

Dynamic Spreadsheet Programming to Select the Most Cost Efficient Manure Handling System

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INTRODUCTION: The number of pigs in Oklahoma increased from 0.2 million in 1991 to 1.98 million by September of 1998 (Oklahoma Agricultural Statistics Service). The industry evolved from many small hog farms to a small number of large hog farms. The change in the industry structure is related to two factors: (1) the industry started to utilize economies of scale (Kim, 1997); and (2) in 1991, the Oklahoma legislature (Senate Bill 518) removed restrictions against corporate farming. The dramatic increase in the volume of hog manure produced by these new and bigger farms created public concern about hog manure pollution, which was expressed in the popular press (Associated Press, 2000; Colberg, 1999; Tulsa World Service, 1998.). These concerns are not circumscribed to Oklahoma, they are national concerns (Freese and Fee, 1994; Kilborn, 1999; Webster, 1999).

Hog manure can be an asset or a liability in agriculture depending on how well it is managed. The presence of nutrients such as phosphorus and nitrogen in swine manure makes hog manure suitable for land application as fertilizer, thus increasing the amount of nutrients available for plant consumption. However, if managed improperly swine manure can create problems such as odor, nutrient leaching (especially nitrogen), salinization of the soil, and/or nutrient accumulation in the soil (specifically phosphorus).

The management systems used in many of the new hog production facilities in Oklahoma were developed in the North Carolina region under different climate conditions. North Carolina is a humid region. Oklahoma, on the other hand, faces weather conditions that vary from humid in the east to medium rainfall in the center, and

semiarid in the west (with lagoon evaporation greater than rainfall), with cyclical patterns from dry to wet.

It is important that farmers have access to accurate cost estimates of swine manure systems specific to their location and environmental constraints. This information, which can minimize environmental risks and future legal liabilities to the firm, should be provided without further delay. Policy makers also can use this information to analyze manure management policies.

OBJECTIVES: The objective of this study was to improve the software available to determine the most cost effective manure management systems for specific locations. Specifically, this study determined the effect of evaporation and rainfall on the cost efficiency of hog manure handling systems in three Oklahoma counties that face humid (Delaware), medium rainfall (Seminole), and semiarid (Texas) weather conditions. The costs were determined for both nitrogen and phosphorus nutrient constraints.

METHODS: Swine manure management can be broken into four stages: type of floor in the animal house, collection method, storage and/or treatment method, and application method. In each stage, several possible methods can be used. The animal house can have a floor that is fully slated, partially slated, or simply a slab floor.

The method selected to collect the manure from the animal house will depend on the type of floor used. The possible collection methods are pit recharge, flushing, scraper, and pull plug. The combination of the type of floor and the collection method determine whether manure is in a liquid or slurry form.

Following collection, the manure will be stored or treated. Liquid manure can be treated using one of several methods: aerobic lagoon, anaerobic lagoon, aerated two-cell lagoon, partly aerated lagoon, facultative lagoon, and stratified lagoon. Slurry manure can be stored in one of several possible facilities: earthen storage pond, concrete above ground tank, underground tank, glass lined tank, liquid-solid separation earthen storage pond, and liquid solid separation concrete above ground tank.

The possible methods of applying the manure to the soil are irrigation with a travelling gun, haul with a tanker wagon, and drag hose application. The amount of manure applied will depend on the nutrient content of manure and on the nutrient constraint. The relevant nutrient constraint, either nitrogen or phosphorus will depend on the type of soil and on the current legislation for that location. A potassium nutrient constraint is possible for certain soils, but it is not realistic for Oklahoma soils, according to Hailin Zhang's opinion as a soil specialist at Oklahoma State University.

The basic model used in this study was developed by Stoecker et al. (1998). The initial spreadsheet was set up to determine the cost of managing manure for a specific type and size of production system in a specified geographical location. Figure 1 shows the main page of the spreadsheet. Determining the least cost equipment combination by location, size of operation, and nutrient constraint is a repetitive and tedious task. The inclusion of a macro in the Excel™ 97 spreadsheet allowed this task to be carried out more efficiently. A macro consists of a series of commands and functions stored in a Visual Basic module and that can be run whenever we need to perform the task.

	A	B	C	D	E	F	G	H	I	J	K
1	Select Production System			Buy Feeder Pigs, Sell Finished					Select County Name		
2											
3	Select Frequency of Arrival			Monthly					Delaware		
4											
5	Enter Number Purchased/Batch			500	One Time Capacity (hea 2000				KANSAS I ESE		
6	Select Type of Floor in House			Fully Slatted							
7	Select In House Waste Mgmt			Pull Plug							
8	Enter Manure Storage Period days			365							
9											
10	Manure Storage or Treatment			Anaerobic Lagoon			Main Line Pipe to Field		Aluminum Surface Pipe		
11											
12	Method of Field Application			Irrigation			Charge To Haul Remaining Waste \$/cu.	\$	0.25		
13										Buy Feeder Pigs, Sell Finished P	
14	Select Type of Irrigation System			Traveling Gun			Selections Made		Pull Plug		
15	Select Size			least cost					Anaerobic Lagoon		
16							mcc		H. Hose Traw		
17	Enter Maximum Days for Applic			30 10-hour days							
18	Nutrient to Limit Applied Manure			Nitrogen			cost/pig space		\$	9.65	Print Summary
19											

Figure 1. Opening Page of the Spreadsheet.

The dynamic problem shown in Figure 2 is solved as a tree problem in the macro. There are three branches (floor types) in stage 1, four branches in stage 2 (in-house manure removal), twelve branches in stage 3 (storage and/or treatment), and three branches in stage 4 (field application). The costs associated with each stage 3 or stage 4 system choice depend recursively on choices made nearer the root in stages 1 and 2.

The total annual cost of an initial system is obtained by a series of recursive calculations that begin at the root and travel up the tree through the stage 1, stage 2, stage 3, and stage 4 branches. Next, the costs of each alternative system formed by examining all feasible stage 4 branches (methods of field application) can be obtained without repeating any previous calculations. The total annual cost with the next stage 3 (storage type), and stage 4 (field application system) are then calculated without reference to the stage 1 and stage 2 system calculations. While the process may appear to involve

complete enumeration, only the tail of each chain of recursive calculations is in fact recalculated in modern spreadsheets. An ordered list of feasible computations or equipment combinations is supplied so the enumerative computations are minimized.

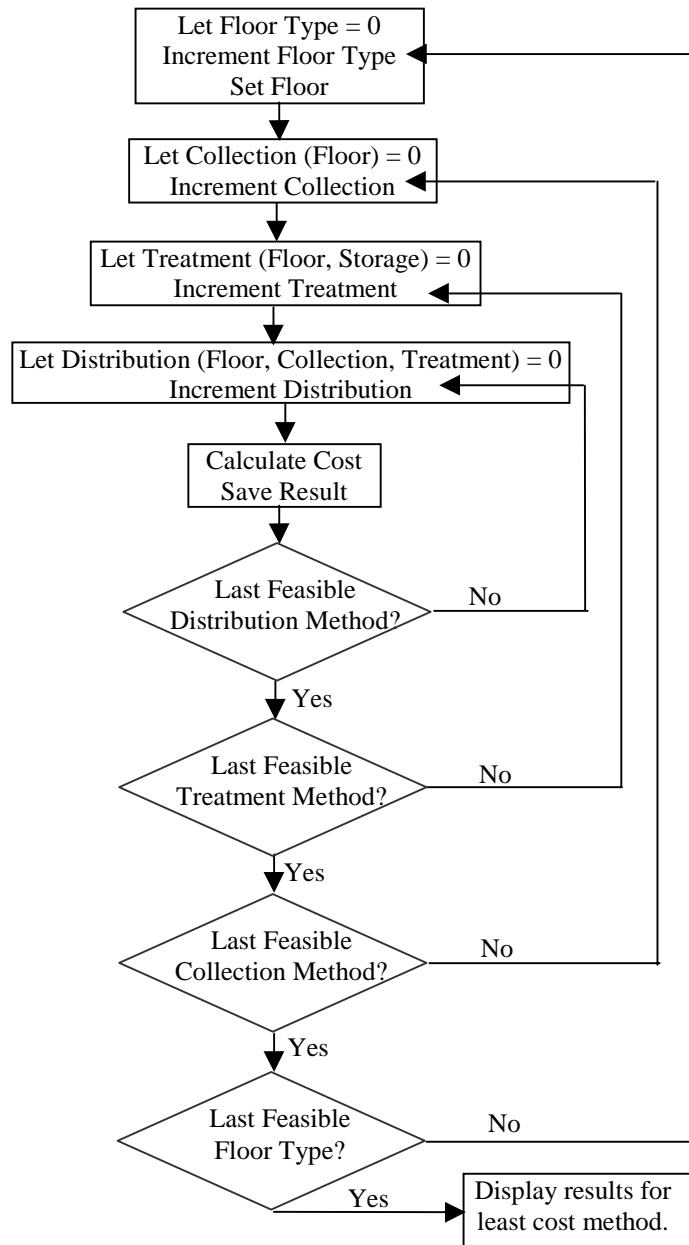


Figure 2. Representation of the Decision Tree Followed by the Macro Program Inserted in the Excel™ 97 Spreadsheet.

ASSUMPTIONS: A representative farm was set up for each county—Texas County, Seminole County, and Delaware County. The area of the representative farm, crops cultivated, and proportion of land used for each crop follow the characteristics of an average farm according to the data in the 1997 Oklahoma Census of Agriculture. It was assumed that the average size farm corresponds to the 60th percentile in terms of total farm area in the county. This means that 60 percent of the farms in each county have a size smaller than the size used in this study for the representative farm in the county. Forty acres of land in each representative farm were set aside for the buildings and manure storage structures.

This study assumes that the representative farms were not irrigated. The two main crops used for each location, according to the production volume in each county, are wheat and soybeans in Delaware County, soybeans and wheat in Seminole County, and dryland wheat and dryland sorghum in Texas County. We further assumed that part of the land in the representative farms of Delaware and Seminole counties could not be cultivated due to the presence of gullies, steep hills, and trees. Plant uptakes of nutrients were calculated according to the yield characteristics for each specific county. This information is summarized in Table 1.

The animal operation studied is a feeder to finish operation with possible sizes between 2,000 and 16,000 head capacity at a certain point in time, with increments of 2,000 animal spaces. The farm purchases pigs monthly. Each animal stays in the farm a period of four months. If the amount of land area available for manure application in the representative farm was insufficient, it was assumed that the remaining manure was

hauled from the farm at a cost of \$0.25/cubic foot. This additional cost was included in the comparison of the costs of the different systems. The combinations of components for manure handling were tested for each representative farm and for each capacity.

Table 1. Characteristics of the Representative Farms in Each County Selected.

Characteristics:	Delaware	Seminole	Texas
Farm Area (acres) ¹⁾	440	640	1920
Crop 1	Wheat	Soybeans	Dryland wheat
Yield Bu/Acre ²⁾	32.9	25	28
Land Used for Crop 1	160	200	1400
Plant Uptake of Nitrogen lbs./A ³⁾	41.1	93.8	34.9
Plant Uptake of Phosphorus lbs./A ³⁾	12.2	9.6	10.4
Plant Uptake of Potassium lbs./A ³⁾	10.3	28.5	8.7
Crop 2	Soybeans	Wheat	Dryland sorghum
Yield Bu/Acre ²⁾	20.4	28.6	35
Land Used for Crop 2	120	160	480
Plant Uptake of Nitrogen lbs./A ³⁾	76.6	35.7	32.7
Plant Uptake of Phosphorus lbs./A ³⁾	7.8	10.6	7.1
Plant Uptake of Potassium lbs./A ³⁾	23.3	8.9	8.2
Pastureland (acres)	120	240	—

- 1) Size of farm is based on data from the Oklahoma Agricultural Statistics Service. Census of Agriculture, 1997.
- 2) Oklahoma Agricultural Statistics Service. Average for the period 1994-1998. Data referent to dryland sorghum in Texas County was calculated for the 1997/1998 period. Data referent to dryland wheat in Texas County was calculated for the 1995-1999 period.
- 3) Plant nutrient uptake was calculated based on data published in the Animal Waste Management Field Handbook, Table 6.6.

RESULTS: The shape of the annual cost per animal curve is determined by 1) the costs per animal space of equipment and labor less the value of fertilizer and 2) the cost of hauling the manure from the farm. The first type of costs is always present and usually decreases as the animal capacity increases although the on-farm distribution increases.

The cost of hauling the manure from the farm is only present if the amount of land in the farm is insufficient for the application to the land of the total volume of manure. When the latter occurs, this cost will increase as the animal capacity of the farm increases.

The results and analysis for Delaware and Seminole counties are very similar to each other for both nutrient constraints. Therefore, we shall analyze the case of Delaware County in more depth. The system that combined fully slated floor, pull plug, anaerobic lagoon, and irrigation with a travelling gun achieved the lowest cost per pig space for all sizes tested in both Delaware and Seminole counties. Figure 3 illustrates the results for Delaware County.

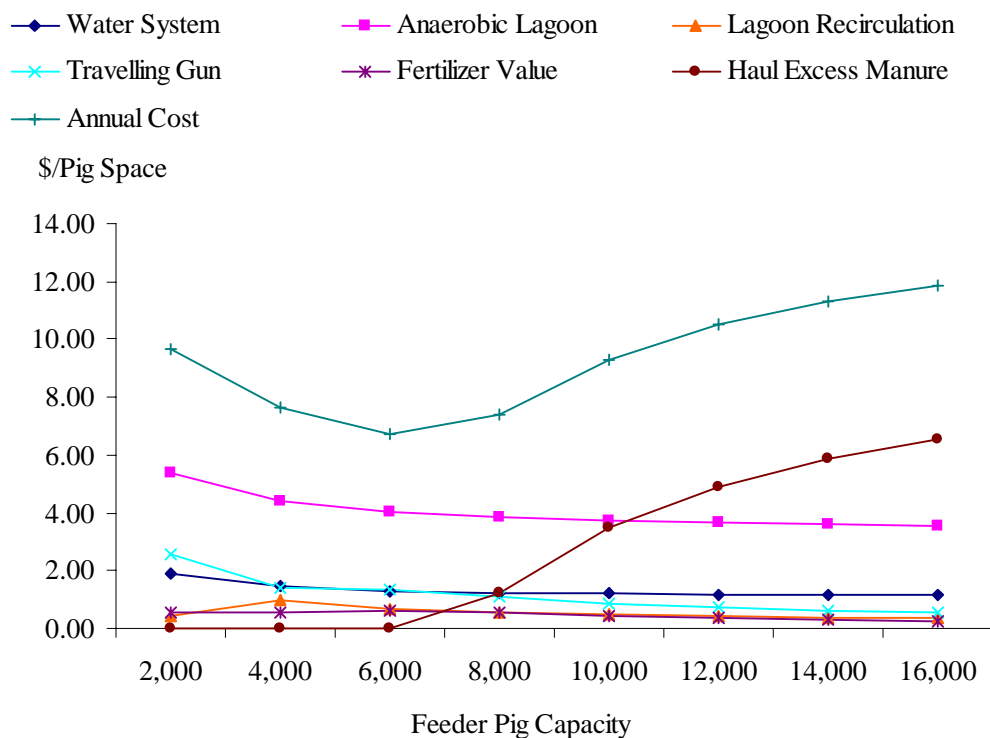


Figure 3. Cost per Animal Space for the Representative Farm of Delaware County under a Nitrogen Constraint Using Fully Slated Floor, Pull Plug, Anaerobic Lagoon, and Application with a Travelling Gun.

In Delaware County, the overall minimum annual cost per animal space was achieved at \$6.75 for a farm with 6,000 animal spaces. In the representative farm of Seminole County, the relevant capacity was 10,000 animal spaces; at his capacity, the overall minimum annual cost per feeder pig was \$5.49.

For a feeder pig capacity smaller than 6,000 animals, the amount of land in the animal farm is sufficient for the application of the total volume of manure produced. For capacities greater than 6,000 animal spaces, the land in the representative farm was insufficient for the total application of the volume of manure produced. Thus, the remaining manure was hauled from the farm, which increased the annual cost per animal space significantly.

In Texas County, two equipment combinations achieved the lowest costs at different levels of production, as can be seen in Table 2.

Table 2. Cost per Pig Space for the Equipment Combinations That Achieved the Lowest Costs in the Texas County Representative Farm under a Nitrogen Constraint.

Feeder Pig Capacity	2,000	4,000	6,000	8,000	10,000	12,000	14,000	16,000
Combination 1 ^a	\$16.28	\$10.54	\$9.48	\$6.94	\$6.64	\$6.30	\$6.18	\$6.29
Combination 2 ^b	\$10.36	\$6.70	\$5.56	\$7.30	\$9.09	\$10.28	\$11.14	\$11.67

^a Fully slated floor, pull plug, anaerobic lagoon, and irrigation with a travelling gun.

^b Partially slated floor, scraper, earthen storage pond, and drag hose application.

Bold font indicates least cost.

For animal capacities greater than 6,000 animal spaces, combination one (fully slated floor, pull plug, anaerobic lagoon, and irrigation with a travelling gun) achieved lower costs per animal space. For animal capacities smaller or equal to 6,000 animal

spaces, the equipment combination partially slated floor, scraper, earthen storage pond, and drag hose application (combination two) achieved lower costs per animal space. Overall, combination two achieved the lowest cost per animal space at \$ 5.56, for an animal capacity of 6,000 animal spaces.

A closer analysis of the cost components of the annual cost per animal space as the feeder pig capacity increases for combination two (Figure 4), reveals that this system becomes more costly because of costs to haul manure from the farm.

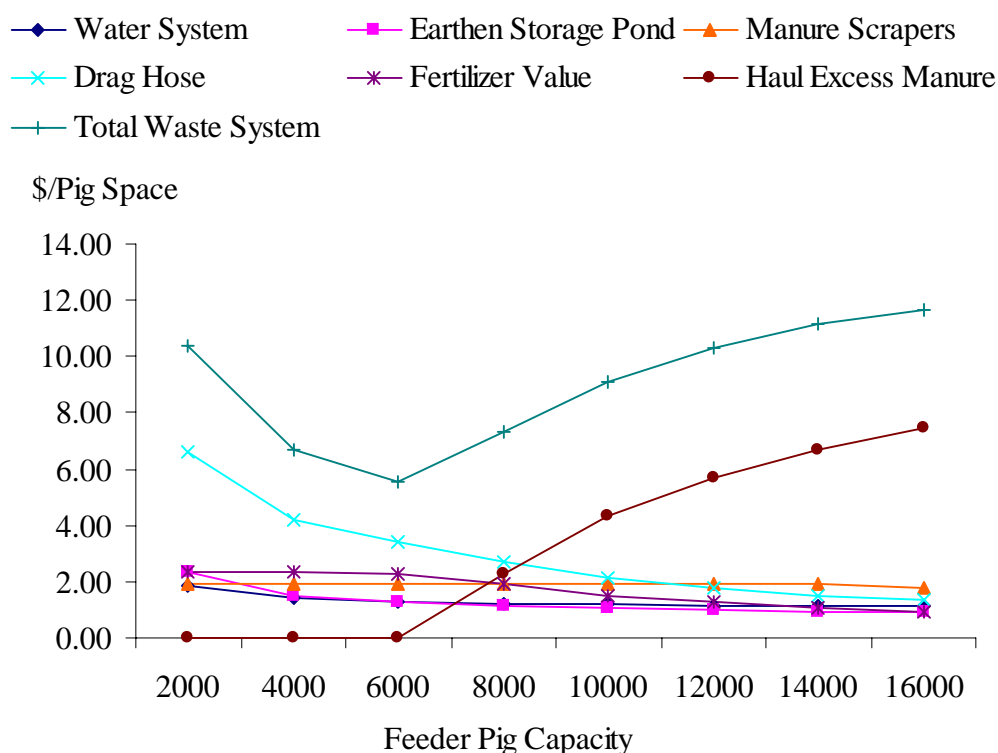


Figure 4. Cost per Animal Space for the Representative Farm of Texas County under a Nitrogen Constraint Using Partially Slated Floor, Scraper, Earthen Storage Pond, and Drag Hose Application.

The insufficiency of land area inside the farm to apply the total volume of manure is related to the storage facility used in combination two—the earthen storage pond. This

method of storage retains more nitrogen than the anaerobic treatment lagoon. If the nitrogen concentration rate in the manure is higher for manure stored in the earthen storage pond, then less manure will be applied per acre. Therefore, land saturation occurs faster and additional land is required, thus increasing the annual cost per animal space.

Combination one, which uses an anaerobic lagoon as the treatment method, does not require the use of additional land for the total volume of manure to be applied. This explains the competitiveness of this equipment combination for greater feeder pig capacities.

Under the phosphorus constraint there was not enough land in the representative farms of Delaware and Seminole counties for the application of the total volume of manure produced for all capacities considered. Similarly to the nitrogen constraint, the equipment combination that worked best in terms of cost per animal space was the fully slated floor, pull plug, anaerobic lagoon, and irrigation with a travelling gun.

As Figure 5 illustrates, in Delaware County, the annual cost per animal space decreases consistently as the feeder pig capacity increases. This indicates that the decrease in the cost of equipment as the animal capacity increases more than compensates for the cost of hauling the manure from the farm. An important consideration should be made at this point. We have assumed that the cost of hauling the remaining manure is constant at \$0.25 per cubic feet. This is an oversimplification of our part. It would not be farfetched to assume that the cost per cubic feet of hauling the remaining manure from the farm should indeed increase as the volume of manure being transported increases. If that was the case then the annual cost per animal might remain stable or even increase.

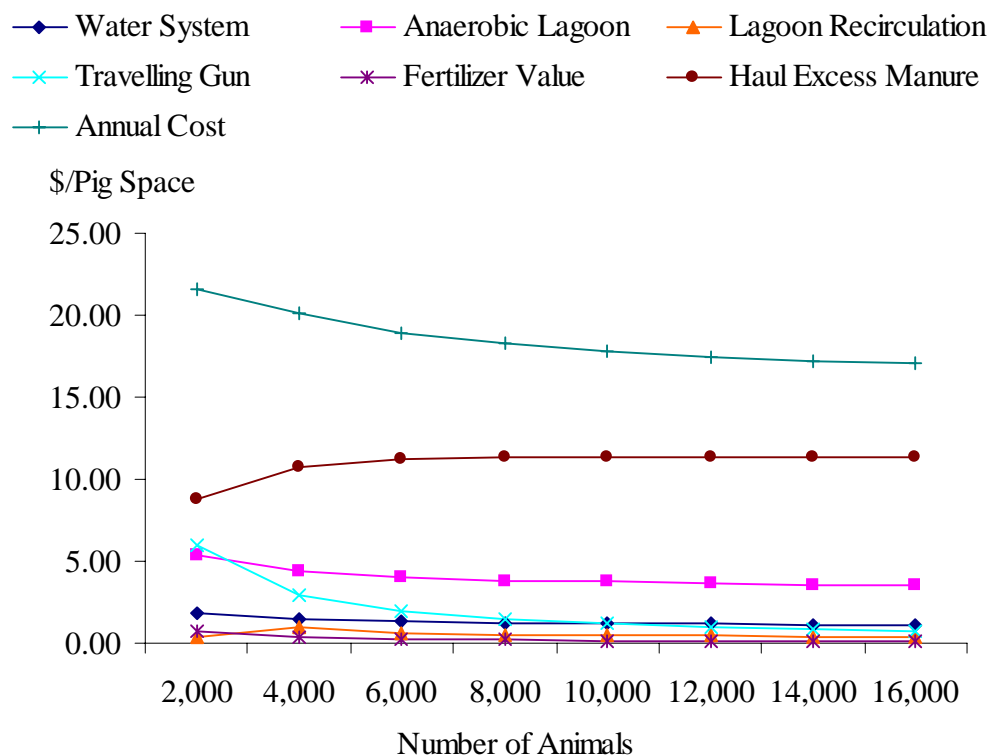


Figure 5. Cost per Animal Space for the Representative Farm of Delaware County under a Phosphorus Constraint Using Fully Slated Floor, Pull Plug, Anaerobic Lagoon, and Application with a Travelling Gun

Nevertheless, this study shows that the largest component of the annual cost per feeder pig is the cost to haul the manure from the farm under phosphorus constraint and land insufficiency conditions. However, we were not able to determine whether the decrease in the annual cost per pig space was also consistent for sizes greater than 16,000 feeder pigs. As stated before, a similar situation occurred for the representative farm of Seminole County.

The equipment combination fully slated floor, pull plug, anaerobic lagoon, and irrigation with a travelling gun was the system that performed the best in the representative farm of Texas County for all the sizes tested. The greater availability of

land in this representative farm allowed for the total volume of manure to be applied up to a feeder pig capacity of 10,000 animal spaces, as can be seen in Figure 6. The minimum annual cost per pig space was achieved at \$7.71 for a 10,000 feeder pig capacity. Therefore, in Texas County the greater availability of land gives the representative farm of this county a cost advantage over the representative farms of the other counties.

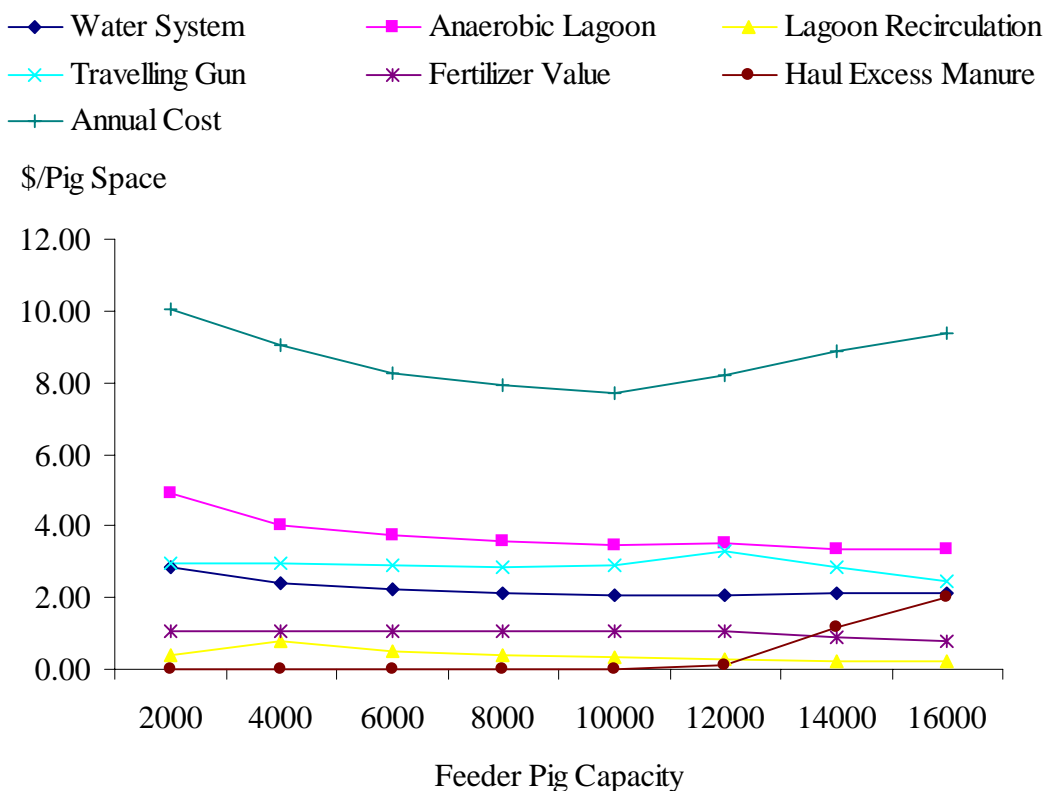


Figure 6. Cost per Animal Space for the Representative Farm of Texas County under a Phosphorus Constraint Using Fully Slated Floor, Pull Plug, Anaerobic Lagoon, and Application with a Travelling Gun

CONCLUSION: This study suggests that hog farms in Oklahoma should be sized according to the availability of land because hauling the remaining manure to a different

location is very costly. Farms located in Texas County enjoy greater opportunities to achieve lower costs per animal space due to greater land availability. For locations where land application is phosphorus constrained, hog farms should have a smaller capacity than for locations with a nitrogen constraint.

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