and disposal costs per hog produced for the three alternative methods. (Fig. 5)**

the disposal costs per hog decreased from 69 to 30 cents for Method A, from 32 to 28 cents for Method B, and from 79 to 36 cents for Method C (Fig. 5).

The value of the manure spread per hog is not affected by size of operation. Thus, when the value of the manure is constant per hog and the disposal costs per hog are decreasing, the net returns from Methods A and C increase rapidly as size of operation expands. With an increase from 500 to 2,500 head of hogs per year, the returns above disposal costs per hog increased from —12 to 27 cents for Method A and from —21 to 21 cents for Method C. Thus the net returns increased 39 and 42 cents per hog as volume of production increased over this range.

## Effect of wage rate

When wide differences in the physical amount of labor required by the alternative methods are present, the level of wages charged may affect the choice of the most profitable method. In this case, the total lagooning method uses no additional labor, hence this method would tend to become more advantageous as the wage rate increases.

When labor costs are excluded from the total disposal costs, critical labor wage rates affecting the choice of manure disposal method can be determined. The data in Table 14 show the returns above disposal costs excluding labor for each method by size of hog operation. With labor cost at zero, Method A is the lowest net cost method of disposing of manure.

When the residual return above disposal costs (excluding labor) is allowed as a return to labor, Method A provides a net return of 24 cents per hour and Method C provides a net cost of $2.69 per hour

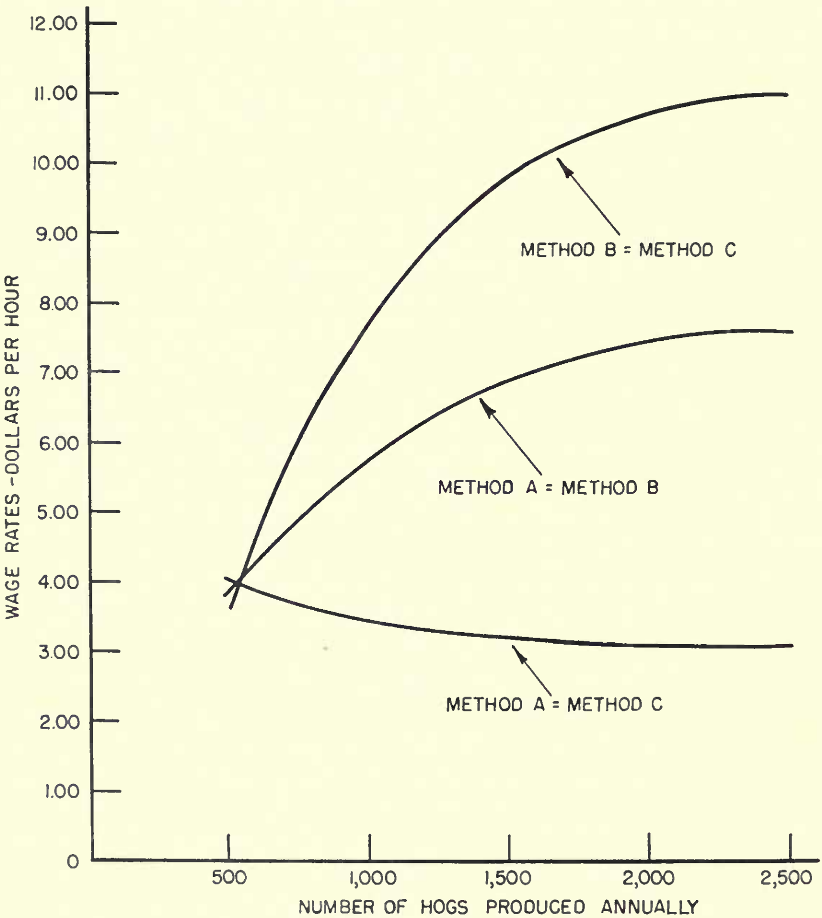
**Table 14. — Returns per Hour of Labor and Break-even Labor Rate for Alternative Liquid Manure Disposal Systems by Three Sizes of Hog Operations**

| Items | Annual costs and returns for method A | B | C |
|---|---|---|---|
| | (500 head produced annually) | | |
| Returns above disposal costs excluding labor[a] | $ 11 | $ −160 | $ − 68 |
| Hours of labor used[b] | 45 | ... | 25.5 |
| Return above disposal costs per hour of labor[c] | $ .24 | ... | $ − 2.69 |
| Break-even labor rate with Method B[d] | $ 3.80 | ... | $ 3.61 |
| Break-even labor rate with Method C | $ 4.05 | | |
| | (1,500 head produced annually) | | |
| Returns above disposal costs excluding labor[a] | $ 512 | $ −421 | $ 331 |
| Hours of labor used[b] | 135 | ... | 77 |
| Return above disposal costs per hour of labor[c] | $ 3.79 | ... | $ 4.29 |
| Break-even labor rate with Method B[d] | $ 6.91 | ... | $ 9.76 |
| Break-even labor rate with Method C | $ 3.12 | | |
| | (2,500 head produced annually) | | |
| Returns above disposal costs excluding labor[a] | $1,014 | $ −695 | $ 717 |
| Hours of labor used[b] | 225 | ... | 128 |
| Return above disposal costs per hour of labor[c] | $ 4.51 | ... | $ 5.60 |
| Break-even labor rate with Method B[d] | $ 7.60 | ... | $ 11.03 |
| Break-even labor rate with Method C | $ 3.06 | ... | ... |

[a] Data from Table 13.
[b] Data from Table 8.
[c] Calculated by dividing return above disposal cost excluding labor by hours of labor used.
[d] Labor rate necessary to make return above disposal costs or net disposal cost equal to the cost of Method B. Calculated by dividing difference in returns above disposal costs of Method A or C and Method B with hours of labor used in the respective method.

with 500 head produced annually. However, when 1,500 head are produced Method A gives $3.79 per hour and Method C $4.29.

The labor-wage levels necessary to make the costs of Method B equal to those of Methods A and C are shown by the break-even labor rate figures in Table 14. These figures are calculated by determining the difference in the "returns above disposal costs excluding labor" of Method B and Method A or Method C and dividing this difference by hours of labor used in hauling and spreading manure by respective methods.




**Labor wage rates and levels of hog production necessary to make disposal costs of the alternative methods equal. (Fig. 6)**

When 500 head of hogs are produced, the labor rate necessary to make net disposal costs equal for Method A and Method B is $3.80 per hour. The break-even labor rate between Method B and Method C is $3.61. A 1,500-head hog operation needs a labor wage rate of $6.91 per hour for Methods A and B and $9.76 for Methods B and C. In the same manner, a 2,500-head hog operation requires a rate of $7.60 and $11.03 per hour for labor used in Methods A and C to equal the net cost of Method B. When wage rates either in terms of money wages for hired workers or reservation price of unpaid labor are above these break-even wage rates, Method B becomes the more profitable method.

The labor-wage rate to make net returns above disposal costs equal for Methods A and C is presented in Table 14. For a 500-head hog operation the break-even wage rate is $4.05 per hour, for a 1,500-head operation $3.12, and for a 2,500-head operation $3.06. When wage rates are above this level Method C becomes more profitable than Method A.

The relation of the break-even labor-wage rates between the alternative manure disposal systems to number of hogs produced is shown in Fig. 6. These relations indicate that the levels of wages needed to make Method B or C more profitable than Method A are well above the current hired-labor wage.

## Effect of fertilizer prices

The replacement cost of the fertilizer nutrients in the manure spread is an important variable affecting the choice of manure disposal systems. In making this decision, a manager needs to consider not only today's fertilizer prices but, perhaps more importantly, the trend in fertilizer prices in his planning horizon of five to ten years. Rapid changes in technology in the fertilizer industry make it difficult to project fertilizer prices. The per unit cost of fertility nutrients is affected by changes in production processes, methods of distribution and application, the discovery of new sources of fertilizer elements, and the expansion of plant capacity in the fertilizer industry. Illinois agronomists estimate the cost of nitrogen in 1970 at 4.5 cents per pound. On the basis of this estimate, the price of nitrogen, applied, would be about 5.5 cents per pound in 1970. The prediction has also been made that the prices of $P_2O_5$ and $K_2O$ will not change greatly during this period.

The data in Table 15 indicate the net returns or costs of disposing of manure by Methods A and C when the value of manure at the variable recovery rate is priced at the expected 1970 price of 5.5 cents

Table 15. — Summary of Costs and Returns of Disposing of Liquid Manure by Alternative Systems for Three Sizes of Hog Operations at 1970 Price Levels

| Items | Annual costs and returns for method | | |
|---|---|---|---|
| | A | B | C |
| | (500 head produced annually) | | |
| Value of salvage manure at 1970 price level[a] | $ 252 | ... | $ 252 |
| Total disposal costs[b] | 344 | 160 | 393 |
| Return over total disposal costs | $ −92 | $−160 | $−141 |
| | (1,500 head produced annually) | | |
| Value of salvage manure at 1970 price level[a] | $ 755 | ... | $ 755 |
| Total disposal costs[b] | 553 | 421 | 645 |
| Return over total disposal costs | $ 202 | $−421 | $ 110 |
| | (2,500 head produced annually) | | |
| Value of salvage manure at 1970 price level[a] | $1,259 | ... | $1,259 |
| Total disposal costs[b] | 761 | 695 | 910 |
| Return over total disposal costs | $ 498 | $−695 | $ 349 |

[a] Manure valued at variable recovery rate with N at 5.5 cents, $P_2O_5$ at 9.2 cents, and $K_2O$ at 5.0 cents per pound. Data from Table 11.
[b] Data from Table 13.

per pound of N, of 9.2 cents per pound of $P_2O_5$, and of 5.0 cents per pound of $K_2O$. These prices do not reduce the value of manure enough to change the choice of the lowest cost method of disposing of manure. At all levels of production considered, Method A has the lowest net cost or highest net return above total disposal costs of the three methods.

## Effect of nutrient recovery rate

Increasing the recovery rate of N from 27 percent to 67 percent does not change the optimum choice from Method A; it does change the size of hog operation at which returns equal costs for the two hauling and spreading methods (A and C). When the nutrient recovery rate of N is raised to 67 percent, the same level as $P_2O_5$ and $K_2O$, the manure value exceeds cost of disposal by either Method A or Method C at all levels of hog production (Fig. 5). When the recovery rate is reduced because of low availability of nitrogen, the value of the manure will cover the total costs of disposal by Method A at an annual production of about 650 head. The cost of disposal by Method C will be covered at about 850 hogs per year.

## Comparison of findings with previous study

The findings of this study, that hauling and spreading is the most economic manure disposal system, conflict directly with the conclusion of an earlier study. The 1959-1960 study concluded that "the most profitable practice for the average farmer who raises hogs in confinement is to dispose of the liquid manure in a lagoon and use commercial fertilizers on his fields."[1]

The choice of the optimum manure disposal system depends upon the relation between the value of manure spread and the costs of disposing of the manure at varying scales of operation. The difference in the conclusions between the two studies arises from developments that affected both the costs and returns of the alternative manure disposal systems. First, the recommended size of lagoon necessary to satisfactorily digest the hog wastes has increased from 20 to 100 square feet per hog. This increased substantially the costs associated with the total lagoon method. Second, the development and use of slotted floors in the confinement feeding facilities has reduced the costs involved in hauling and spreading manure. The use of slotted floors eliminates the need for the separate storage tanks in the early liquid manure system. Slotted floors also reduce the need to use water in cleaning the floor and thus the volume of material that is handled per unit of production. Third, the expected value of manure was discounted more than the level used in the current study. The average recovery rate was expected to be less than 50 percent of all fertilizer nutrients. In the current study the overall expected recovery rate is 27 percent of N, 67 percent of $P_2O_5$, and 67 percent of $K_2O$. Lastly, the conclusion of the earlier study applied only to the farmer producing around 500 head of hogs. The choice of the optimum manure disposal system varies with size of operation. Even in the earlier study, hauling and spreading was more economical than lagooning for larger operations where more than 750 head of hogs were produced.

## CONCLUSIONS

Total hauling and spreading (Method A) is the lowest net cost method of disposing of liquid hog manure from slotted-floor confinement facilities when cropland is available to use the manure to replace commercial fertilizer. The combination hauling, spreading and lagooning (Method C) is the second lowest net cost method. Total lagooning (Method B) is the highest net cost method.

The advantage for hauling and spreading increases as size of hog operation increases. The net cost of manure disposal per unit declines as the volume of hog production increases. The decreases in disposal

[1] Van Arsdall, R. M., The Economic Value of Manure from Confinement Finishing of Hogs. Ill. Agr. Exp. Sta. Bul. 687, 1962.

costs per hog are greater for Methods A and C than for Method B, because the investment costs of the lagoon are related to the number of hogs produced while the initial investment in manure disposal equipment is constant for all levels of hog production.

The net return above disposal costs depends upon the relation between value of manure and cost of disposing of the manure. The results of this study give some general guidelines. Changes in either the costs of disposing of manure or the returns from manure may affect the choice of optimum disposal system on a particular farm.

Other considerations may lead to choices other than Method A on a particular farm. A farmer may be willing to accept the higher net cost of lagooning (Method B) because it allows him to avoid the somewhat disagreeable task of hauling and spreading. Similarly, he may be willing to accept the lower net return of the combination lagooning and spreading (Method C) because it gives more flexibility in the timing of disposal operations than the total hauling and spreading (Method A).

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