ECONOMIC ANALYSIS OF ALTERNATIVE MANURE HANDLING SYSTEMS BY SIZE OF DAIRY HERD[1/]

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Introduction

Sensitivity of the general public to pollution of air, water and land has been rapidly increasing as urban development spreads into rural areas of Maryland, the Northeast and the nation. Among the rural groups who have become vitally concerned with this situation are dairy farmers. They are especially concerned over impending regulations for handling animal wastes and the possible effect on the economics of dairy operations.

Basic to the economic effects of future environmental regulations is an economic cost analysis of alternative manure handling systems by size of herd. With such knowledge of costs, dairy farmers could estimate more effectively the economic impact of having to conform to various types of pollution control regulations and possibly countermand policy proposals in public forums that might prove detrimental to the economic welfare of the dairy industry.

Methodology

The Monocacy River Watershed was selected as the representative site for the detailed study of manure handling systems in dairy farms. This watershed originates in Adams County, Pennsylvania and continues into the Maryland counties of Carroll, Frederick and Montgomery. Nine hundred dairy herds were located in this watershed. A sample of 163 herds from Maryland and Pennsylvania was chosen to obtain bench-mark planning data on land, labor, capital, management and costs of manure handling systems

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for dairy operations of different sizes. The survey included a personal interview and resulted in data from 46 herds with less than 50 cows, 41 herds with 50-89 cows, 40 herds with 90-129 cows, 15 herds with 130-159 cows and 21 herds with 160 or more cows.

Engineering and cost data used for budgeting investment and annual costs of the alternative manure handling systems were obtained through the survey, contacts with extension agents, the Department of Agricultural Engineering and the University of Maryland[2/], manufacturer representatives for farm machinery and equipment, local supply dealers and building contractors.

Description of Systems

All manure handling systems were developed for 50, 100 and 200 cow herd sizes. The systems were designed to make final disposal of 85 pounds of manure per day or 15.5 tons for each cow in the herd. Raw manure production is in excess of this figure but normal losses reduce the amount handled in the final spreading operation. Equipment common to all systems included a 40 hp tractor for scraping and/or loading, a 70 hp tractor for spreading, a rear mounted scraper blade and a manure spreader.

Conventional Systems

Scrape-Load-Spread. This system involves scraping a concrete pad daily with a rear mounted tractor blade. After the manure is scraped into a pile, a tractor mounted front end loader is used to load a beater or paddle type manure spreader. Beater spreaders of 116 bushels, 206 bushels, and 365 bushels capacity were selected for the 50, 100 and 200 cow herds, respectively. This system is rather labor intensive since it requires daily spreading unless unfavorable weather, field, labor or other conditions exist.

Scrape-Store-Load-Spread. This system is similar to the scrape-load-spread system except for type of spreader used and the storage compound. A 200 bushel barrel type spreader is used instead of the beater type because stored manure has a tendency to be more liquid. The storage structure consists of a concrete slab with reinforced concrete block walls and allows for six months storage capacity. This allows spreading time to be coordinated with slack times in other farm activities and avoids labor conflicts during planting, tillage and harvesting periods.

Scrape-Ramp-Spread. The only difference between this system and the scrape-load-spread system is the elimination of the loader and the addition of a ramp which combines the loading with the spreading operation. This economizes on equipment--no loader being required--and labor.

[2/] Herbert L. Brodie, Agricultural Engineer, University of Maryland, College Park.

Scrape-Ramp-Store-Load-Spread. This system allows for storage below a ramp. This permits labor flexibility and also gives the option of eliminating loading labor through daily spreading. The six months storage capacity is the same as the scrape-store-load-spread system. The ramp does not require the usual concrete apron, since this function is provided by the concrete storage slab.

Other Systems

Stacker System. Manure is scraped with a rear mounted blade and pushed onto the chain conveyor of the stacker. The conveyor deposits the manure into the storage compound that has six months storage. A barrel type spreader is used.

Liquid System. The liquid system requires an underground reinforced concrete storage tank under the lot area. During the scraping operation, manure drops directly through small openings into the tank. The 40 hp tractor performs the scraping operation as well as pumping the material from the underground tank into a trailer mounted tank spreader. The 70 hp tractor is used to pull the tank spreader and drive a PTO manure pump while spreading. This pump acts as a chopper-agitator and combines solids and liquids into a homogeneous slurry.

Labor Requirements

Since labor requirements vary by herd size and type of manure handling system, the amount of labor required is an important consideration when planning manure handling systems. Labor contraints may require an operator to consider a reduced herd size or a more capital intensive means of manure disposal.

Labor requirements by manure handling system and herd size were developed from observations of actual dairy operations during the summer and fall of 1974. A detailed summary of labor requirements by system and operation is presented in Table 1.

Labor requirements were identical for the scrape-store-load spread, scrape-ramp-store-load-spread and stacker systems for all size herds.

The scrape-ramp-spread system required 16 more hours than the above-mentioned systems at the 50 cow herd size but labor was saved at the 100 cow and 200 cow herd size. The respective savings in labor for the two larger herd sizes over the other systems were 48 and 191 hours.

The basic scrape-load-spread system required the greatest amount of labor per year at the 50 cow herd size but was some less than the other systems, with exception of scrape-ramp-spread and the liquid system, at the 100 cow and 200 cow herd size.

Table 1
Annual Labor Requirements for Various Manure
Handling Systems by Herd Size[a/]

Manure Handling System	Herd Size					
	50 Cow		100 Cow		200 Cow	
	(hours)					
Scrape-load-spread	295		510		901	
Scrape-store-load-spread	255		511		1,021	
Scrape-ramp-spread	271		463		830	
Scrape-ramp-store-load-spread	255		511		1,021	
Stacker	255		511		1,021	
	30 Day	60 Day	30 Day	60 Day	30 Day	60 Day
Liquid	120	120	238	238	477	477

[a/] A detailed breakdown of labor requirements by operation are on file in the Department of Agricultural and Resource Economics, University of Maryland.

Less labor was used in the liquid system at all herd sizes. However, labor requirements within a herd size did not vary with storage capacity. Labor requirements in the liquid system when compared to the systems requiring the highest number of hours, within a herd size, were 175 hours, 273 hours, and 544 hours less for the respective 50, 100 and 200 cow herd sizes.

Investment and Annual Costs

Prices used in the budgets reflect costs through the summer of 1974. Fixed costs for the structures for the various systems include: depreciation (straight line), interest at 9 percent of average investment, repairs at 1 percent of new cost and taxes at \$2.73 per \$100 assessed valuation (based on a 50 percent assessment). Fixed costs for machinery and equipment for the various systems include: depreciation (straight line), interest at 9 percent of average investment, repairs at 5 percent of new cost and insurance at \$12 per \$1,000 of average value. Personal property, such as machinery, is not taxed in Maryland, while real estate (storage slabs and liquid tanks), is subject to taxation. The insurance is primarily fire insurance. Repairs, although technically not entirely a fixed cost, are included in this category for reasons of convenience.

Investment in tractors was prorated according to annual hours of use and based on initial costs of \$6,313 for the 40 hp tractor and \$9,843 for the 70 hp tractors. Fixed costs for the tractors were \$1.33 and \$2.08 per hour for the 40 hp and 70 hp tractors, respectively. Fixed costs included depreciation[3/], interest, repairs and insurance. The hourly

[3/] Based on 8 year life, 20% salvage value, 1,000 hours of operation per year.

variable cost charges (fuel and lubricants[4/]) were $.92 for the 40 hp tractor and $2.07 for the 70 hp tractor.

Spreaders were depreciated on a straight line basis with eight years of life and no salvage value.

Variable costs for the systems primarily include labor and tractor use. The labor input was charged at $2.25 per hour.

Detailed investment requirements for the various systems are shown in Table 2. Based on these investment requirements, annual costs were calculated for each system by herd size as shown in Table 3.

Evaluation on a Per Cow Basis

To facilitate comparison of initial investment, annual cost and labor requirements among systems by size of herd, basic data were converted to a per cow basis. Investment requirements per cow are shown in Table 4 for each of the systems by herd size. This table indicates that economies of size exist within all systems with regard to initial investment per cow. The lowest initial investment per cow for all herd sizes was incurred with the scrape-load-spread system. The liquid system with 60 days storage required the greatest initial investment. Initial investment was about $174, $129 and $104 higher than the low cost scrape-load-spread system for the respective 50, 100 and 200 cow herd size.

Variation in annual cost per cow generally followed that of initial investment per cow, with the scrape-load-spread system as shown in Table 5 having the lowest annual cost per cow. However, on basis of annual costs, the stacker system, which had somewhat lower investment costs per cow than the liquid system with 60 days storage, had the highest annual costs per cow.

Annual labor requirements per cow were lowest for the liquid system in all herd sizes. Table 6 presents detailed labor requirements for the various systems by herd size.

Effective Value of Manure

Traditionally, manure has been a source of plant nutrients on livestock farms. Commercial fertilizer materials were so low in price until recent years that some agriculturists considered manure more a nuisance than an input of value. However, recent high price levels for fertilizer have reversed this type of thinking.

The maximum value of manure is based on its nutrient content at the time it is produced. The real value of the manure should be based on its effective fertilizer value. The price a farmer pays for fertilizer elements in other forms determines the true value of manure. It is the effective value of manure that determines the real value of manure as a fertilizer material.

[4/] Based on 2.0 gallons of diesel fuel per hour for 40 hp tractors and 4.5 gallons per hour for 70 hp tractors, lubricants at 15% of fuel cost.

Table 2
Initial Investment Requirements for Various Manure Handling Systems by Herd Size

Manure Handling System and Operation	Herd Size 50 Cow	100 Cow	200 Cow
Scrape-Load-Spread			
Tractor, 40hp[a]	1,218	2,437	4,722
Tractor, 70hp	1,240	1,683	2,205
Scraper	379	379	379
Loader	1,450	1,450	1,450
Spreader	1,432	1,871	3,658
Total	5,719	7,820	12,414
Scrape-Store-Load-Spread			
Tractor, 40hp	1,218	2,443	4,880
Tractor, 70hp	846	1,693	3,386
Scraper	379	379	379
Loader	1,450	1,450	1,450
Spreader	2,576	2,576	2,576
Storage Slab	3,378	6,213	11,465
Total	9,847	14,754	24,136
Scrape-Ramp-Spread			
Tractor, 40hp	1,067	2,140	4,274
Tractor, 70hp	2,667	4,557	8,170
Scraper	379	379	379
Spreader	1,432	1,871	3,658
Ramp and Apron	574	574	574
Total	6,119	9,521	17,055
Scrape-Ramp-Store-Load-Spread			
Tractor, 40hp	1,218	2,443	4,880
Tractor, 70hp	846	1,693	3,386
Scraper	379	379	379
Loader	1,450	1,450	1,450
Spreader	2,576	2,576	2,576
Ramp and Storage	3,842	6,677	11,929
Total	10,311	15,218	24,600
Stacker			
Tractor 40hp	1,218	2,443	4,880
Tractor 70hp	846	1,693	3,386
Scraper	379	379	379
Loader	1,450	1,450	1,450
Spreader	2,576	2,576	2,576
Storage Slab	3,378	6,213	11,465
Stacker	3,109	3,109	3,109
Total	12,956	17,863	27,245

Liquid	50 Cow 30 Day	50 Cow 60 Day	100 Cow 30 Day	100 Cow 60 Day	200 Cow 30 Day	200 Cow 60 Day
Tractor 40hp	758	758	1,502	1,502	3,011	3,011
Tractor 70hp	472	472	915	915	1,841	1,841
Spreader	4,757	4,757	4,757	4,757	4,757	4,757
Pump	2,039	2,039	2,039	2,039	2,039	2,039
Scraper	379	379	379	379	379	379
Tank	3,831	6,010	6,010	11,074	11,074	21,211
Total	12,236	14,415	15,602	20,666	23,101	33,238

a/ The 40 hp tractor is used 193 hours per year for scraping and loading. Based on a 1,000 hours of total annual use and a new cost of $6,313 the prorated investment cost is 0.193 X $6,313 = $1,218. The same procedure is used for the 70 hp tractor and other manure handling systems.

Table 3
Annual Costs for the Systems by Herd Size

System and Cost Category	Herd Size 50 Cow		100 Cow		200 Cow	
			(dollars)			
Scrape-load-spread						
Fixed Costs	1,231		1,681		2,677	
Variable Costs	1,052		1,760		3,032	
Total Annual Costs	2,283		3,441		5,709	
Scrape-store-load-spread						
Fixed Costs	1,864		2,685		4,266	
Variable Costs	879		1,763		3,521	
Total Annual Costs	2,743		4,448		7,787	
Scrape-ramp-spread						
Fixed Costs	1,275		2,000		3,616	
Variable Costs	976		1,611		2,807	
Total Annual Costs	2,251		3,611		6,423	
Scrape-ramp-store-load-spread						
Fixed Costs	1,927		2,748		4,329	
Variable Costs	879		1,763		3,521	
Total Annual Costs	2,806		4,511		7,850	
Stacker						
Fixed Costs	2,517		3,338		4,919	
Variable Costs	894		1,792		3,580	
Total Annual Costs	3,411		5,130		8,499	
Liquid	30 Day	60 Day	30 Day	60 Day	30 Day	60 Day
Fixed Costs	2,399	2,695	2,945	4,129	4,642	6,470
Variable Costs	479	479	947	947	1,900	1,900
Total Annual Costs	2,878	3,174	3,892	5,076	6,542	8,370

Table 4
Initial Investment Requirements per Cow by Herd Size and Type of Manure Handling System

Item	Herd Size					
	50 Cow		100 Cow		200 Cow	
	(dollars)					
Scrape-load-spread	114.38		78.20		62.07	
Scrape-store-load-spread	196.94		147.54		120.68	
Scrape-ramp-spread	122.38		95.21		85.28	
Scrape-ramp-store-load-spread	206.22		152.18		123.00	
Stacker	259.12		178.63		136.23	
	30 Day	60 Day	30 Day	60 Day	30 Day	60 Day
Liquid	244.72	288.30	156.02	206.66	115.51	166.19

Table 5
Annual Costs per Cow by Herd Size and Type of Manure Handling System

System	Herd Size					
	50 Cow		100 Cow		200 Cow	
	(dollars)					
Scrape-load-spread	45.66		34.41		28.55	
Scrape-store-load-spread	54.86		44.48		38.94	
Scrape-ramp-spread	45.02		36.11		32.12	
Scrape-ramp-store-load-spread	56.12		45.11		39.25	
Stacker	68.22		51.30		42.50	
	30 Day	60 Day	30 Day	60 Day	30 Day	60 Day
Liquid	57.56	63.48	38.92	50.76	32.71	41.85

Table 6
Annual Labor Requirements per Cow by Herd Size and Type of Manure Handling System

System	Herd Size		
	50 Cow	100 Cow	200 Cow
	(hours)		
Scrape-load-spread	5.9	5.1	4.5
Scrape-store-load-spread	5.1	5.1	5.1
Scrape-ramp-spread	5.4	4.6	4.2
Scrape-ramp-store-load-spread	5.1	5.1	5.1
Stacker	5.1	5.1	5.1
Liquid	2.4	2.4	2.4

Based on data from Casler and La Due [1] the effective value of a ton of fresh cow manure spread in the field is 3.2 pounds of N, 2.6 pounds of P_2O_5 and 7.2 pounds of K_2O. However, these values only represent two systems in this analysis, the scrape-load-spread and the scrape-ramp-spread. The other systems store the manure either in a solid manure pack or as a liquid. Data presented in the Livestock Waste Facilities Handbook [2] p. 82, shows differences exist in nutrient content by type of system. However, the study does not give the effective value spread in the field. Based on the effective value of fresh manure as presented by Casler and La Due, and adjusted for differences in systems as presented in the Livestock Wastes Facilities Handbook, Table 7 shows the effective value of manure from the various systems. The poundage per cow is based on 15.5 tons of manure spread per cow.

Table 7
Effective Fertilizer Content of Manure per Cow by Manure Handling System[a/]

System	Effective Content		
	N	P_2O_5	K
		(pounds)	
Scrape-load-spread	50	40	112
Scrape-store-load-spread	43	38	121
Scrape-ramp-spread	50	40	112
Scrape-ramp-store-load-spread	43	38	121
Stacker	43	38	121
Liquid	49	42	115

a/ Based on 15.5 tons of manure per cow spread in field.

The value of the elements shown in Table 7 was based on the average price of anhydrous ammonia (82% N), Superphosphate (20% P_2O_5) and Muriate of Potash (60% K_2O) as shown in Agricultural Prices [3] for Maryland and Pennsylvania during the last three years. For example, the effective value of the manure per cow was $15.32 in 1973, $29.28 in 1974 and $33.50 in the first half of 1975 for the scrape-load-spread and scrape-ramp-spread systems. The simple average over the last three years for the manure in these systems was $26.03 per cow. The manure in other systems using storage, with the exception of the liquid system, averaged $25.33 per cow. The average manure value in the liquid system was $26.64 per cow. All these values represent the effective value of the manure as a fertilizer material. The range in these average manure values was only $1.31 per cow between the high manure value and low manure value systems.

Net Annual Costs

When the annual costs per cow for the manure handling systems are adjusted for the value of the manure, a net annual cost is derived. These net cost figures are shown in Table 8.

Table 8
Annual Costs per Cow by Herd Size and Type of Handling System Adjusted for Effective Value of Manure[a/]

System	Herd Size 50 Cow		100 Cow		200 Cow	
	(dollars)					
Scrape-load-spread	19.63		8.38		2.52	
Scrape-store-load-spread	29.53		19.15		13.61	
Scrape-ramp-load-spread	18.99		10.08		6.09	
Scrape-ramp-store-load-spread	30.79		19.78		13.92	
Stacker	42.89		25.97		17.17	
	30 Day	60 Day	30 Day	60 Day	30 Day	60 Day
Liquid	30.92	36.84	12.28	24.12	6.07	15.21

a/ Based on average price of elements for 1973, 1974 and first half of 1975.

Summary and Conclusions

A field survey of 163 dairy farms in the Monocacy River Watershed of Maryland and Pennsylvania provided basic data on typical manure handling systems by herd size.

The systems developed in the study were for 50, 100 and 200 cow herd sizes and included: conventional systems (scrape-load-spread, scrape-store-load-spread, scrape-ramp-spread, and scrape-ramp-store-load-spread), stacker system and liquid system.

The economic analysis included the development of labor, investment and annual cost figures for the various systems and herd sizes.

Annual labor requirements varied from a low of 2.4 hours per cow for all herd sizes with a liquid system to a high of 5.9 hours per cow for the 50 cow herd using the scrape-load-spread method of handling manure.

Initial investment requirements varied from a low of $62.07 per cow for the 200 cow herd using a scrape-load-spread system to a high of $288.30 per cow for the 50 cow herd with the liquid system (60 day storage) of handling manure.

Annual cost requirement with the adjustment for effective value of manure ranged from a low of $2.52 per cow for the 200 cow herd using the scrape-load-spread system to a high of $42.89 per cow for the 50 cow herd using the stacker system of handling manure. Although the value of the manure has become a more important factor in recent years, the type of system had a relatively small impact on effective value, a range of only $1.31 per cow.

Every dairy farm has a different set of capital, labor and cost structure conditions within which it has to operate. This makes selection of any one manure handling system an individual decision process for each farm.

Providing investment and annual costs are prime considerations, labor is not a constraint and manure can be spread daily; the scrape-load-spread and scrape-ramp-spread systems offer the most economic alternatives for handling manure. However, if storage is needed, the scrape-store-load-spread system has the lowest investment and annual costs for a system having storage capacity and labor requirements, in general, are slightly lower.

However, if sufficient capital is available and labor on the farm is a limiting factor, the use of the liquid system reduces annual labor requirements considerably and the annual cost increase is relatively small for the amount of labor saved. For example, the 200 cow herd liquid system with either 30 or 60 day storage uses only 477 hours of labor as compared to 1,021 hours for the two conventional storage systems, scrape-store-load-spread and scrape-ramp-store-load-spread. This is a saving of 544 hours of labor that possibly could be used for more profitable alternative purposes. Yet the total annual cost for the handling of the manure was only $583 more for the liquid system than the scrape-store-load-spread system and only $520 more for the liquid system than the scrape-store-load-spread system. Provided the labor can be profitably used for other purposes, the use of the liquid system would offset added annual costs and result in respective net economic gains of $641 or $704 when compared to the two conventional systems. However, the initial capital investment would exceed that of the two conventional systems used as examples by $9,102 and $8,638, respectively. The net economic gain over the life of the liquid system would not amortize the added initial investment. However, the total saving in labor, assuming it could be used profitably, would offset the added investment costs over a period of about seven years.

References

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