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Feedlot Manure in Agricultural Production: Costs and Application Rates

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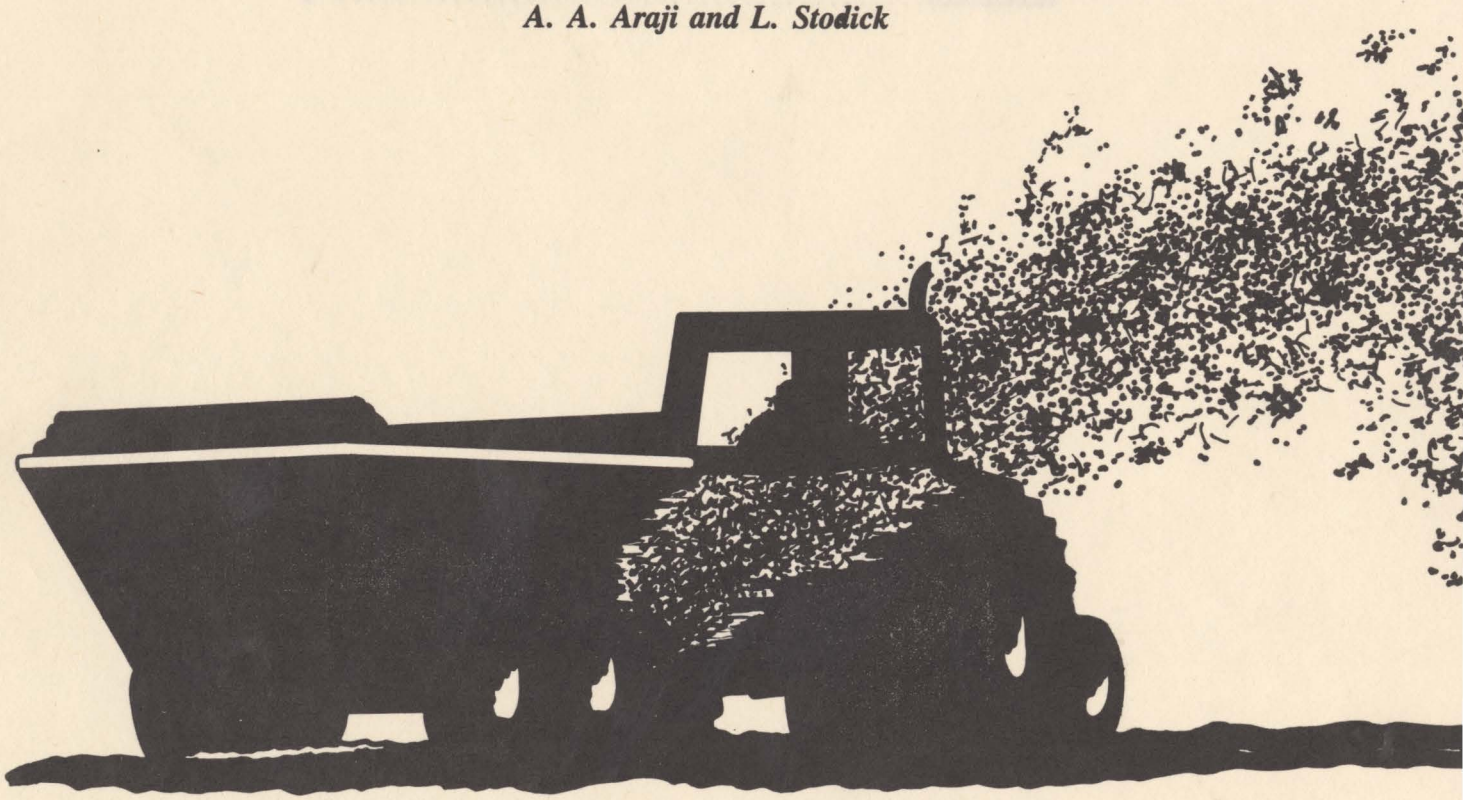

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Feedlot Manure in Agricultural Production: Costs and Application Rates

A. A. Araji and L. Stodick

Manure has been used as a source of plant nutrients for centuries. Although the most important nutrient elements in manure are nitrogen, phosphorus and potassium, other micronutrients and macronutrients also are present and contribute to crop nutrition (Pratt 1982).

In addition to its value as fertilizer, manure improves the soil's physical structure. The direct benefits of manure application to farmland are increased soil organic matter, improved water-holding capacity and improved soil tilth (Graber 1974, Rost and Kramer 1957, Weidemann and Millar 1951). Applying manure to the soil also tends to reduce soil erosion, increase solar heat absorption and increase the solvency action of water on soil minerals (Beaumont 1974).

Plants need the elements nitrogen, phosphorus and potassium in relatively large quantities for growth. Studies show that phosphorus in manure is as readily available to plants as it is in inorganic sources (Azevedo and Stout 1974; Elias-Azar, Laag and Pratt 1980; Reddy et al. 1978). Potassium in manure is not part of any organic structure and is considered to be as available to plants as inorganic sources of potassium (Tisdale and Nelson 1975, Pratt 1982).

Manure nitrogen, on the other hand, must be mineralized before it becomes available to plants. Three factors control nitrogen availability in manure: (1) the amount of nitrogen in the manure, (2) the distribution of nitrogen between organic and inorganic forms and (3) the rate of mineralization of the organic nitrogen. Pratt (1982) showed that manure added at rates sufficient to supply all or most of the nitrogen needs of crops will also supply more-than-adequate quantities of phosphorus, potassium and secondary and minor elements.

The cost of managing, hauling and spreading manure will determine its usefulness as a crop fertilizer. This cost varies with the quantity of accumulated manure in the feedlot, the hauling and spreading distance and the manure application rate per acre. The manure application rate per acre is determined by the manure's nutrient content, the annual mineralization rate of organic molecules and the nutrient requirements of crops in a rotation system.

We simultaneously evaluated annual manure accumulation in variously sized feedlots, hauling and spreading distance, transportation cost and manure application rate per acre to determine their effects on the cost of using manure in agricultural production. We then compared the cost of using manure on various crops with the cost of using commercial chemical fertilizer.

Manure Production

Daily manure production per beef animal varies with ration, animal sex and animal weight. In general, a 1,000-pound beef animal on a finishing ration will produce from 41 to 88 pounds of manure per day with an average of 60 pounds per day (U.S. Department of Agriculture 1975). This represents 6 percent of the animal's body weight.

We estimated total production of fresh manure per animal during the feeding period using the following equation:

$$(1)\quad M_p = 0.06 \left(\frac{B_1 + B_2}{2} \right) t,$$

where:

M_p = total production in pounds of fresh manure during a feeding period,

B_1 = animal body weight in pounds at the beginning of a feeding period,

B_2 = animal body weight in pounds at the end of a feeding period, and

t = length of feeding period in days.

An animal's weight when placed in a feedlot is influenced by the price of fed beef, the price of feeder cattle and the price of feed. The common practice, however, is to place feeder cattle in feedlots when they weigh between 600 and 700 pounds.

A beef animal with a beginning weight of 600 pounds and an average daily gain of 2.5 pounds will produce an estimated 6,510 pounds of manure during 140 days in the feedlot and 8,594 pounds during 175 days. A 700-pound beef animal will produce 7,350 pounds of manure during 140 days of feeding and 9,644 pounds during 175 days of feeding (Table 1).

Manure Accumulation

Accumulation During Feeding Period

Manure accumulation during the feeding period is influenced by temperature, moisture, feedlot surface, surface slope, cattle density, ration feed and the use of mounds within the confinement (Gilbertson et al. 1970 and 1971). In general, where mounds are constructed within confinements, approximately 40 percent of the

Table 1. Estimated manure production per head.

Feeding period	Total manure production	
	600-lb beginning wt	700-lb beginning wt
(days)	(lb/head)	(lb/head)
0	0	0
10	367	427
20	750	870
30	1,147	1,327
40	1,560	1,800
50	1,987	2,287
60	2,430	2,790
70	2,887	3,307
80	3,360	3,840
90	3,847	4,387
100	4,350	4,950
110	4,867	5,527
120	5,400	6,120
130	5,947	6,727
140	6,510	7,350
150	7,087	7,987
160	7,680	8,640
170	8,287	9,307
175	8,594	9,644

Note: The manure production figures assume an average daily gain of 2.5 pounds.

organic solids in the manure pack may decompose during summer (Graber 1974). Decomposition is considerably less in winter because cold weather slows bacterial action. About 60 percent of the manure from a yearling on a grain ration is recoverable (Pherson 1973). Fresh manure from beef animals on a fattening ration contains an average of 15 percent solids (Taylor 1974).

We used the following equation to estimate manure accumulation during a feeding period:

$$(2)\ M_a = .15\ M_p \left(\frac{N}{S}\right),$$

where:

M_a = manure accumulation during the feeding period (lb/head),

M_p = total manure production per head during the feeding period (Equation 1),

.15 = decimal portion of solids in the fresh manure,

N = recoverable manure solids after decomposition (decimal portion of total solids)

= .60 during warm weather or summer feeding periods (40 percent decomposition of solids)

= .85 during cool weather or winter feeding periods (15 percent decomposition of solids), and

S = solids in feedlot manure pack (decimal portion),

= .60 in warm summer feeding periods (40 percent moisture content)

= .35 during cool winter feeding periods (65 percent moisture content).

Table 2. Estimated manure pack accumulation per head.

Animal beginning wt	Manure pack accumulation		
	Summer	Winter	Annual
	(lb/head)	(lb/head)	(lb/head)
	140-day feeding period (2.5 turnovers)		
600	976	2,372	3,348
700	1,102	2,678	3,780
	175-day feeding period (2 turnovers)		
600	1,289	3,131	4,420
700	1,446	3,513	4,959

Equation 2 can be used to estimate manure accumulation per head for various beginning weights and lengths of feeding period (Table 2).

Annual Accumulation

Equation 3 estimates the quantity of accumulated manure requiring removal from feedlots of various sizes during a calendar year:

$$(3)\ X = \frac{M_s + M_w}{2}\ (Z)\ (T)\ (U),$$

where:

X = annual manure accumulation requiring removal from the feedlot,

M_s = manure pack accumulation (lb/head) during the summer feeding period (Equation 2),

M_w = manure pack accumulation (lb/head) during the winter feeding period (Equation 2),

Z = feedlot one-time feeding capacity (head),

T = feedlot turnovers per year, and

U = feedlot capacity per year.

For example, a feedlot with a 1,000-head one-time feeding capacity, 90 percent utilization rate, 2.5 annual turnovers and 600-pound animal beginning weight would have 1,883 tons (3,766,500 pounds) of manure to be removed annually (Table 3).

The frequency and timing of manure removal from feedlots are influenced by weather, availability of land for spreading and termination of feeding period. Usually, feedlots are cleaned during fall or spring when cropland is available for receiving the manure and when weather conditions are most favorable.

Nutrient Content of Manure

Concentrations of nitrogen, phosphorus and potassium in manure vary both within and between animal types (Table 4). No correlations have been found between nutrient concentration and geographical or climatic region.

Mineralization Rate of Organic Nitrogen

The factors controlling nitrogen availability from manure are (1) the amount of nitrogen in the manure, (2) the distribution of nitrogen between organic and inorganic forms and (3) the mineralization rate of organic nitrogen. Pratt (1982) studied a number of decay series and selected three that are appropriate for dry corral manure with a specific nitrogen content (Table 5).

For an application of manure containing 2.5 percent nitrogen, 40 percent of the nitrogen is mineralized the first year, 25 percent of the residual is mineralized the second year, and 6 percent of the residual is mineralized the third and all subsequent years. The final mineralization rate in each series (.06 and .05) is considered a relatively high final rate of residual organic nitrogen mineralization in cold climates.

Manure Application Rates

Nitrogen is the controlling factor in determining the rate of manure application. Therefore, the first step in determining manure application rate per acre is to learn the crop's need for nitrogen in its rotation system in a given year. The second step is to determine the nitrogen content of the manure.

The crop's fertilizer nitrogen need depends on the amount of inorganic nitrogen in the soil, the yield potential and management inputs. The amount of nitrogen applied per acre for the principal crops grown in Idaho varies by area of the state. For sugarbeets, we assumed an application rate of 200 pounds of nitrogen per acre. For potatoes, we assumed an application rate of 150 pounds nitrogen per acre applied during the planting stage. For winter wheat, we assumed an application rate of 100 pounds nitrogen per acre. For spring wheat, we assumed 120 pounds nitrogen per acre.

Table 3. Annual accumulated manure requiring removal from feedlots.

One-time feeding capacity	600-lb beginning wt		700-lb beginning wt	
	140 days*	175 days**	140 days*	175 days**
(head)	(tons)	(tons)	(tons)	(tons)
1,000	1,883	1,989	2,126	2,231
2,500	4,708	4,972	5,315	5,577
5,000	9,415	9,945	10,630	11,155
7,500	14,122	14,918	15,945	16,732
10,000	18,830	19,890	12,260	22,310
12,500	23,537	24,862	26,575	27,887
15,000	28,245	29,835	31,890	33,465
17,500	32,952	34,807	37,205	39,042
20,000	37,660	39,780	42,520	44,620
22,500	42,368	44,752	47,835	50,197
25,000	47,075	49,725	53,150	55,775
27,500	51,782	54,697	58,465	61,352
30,000	56,490	59,670	63,780	66,930
32,500	61,197	64,642	69,095	72,507
35,000	65,905	69,615	74,410	78,085
37,500	70,612	74,587	79,725	83,662
40,000	75,320	79,560	85,040	89,240

*Annual accumulated manure for a 140-day feeding period is calculated on the basis of 2.5 annual turnovers and 90 percent utilization of feedlot capacity.

**Annual accumulated manure for a 175-day feeding period is calculated on the basis of 2.0 annual turnovers and 90 percent utilization of feedlot capacity.

Application Rates for Individual Crops

The Department of Agricultural Economics and Rural Sociology at the University of Idaho has developed a computer program that determines manure application rate per acre given the nitrogen content of the manure and the nitrogen requirement of the crops (Figs. 1-6). The program was developed to determine the relationship between yearly manure mineralization rate and the annual rates of manure application needed to satisfy crop nutrient requirements.[1]

Due to the mineralization process, the annual rate of manure application needed to satisfy the crop's nutrient requirement will change from year to year. For example, to substitute manure containing 1 percent nitrogen for inorganic nitrogen in a winter wheat cropping system that needs 100 pounds of available nitrogen per acre, it would be necessary to add 25 tons the first year and decrease the rate to about 5 tons in the 25th year (Fig. 3). If 25 tons were added each year, the requirements of the cropping system would be greatly exceeded after just a few years. On the other hand, if manure were added at a constant rate of 5 tons

[1]For information on the computer program contact A. A. Araji or L. Stodick at the Department of Agricultural Economics and Rural Sociology, University of Idaho, Moscow, ID 83843.

Table 4. Concentrations of nitrogen, phosphorus and potassium in dry manure from beef and dairy animals, swine and chickens.

Animal type	Nitrogen	Phosphorus	Potassium
	(%)	(%)	(%)
Beef	0.6 to 4.9	0.11 to 1.6	0.05 to 4.0
Dairy	1.5 to 3.9	0.56 to 1.6	1.40 to 3.4
Swine	2.0 to 7.5	0.56 to 2.5	1.50 to 4.9
Chicken	1.1 to 11.0	0.38 to 6.3	0.73 to 5.2

Source: Powers et al. 1975.

Table 5. Yearly mineralization rates of nitrogen in dry corral manure after the initial application to farmland.

Decay series	Nitrogen content	Year				
		1	2	3	4	5
	(%)					
A	2.5	0.40	0.25	0.06	0.06	0.06
B	1.5	0.35	0.15	0.10	0.05	0.05
C	1.0	0.20	0.10	0.05	0.05	0.05

Source: Pratt 1982.

per acre, the crop would be starved for 15 years before mineralization built up nitrogen to the desired level.

Application Rates for Crops Grown in Rotation

Our computer program also determines manure application rates per acre needed to satisfy the nutrient requirement of crops grown in a rotation system (Figs. 7-10). The following four crop rotation systems are common in Idaho:

Rotation 1: Winter wheat — Winter wheat — Fallow

Rotation 2: Spring wheat — Spring wheat — Potatoes

Rotation 3: Potatoes — Spring wheat — Spring wheat — Alfalfa — Alfalfa

Rotation 4: Sugarbeets — Spring wheat — Beans

For example, the annual application rates of manure with 1 percent nitrogen needed to satisfy the nutrient requirements of the sugarbeets-spring wheat-beans rotation are 50 tons per acre the first year, 10 tons per acre the second year, none the third year, 27 tons per acre the fourth year, 9.5 tons per acre the fifth year and none in the sixth year (Fig. 10). Application rates stabilize at the 25th year at 8 tons — 8 tons — 0 tons.

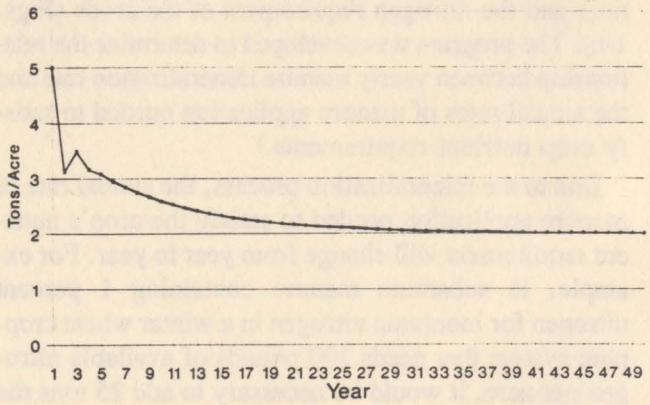

Fig. 1. Annual manure application rate for winter wheat assuming 2.5 percent nitrogen content (decay series A).

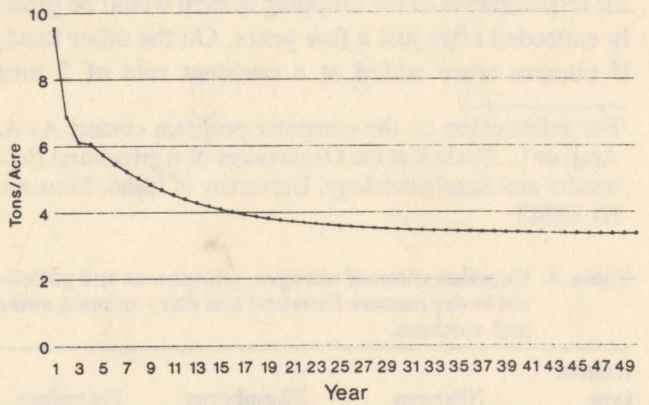

Fig. 2. Annual manure application rate for winter wheat assuming 1.5 percent nitrogen content (decay series B).

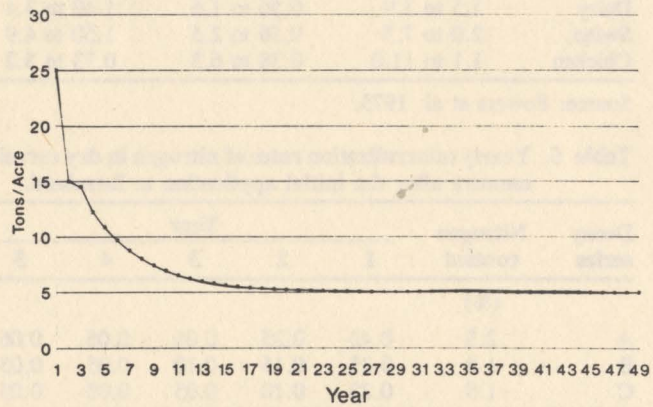

Fig. 3. Annual manure application rate for winter wheat assuming 1.0 percent nitrogen content (decay series C).

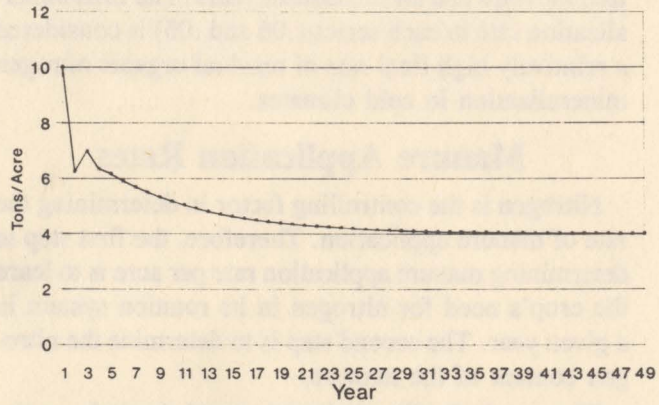

Fig. 4. Annual manure application rate for sugarbeets assuming 2.5 percent nitrogen content (decay series A).

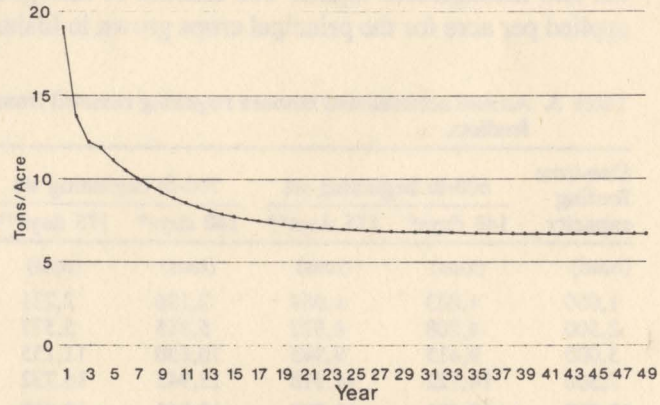

Fig. 5. Annual manure application rate for sugarbeets assuming 1.5 percent nitrogen content (decay series B).

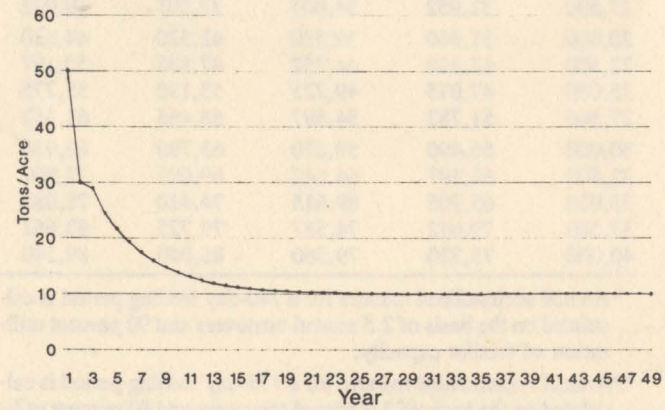

Fig. 6. Annual manure application rate for sugarbeets assuming 1.0 percent nitrogen content (decay series C).

Manure Application Cost

Two types of costs are associated with the management and removal of manure from the feedlot: (1) the in-lot fixed cost of building diversion ditches and catchment ponds for surface runoff control and (2) the manure application cost, including the cost of cleaning, loading, hauling and spreading manure. The fixed cost of building earthen diversion ditches and catchment ponds is minimal and considered part of the fixed cost of feedlot construction.

Manure application cost is the primary cost associated with using manure in agricultural production. This cost depends upon the cost of cleaning, loading, hauling and spreading manure. The hauling and spreading cost depends upon the distance between the feedlot and the field and upon the manure application rate required to satisfy the nutrient need of the crops.

We used the charge for custom cleaning services for the fixed and variable costs of cleaning, hauling and spreading manure. A 1989 telephone survey of 12 custom feedlot cleaning services in three different Idaho locations showed that these services used trucks with capacities ranging from 8 to 20 tons of manure of 40 to 45 percent moisture. Depending on truck size, spreader width ranged from 8 to 10 feet.

In general custom cleaning services charged an average of $1 per ton of manure for cleaning, loading and 1-mile round-trip hauling and spreading. The custom cleaning services also charged $.20 per ton-mile for each additional mile.

Our computer program calculates manure application cost per acre for the four rotation systems and three decay series. The results, based on a 1-mile distance between the field and the feedlot, were compared to the cost of applying commercial fertilizer (Table 6).

For the four rotation systems and three decay series, the average cost per acre of applying manure is significantly lower than the cost of applying commercial fertilizer. For decay series A, the cost of applying manure ranges between 15 and 20 percent of the low com-

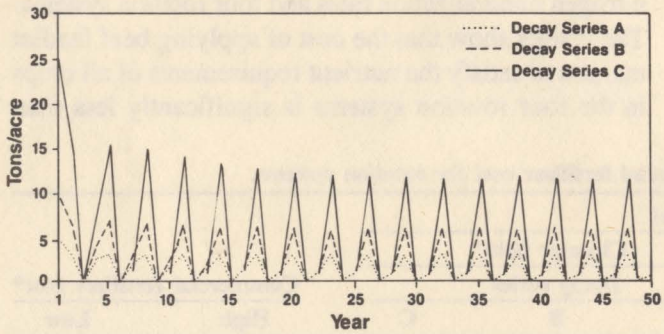

Fig. 7. Annual manure application rates for a winter wheat-winter wheat-fallow rotation with nitrogen requirements of 100 lb/acre — 100 lb/acre — 0 lb/acre.

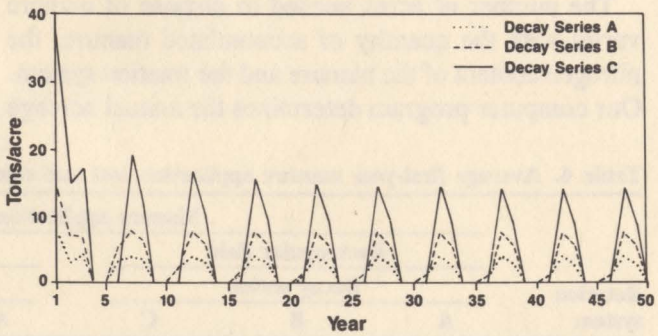

Fig. 9. Annual manure application rates for a potatoes-spring wheat-spring wheat-alfalfa-alfalfa rotation with nitrogen requirements of 150 lb/acre — 120 lb/acre — 120 lb/acre — 0 lb/acre — 0 lb/acre. (For potatoes the fertilizer rate is for preplant application only.)

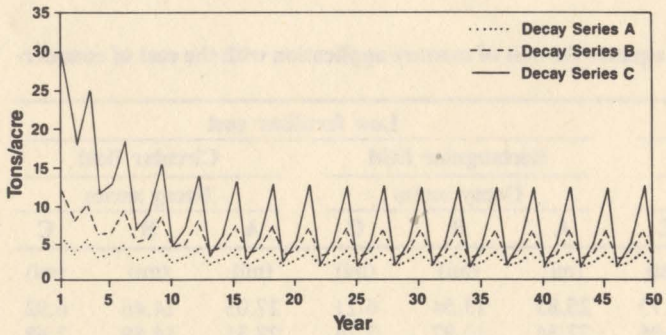

Fig. 8. Annual manure application rates for a spring wheat-spring wheat-potatoes rotation with nitrogen requirements of 120 lb/acre — 120 lb/acre — 150 lb/acre. (For potatoes, the fertilizer rate is for preplant application only.)

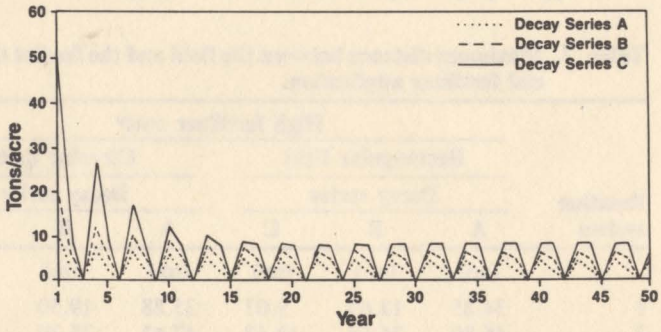

Fig. 10. Annual manure application rates for a sugarbeets-spring wheat-beans rotation with nitrogen requirements of 200 lb/acre — 120 lb/acre — 0 lb/acre.

mercial fertilizer cost and between 10 and 15 percent of the high commercial fertilizer cost. For decay series B, the cost of applying manure ranges between 24 and 30 percent of the low fertilizer cost and between 16 and 22 percent of the high fertilizer cost. For decay series C, the cost of applying manure ranges between 38 and 47 percent of the low fertilizer cost and between 25 and 36 percent of the high fertilizer cost.

Maximum Distance from Feedlot to Field

The distance between the feedlot and the field affects the cost of applying manure to crops. Our computer program calculates the maximum distance manure can be transferred in order to equate the cost of applying manure with the cost of applying commercial fertilizer (Table 7). The maximum distance is influenced by the rotation system, the decay series and the costs of commercial fertilizer. The maximum distance ranges from a high of 47 miles for rotation 3, decay series A and a high fertilizer cost to a low of about 7 miles for rotation 1, decay series C and a low fertilizer cost.

Acres Required for Manure Disposal

The number of acres needed to dispose of manure varies with the quantity of accumulated manure, the nitrogen content of the manure and the rotation system. Our computer program determines the annual acreage required to dispose of manure for various feedlot sizes, manure nitrogen contents and rotation systems.

For example, a feedlot with a one-time feeding capacity of 1,000 head is expected to accumulate between 1,883 and 2,231 tons annually, depending on the animals' beginning weights and the feeding period. Assuming this feedlot accumulates 2,231 tons of manure with 1 percent nitrogen content, disposal will require about 132 acres in rotation 1 during the first year of application. The acreage required for disposal will gradually increase until it stabilizes at about 566 acres at year 29.

Summary

Feedlot waste can be used economically as a source of fertilizer to satisfy the nutrient requirements of various crops. The cost of applying manure in agricultural production is influenced by the manure's nitrogen content, the mineralization rate of organic molecules in the manure and the cost of hauling and spreading manure.

We estimated the manure application cost for three nitrogen mineralization rates and four rotation systems. The results show that the cost of applying beef feedlot manure to satisfy the nutrient requirements of all crops in the four rotation systems is significantly less than

Table 6. Average first-year manure application cost and commercial fertilizer cost for rotation systems.

Rotation system	Manure application cost						Commercial fertilizer cost*	
	Rectangular field			Circular field				
	Decay series			Decay series				
	A	B	C	A	B	C	High	Low
	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)
1	6.15	9.05	14.59	6.02	8.66	13.93	40.00	31.00
2	7.08	11.04	16.97	6.87	10.71	16.38	64.33	40.00
3	7.07	11.05	17.37	6.87	10.67	16.80	64.94	40.59
4	8.29	12.97	20.33	7.82	12.71	19.46	79.00	53.50

Note: Manure application cost assumes a 1-mile distance between the feedlot and the field.

*Commercial fertilizer cost per acre ranges between $30 and $44 for wheat, $77 and $104 for sugarbeets, and $60 and $85 for potatoes when applied preplanting (Smathers et al. 1989a-g).

Table 7. Maximum distance between the field and the feedlot that equates the cost of manure application with the cost of commercial fertilizer application.

Rotation system	High fertilizer cost*						Low fertilizer cost					
	Rectangular field			Circular field			Rectangular field			Circular field		
	Decay series			Decay series			Decay series			Decay series		
	A	B	C	A	B	C	A	B	C	A	B	C
	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(mi)
1	34.85	18.69	9.07	35.88	19.50	9.75	25.85	13.54	6.21	27.05	14.46	6.92
2	46.80	24.68	13.63	47.42	25.20	14.06	27.34	13.87	7.14	28.31	14.59	7.68
3	47.29	24.95	13.36	47.90	25.47	13.66	27.81	14.13	7.03	28.77	14.84	7.49
4	46.62	25.01	13.75	48.73	25.39	13.99	30.17	15.74	8.21	32.04	16.28	8.58

*Commercial fertilizer cost per acre ranges between $30 and $44 for wheat, $77 and $104 for sugarbeets, and $60 and $85 for potatoes when applied preplanting (Smathers et al. 1989a-g).

the cost of applying commercial fertilizer. Depending on the mineralization rate, rotation system and cost of commercial fertilizer, the cost of applying manure ranges between 10 and 47 percent of the cost of applying commercial fertilizer.

The results also show that the maximum distance between feedlot and field that will equate the cost of applying manure with the cost of applying commercial fertilizer ranges between 7 and 47 miles, depending on the manure's nutrient content and the cost of commercial fertilizer.

The manure application rate per acre needed to satisfy the nutrient requirements of crops in the rotation system is the principal variable affecting the cost of applying manure. Manure application rate per acre depends primarily upon the manure's nitrogen content. Therefore, the first step in using manure in agricultural production should be to test the manure for nitrogen content. The percentage of nitrogen in beef or dairy animal manure will determine the application rate per acre, the cost of applying manure and the number of acres needed to dispose of a given quantity of manure. A computer program is available at the Department of Agricultural Economics and Rural Sociology, University of Idaho, to calculate the cost and application rate per acre for any rotation system, type of manure and distance from feedlot to field.

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