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Manure

Toward Efficient Use of Swine Manure

In A Sustainable Agricultural

Production System

Vern Pierce[1]

Jim Kliebenstein

Mike Duffy

[1] Vern Pierce is Instructor, Jim Kliebenstein is Professor, Mike Duffy is Associate Professor, Iowa State University Department of Economics.

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ABSTRACT

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This study includes development of typical Iowa crop/livestock farm production systems using an economic engineering analysis. Information evaluated for these case study farms include labor constraints, manure application strategies, crop nutrient need support, and projected farm income levels. The evaluation is done in a linear programming framework.

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INTRODUCTION

American agriculture has enjoyed a growth in technological productivity since the early 1900's. Barely does one method of efficiency become commonplace before the newest "state of the art" technologies push their way to the forefront in our eagerness to improve our productive efficiencies even more. With this trend issues of environmental soundness have arisen. Agriculture has moved to fewer and larger production complexes. Livestock production has, like most other farm enterprises, become more concentrated. Concentration has given rise to animal waste disposal problems and their parallel environmental impacts. Animal manure has typically been treated as a waste product to be disposed in the least cost way. Its value as a fertilizer has been overlooked.

Some efforts more recently have focused on evaluating production systems which provide a cost effective and environmentally sound production system. The movement, although loosely defined in the literature to date, is known as "Low Input Sustainable Agriculture" (LISA). Simply stated, the idea is to produce a safe food supply with farm productions systems which are economically viable and environmentally safe and sustain our natural resources in the long run.

In recent years there has been increased pressure and awareness on developing environmentally safe and sustainable agricultural systems. The focus has been on increased utilization of production systems which are less damaging to the environment. These systems would lead to an agriculture more sustainable over time. Risks of potential for adverse environmental effects can be minimized.

Movement toward a sustainable agricultural system can involve impacts across the farm operation. These impacts need evaluation for potential adjustments to other farm enterprises. Proposed changes in current agricultural production practices must be carefully evaluated if they are to be effectively adopted and succeed.

This paper is based on the results of a study of a system level evaluation of a typical Iowa swine and crop production system. Associated management and labor implications are presented. The farm has 400 tillable acres with a farrow to finish total confinement hog facility. The hog facility has the capacity of 180 litters of hogs per year. The farm has potential to farrow 45 litters every 4 months. For simplicity, the crop enterprise is restricted to continuous corn. Farm implements available, sizes, field capacities and labor requirements used are standard for an Iowa swine/corn operation.

The Labor System

Days available for field work are based on "Fieldwork Days in Iowa."[2] Reported days available are the average available over the period 1957 to 1988.

Labor availability is one full-time individual. The calendar year has been divided into 15 time periods. The distribution of actual time used is reported in the results section of this paper. In addition to the intra-period constraints on operator labor, the operator is restricted to 2500 total hours of labor per calendar year. A labor hiring activity is included at $5.00 per hour in the model during times of competition between the crop and hog enterprises. The distribution of labor requirements from the model is included in the results section of this paper.

The Cropping System

All 400 acres of the representative farm are tillable and of good productive capacity. Livestock enterprises are located on additional land not competing with the cropping system. Crop operations performed are standard for this size operation.

Information on crop yield related to the level of fertilizer applied is reported in Table 1. Nitrogen is based on pounds of nitrogen applied per acre.

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[2]. "Fieldwork Days Available in Iowa" Mike Duffy. Staff working paper. Department of Economics, Iowa State University, 1989.

Table 1	Nutrient Requirements by Corn Yield			
Nutrient	Pounds of nutrient			
Nitrogen	0	80	160	240
Phosphorus[3]	20	37	49	55
Potassium	16	30	39	44
Expected Yield	53	99	130	147

Source: Northern Research Center annual publication, 1986

The corn price used is $2.15[4] per bushel or the average price for the 1984 through 1987 calendar years. The 1988 calendar year was not included in the calculations. Due to drought conditions, 1988 prices varied considerably from the average of that period and were not included.

The impact of planting time on corn yields is reported in "Fertilizer Value of Swine Manure." Yields are reported as a percentage of maximum, based on variation in planting time from the optimum. Adjustments in yield potential are made accordingly in this model. Objective function coefficients are based on information reported in the "Estimated Costs of Crop Production in Iowa-1989."

The swine production system

The swine system includes facilities for up to 180 litters of hogs in a total confinement system with 45 litters per farrowing. Farrowings occur four times per year in March, June, September, and December. The labor distribution is held constant throughout the year during non-farrowing months with increased labor requirements during the farrowing months. Labor required is 12 hours per litter.

The majority of the work for the hog operation can be completed regardless of the weather. Therefore, it is necessary to use labor requirements for the hog operation so as to minimize its conflict with the cropping operation. A minimum amount of work is required each day for maintenance and feeding. That amount is used as a constraint value for the hog operation during times when the labor would conflict with the crop enterprise. Other tasks can be completed during days not suitable for fieldwork. The coefficients of labor requirements are reported in Table 2.

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3. The quantity of phosphorus and potassium applied is equal to the expected content of that nutrient in the crop that is harvested, that is, the "removal rate".

4. All prices based on average central Iowa cash prices.

Table 2 Labor Requirements per Litter by period

Labor period	Total labor Required	Adjusted Labor requirement
January	.93	.93
February	.93	.93
March	1.14	1.14
April (1st)	.465	.1029
April (2nd)	.465	.2291
May (1st)	.465	.269
May (2nd)	.465	.299
June (1st)	.57	.3868
June (2nd)	.57	.3868
July	.93	.93
August	.93	.93
September	1.14	1.14
October	.93	.681
November	.93	.6231
December	1.14	1.14

The objective function value for the swine enterprise system is derived from the livestock enterprise budgets discussed above. The market hog price $49.62 per cwt. with an average weight at sale of 235 pounds. The cull sow price is $40.78 with an average weight of 400 pounds. Prices are the calendar year averages for central Iowa cash markets for the years 1984 through 1987[5]. It is further assumed that 7.4 head of market hogs and .38 cull sows will be marketed for each litter.

A study by Melvin, Sutton and Vanderholm, provides information on the quantity of manure produced by hogs. The study also provides information on fertilizer nutrient composition of the manure, and nitrogen losses to the air as affected by application method and time of the year the manure is applied. The latter will be discussed in greater detail in the manure application section. Nutrients in manure produced per litter of hogs is reported in the Melvin study as 73.75 pounds of nitrogen, 67.57 pounds of phosphorus and 55 pounds of potassium. A litter of pigs and sow will produce 2500 gallons manure. The herd of 180 litters produces about 450,000 gallons of manure per year. This averages 37,500 gallons per month.

[5]. Iowa State University Extension Market News Service.

The Manure Application System

All manure is applied to meet nitrogen requirements. Phosphorus and potassium levels will be more than satisfied under these restrictions. Three separate manual manure application alternatives are considered in the model. They are:

1. Spring/Fall- Application of half of the manure just prior to planting in the spring, with the remainder applied after harvest in the fall with immediate incorporation.
2. Fall- All the manure applied after harvest in the fall and immediately incorporated.
3. Winter- All the manure applied during the winter.

The model considers the use of three different size liquid manure spreaders. Available nitrogen is adjusted in the model according to the Melvin, et. al. study.

Commercial fertilizer application is assumed to be the alternative to manual application. Commercial fertilizer is applied when needed. The following prices are assumed for ingredients[6]:

Table 3 Fertilizer Nutrient Cost

Ingredient	Cost per ton	Cost per pound
82% nitrogen (anhydrous ammonia)	$ 200	$ .122 (N)
11-52-0 (52% phosphorus)	245	.209 (P)
0-0-60 (60% potassium)	165	.1375 (K)

Source: Alleman Co-op 1989 cash price list.

Rates of application are based on the relative proportion of phosphorus and potassium to nitrogen as required to compensate for plant removal. Table 4 calculates the cost of commercial fertilizer application. All commercial applications use this relative proportion of N-P-K. Application charges are $5.50 and $2.60 per acre for anhydrous and bulk respectively.

6. Based on information from the 1989 Central Iowa cash prices.

Table 4 Cost of Commercial Fertilizer Per Pound

Nutrient	Lbs./acre	Percent of nitrogen	Per lb. cost of nutrient
Nitrogen	80	1.00	$ .122
Phosphorus	37	.4625	.0966
Potassium	30	.375	.0516
Total nutrient cost			.2702
Cost of application per pound of N			.10125
Total cost of fertilizer per pound of nitrogen based on 80 pounds N			.37145
Nitrogen	160	1.00	$ .122
Phosphorus	49	.3063	.064
Potassium	39	.2438	.0516
Total nutrient cost			.2376
Cost of application per pound of N			.0506
Total cost of fertilizer per pound of nitrogen based on 160 pounds N			.2882
Nitrogen	240	1.00	$ .122
Phosphorus	55	.2292	.0479
Potassium	44	.1833	.0252
Total nutrient cost			.1951
Cost of application per pound of N			.03375
Total cost of fertilizer per pound of nitrogen based on 240 pounds N			.2288

The manure storage system

The manure storage system is an above ground steel tank structure. Interest and insurance rates are assumed to be 12.5 percent and .75 percent respectively. Useful life is assumed to be 25 years with a zero salvage value. Estimated storage capacity, initial costs, and yearly costs are based on average expected prices.

The economic optimization model

Linear programming is used as the optimization model. The PC version of LINDO was used as the computer package. The model is specified as follows:

$$\text{Maximize } \sum_{j=1}^{n} c_j x_j \text{ (for all j)}$$

Subject to the constraints:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \text{ (for all i and j)}$$

$$x_j \geq 0 \text{ (for all j)}$$

Where:

x_j = the possible alternative activities
c_j = net income over variable costs
a_{ij} = the relationship between the ith resource and the jth activity, and
b_i = the ith resource or constraint restriction level.

Results

Nine separate linear programming models are used in this analysis. Three different size manure spreaders, each with three possible application time scenarios as discussed in the first part of this paper are used in the analysis. Variations in the coefficients according to size of manure spreader and time of application can be found in the description of the activities and constraints.

Objective function results

Returns over variable cost, as represented by the objective function values, for each of the nine scenarios is represented in Table 5. In each case the smaller manure spreader resulted in higher objective function values. The variation in the objective function values are shown in Figure 1.

Table 5 Objective function values for different scenarios tested

Time of	Size of manure spreader		
Application	1500	2200	3200
Spring	95170	94798	94387
Fall	95094	94722	94311
Winter	94258	93886	93475

Enterprise mix

The optimum combination of enterprises in each case include the planting of all available acreage and full utilization of the hog facilities. Results included full use of the hog manure in each case. Returns are maximized through consistently taking advantage of hog manure for fertilizer credit regardless of size of spreader or time of manure application. When necessary labor is hired to perform these activities. In each of the scenarios the enterprise mix shown in table below was chosen to be optimal. The model has 400 acres, 180 litters of hogs and 13,275 pounds of nitrogen from hog manure available. The only differences in results are the levels of commercial nitrogen applied and hired labor. Variations in the objective function values, therefore, are due largely to variations in the amount of commercial fertilizer that must be purchased with changing application times and manure availability.

Table 6 Levels of Commercial Fertilizer and Manure applied

Application Time	Sprdr. Size	Commercial April (1)[7]	Commercial April (2)	Total Commercial	Manure Applied
Spring/Fall	1500	57449	26271	83720	13275
	2200	69728	13992	83720	13275
	3200	69728	13992	83720	13275
Fall	1500		84053	84053	13275
	2200	69728	14325	84053	13275
	3200	69728	14325	84053	13275
Winter	1500	61432	26272	87704	13275
	2200	61432	26272	87704	13275
	3200	69728	17976	87704	13275

Labor distribution

The distribution of total labor requirements is shown in Table 7 by the nine scenarios tested. The table is subdivided by time of application and then by size of manure spreader within each of the three sections. The distributions are distinguished mainly by the labor demand variation due to the time of manual manure application.

[7] Number in parenthesis indicates half of month applied.

Each of the models contains an activity which allows the operator to perform the extra tasks in the hog operation during non-field work hours. The operator is constrained to 350[8] hours for these activities. Additional labor required to maintain the hog enterprise must be hired and is listed in the tables as "HOGLABOR." The total manual operator labor is that listed in the table plus the 350 hours discussed above. Total operator labor for each model, therefore, is approximately 2600 hours which does not include time required for non-physical labor management activities. The distribution of labor is shown in Figure 1 for the 1500 gallon spreader. The figures show a variation in labor per day within each period primarily where the enterprise mix chosen by the program differs among the choices of time of application of the hog manure. Not withstanding these variations, the total farm labor per day ranges from about 2 hours per day to over 30 for peak labor requirement periods. These ranges are expected considering the labor patterns of a typical corn-hog operation.

Table 7 Labor Requirements by Period

Spring/Fall application of Manure

	1500 gal. spreader			2200 gal. spreader			3200 gal. spreader		
	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day
JAN	167		6	167		6	167		6
FEB	167		7	167		7	167		7
MAR	205		9	205		9	205		9
APR1	186	125	22	186	72	18	186	150	24
APR2	289	186	34	289	226	37	289	212	36
MAY1	129		9	129		9	129		9
MAY2	56	65	9	56		4	56		4
JUN1	182	47	16	182	111	21	182	47	16
JUN2	51		2	51		2	51		2
JUL	167		7	167		7	167		7
AUG	167		6	167		6	167		6
SEP	205		9	205		9	205		9
OCT	294		11	294		11	294		11
NOV	371	204	21	371	191	20	371	178	20
DEC	205		9	205		9	205		9
HOGLABOR	27			27			27		
TOTALS	2843	653		2843	627		2843	614	
TOTAL OPERATOR/YR.		2540			2566			2580	

[8]. 350 is the difference between the amount of time the was used for fieldwork in each period and the total available for that time period based on assumptions of length of workdays discussed earlier.

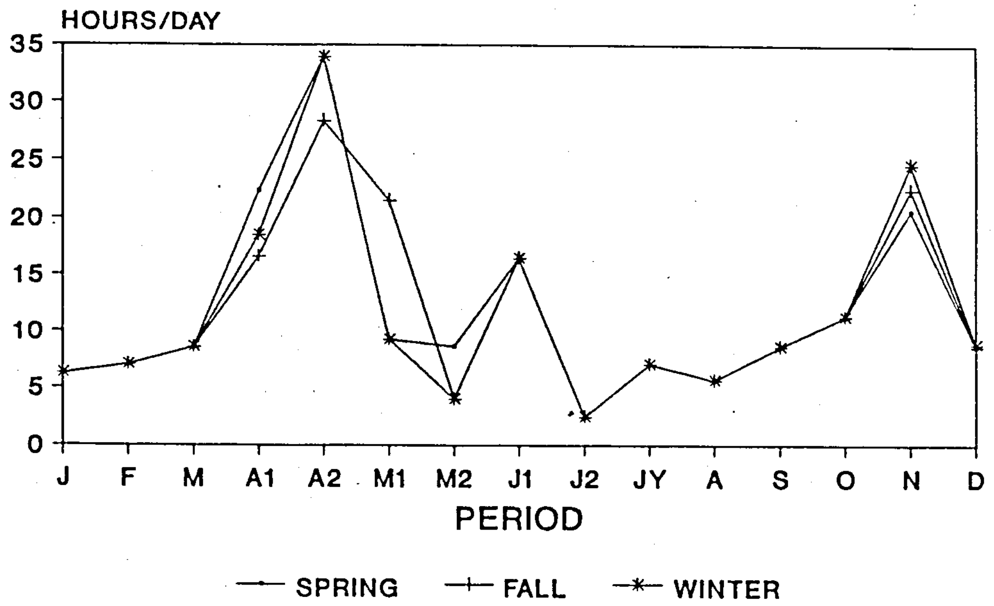
Fall application of Manure

	1500 gal. spreader			2200 gal. spreader			3200 gal. spreader		
	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day
JAN	167		6	167		6	167		6
FEB	167		7	167		7	167		7
MAR	205		9	205		9	205		9
APR1	186	45	17	186	72	18	186	137	23
APR2	289	106	28	289	186	34	289	186	34
MAY1	129	171	21	129		9	129		9
MAY2	56		4	56		4	56		4
JUN1	182	47	16	182	47	16	182	47	16
JUN2	51		2	51		2	51		2
JUL	167		7	167		7	167		7
AUG	167		6	167		6	167		6
SEP	205		9	205		9	205		9
OCT	294		11	294		11	294		11
NOV	371	257	22	371	231	21	371	217	21
DEC	205		9	205	65	11	205		9
HOGLABOR	27			27			27		
TOTALS	2843	653		2843	627		2843	614	
TOTAL OPERATOR/YR.		2540			2566			2580	

Winter application of Manure

	1500 gal. spreader			2200 gal. spreader			3200 gal. spreader		
	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day	Total Labor	Hired Labor	Labor Per Day
JAN	167		6	167		6	167		6
FEB	167		7	167		7	167		7
MAR	205		9	205		9	205		9
APR1	186	72	18	186	72	18	186	72	18
APR2	289	186	34	289	186	34	289	317	43
MAY1	129		9	129		9	129		9
MAY2	56		4	56		4	56		4
JUN1	182	47	16	182	47	16	182	47	16
JUN2	51		2	51		2	51		2
JUL	167		7	167		7	167		7
AUG	167		6	167		6	167		6
SEP	205		9	205		9	205		9
OCT	294		11	294		11	294		11
NOV	371	317	25	371	296	24	371	151	19
DEC	205	5	9	205		9	205		9
HOGLABOR	27			27			27		
TOTALS	2843	653		2843	627		2843	614	
TOTAL OPERATOR/YR.		2540			2566			2580	

TOTAL LABOR/DAY BY TIME OF MANURE APPL. 1500 GALLON SPREADER (FIGURE 1)



The total labor requirement for each size manure spreader is identical regardless of the time of application. The size of the manure spreader causes differences in the distribution between owner and hired labor. The use of the 3200 gallon spreader consistently requires the smallest amount of hired labor for the year compared to the other sizes.

<u>Summary and Conclusions</u>

Effective use of hog manure in crop production requires increased management. The purpose of this study was to investigate the economic potential for the use of swine manure for crop nitrogen needs. Under the assumptions of the model, the hiring of labor to apply manure is found be of economic benefit under all scenarios studied. Labor employment ranges from 614 hours with the use of a 3200 gallon spreader to 655 hours with the smaller 1500 gallon unit. Operator labor is constrained in two ways: 1) by period during the year, and 2) total time for the year. Labor is hired when operator labor is insufficient and it as profitable to hire labor.

The specific enterprise mix and timeliness of planting are detailed in the results section. Both the mix and planting times concur with what would be expected under similar circumstances in an actual operation.

Specific conclusions are as follows:

1. The use of manure to help meet corn production nitrogen requirements requires hiring part-time labor. This allows the operator to fully utilize all crop acreage and swine facilities.

2. It is profitable to hire additional labor required by manure application in order to take advantage of nutrients provided in the manure.

3. Application and incorporation of manure in a split spring/fall system, when nutrient availability is highest, is more profitable than either the fall or winter only applications.

The spring/fall application of manure has the greatest conflict with available operator labor when labor demands for planting and harvesting is at its peak.

4. Total labor demands per day during peak periods do not exceed that which would be considered feasible for a full time operator with one additional person. Peak farm labor requirements per day do not exceed 34 hours.

5. The manure handling system did not affect planting times. Planting times are consistent with that which would be expected for this type of farm. All crops are planted by the middle of May.

6. The trade off of spreading out planting dates and more fully utilizing operator labor was more than offset by reduced yields resulting from a later planting date. It was more cost effective to hire labor to enable earlier planting.

7. Farm profit is increased through effective use of manure from swine operation.

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