METHANE AND FERTILIZER PRODUCTION FROM POULTRY LITTER: TRANSPORTATION COST AND BREAK-EVEN ANALYSIS

By

LAWRENCE DANIEL MAPEMBA

Bachelor of Science in Agriculture

University of Malawi

Lilongwe, Malawi

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Thesis Approved:

Brian Adam

Thesis Advisor

Rodney B. Holcomb

Daniel S. Tilley

Allen Finchum

Timothy J. Pettibone

Dean of the Graduate College

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DEDICATION

In Loving Memory of My Father

Lawrence Jolam Mapemba, Sr.

1910 – 1984

who instilled in my mind the

importance of education

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CHAPTER I

INTRODUCTION

Poultry Production in the U.S. and the State of Oklahoma

Livestock and poultry products (meat, milk and eggs) provide a large portion of the protein needs of the American people (Day and Funk, 1998). Recently there has been an increase in demand for low-cholesterol meat products, which has resulted in significant increases in poultry production (Table 1.1). One of the byproducts of this large increase in production is poultry manure, which is an excellent organic fertilizer (Moore, 1998). Over 45 billion kg of poultry manure and/or litter are produced each year in the U.S. (Table 1.2). Over half of this production is in six states: Georgia, Arkansas, Alabama, Mississippi, North Carolina, and Texas.

Table 1.1 Poultry Production in the U.S. 1990-2000[1]

Year	Layers[2]	Pullets	Broilers	Turkey	Total Birds
	------------------------------------1000 Birds			------------------------------------	
1990	270,946	73,167	5,864,521	282,445	6,491,079
1991	275,451	76,616	6,137,150	284,910	6,774,127
1992	278,824	79,870	6,402,490	289,880	7,051,064
1993	284,770	81,774	6,694,310	287,650	7,348,504
1994	290,816	79,853	7,017,540	286,585	7,674,794
1995	293,648	81,369	7,325,670	292,356	7,993,043
1996	297,958	81,572	7,596,760	302,713	8,279,003
1997	303,166	90,344	7,764,200	301,251	8,458,961
1998	312,035	95,645	7,934,280	283,503	8,625,463
1999	329,320	97,362	8,146,010	270,494	8,843,186
2000	332,205	94,408	8,262,630	269,969	8,959,212

[1] Adapted from USDA Agricultural Statistics 1998-2001.

[2] Includes Pullets of laying-age.

Since the industry is geographically concentrated, there are relatively small geographic areas that have a tremendous amount of manure production. Several authors have reported that the rapid growth and spatial concentration of poultry production in the United States has led to increasing concern regarding the utilization or disposal of poultry wastes and its potential impact as a nonpoint source of agricultural pollution (Willet et al., 2001; Bosch and Napit, 1992; Moore, 1998; Paudel and McIntosh, 2000; Jones and D'Souza, 1998; Karlen, Russell, and Mallarino, 1998; Sharpley, Meisinger, Breeuwsma, Sims, Daniel, and Schepers, 1998; Wood, 1992; Eaton, 1999).

The state of Oklahoma is the 12th largest poultry producer in the country according to USDA (refer to Table 1.2). The poultry industry in Oklahoma is concentrated in the eastern Oklahoma and includes the production of broilers, layers, pullets, and turkeys. Of these, broiler production is the largest in terms of animal numbers (Table 1.3), revenue generated (Oklahoma Agricultural Statistics Services, 1999), and the amount of litter produced (Table 1.2). Poultry and winter wheat compete for second place in Oklahoma in value of agricultural commodities produced, after cattle and calves (Oklahoma Agricultural Statistics Services, 1999). Poultry production contributed about $447 million in revenue to the Oklahoma economy in 1999 representing 13.3% of the total agricultural value. In 1997 poultry production in Oklahoma contributed $55.6 million in export earnings ranking second after wheat (U.S. Agricultural Exports and The Economy).

Table 1.2 Poultry Production and Manure Generated (dry basis) in the U.S. in 2000

State	-----------Broiler---------		---------Layers[a]--------		---------Pullets-------		---------Turkey--------		-------Total Birds-------	
	Number Produced[b]	Manure Generated[c]	Number Produced[b]	Manure Generated[d]	Number Produced[b]	Manure Generated[e]	Number Produced[b]	Manure Generated[f]	Number Produced	Manure Generated
	Million	Mg x 10^3	Million	Mg x 10^3	Million	Mg x 10^3	Million	Mg x 10^3	Million	Mg x 10^3
Alabama	1038.7	5089.6	10.2	71.3	4.4	11.8	-	-	1053.2	5172.7
Arkansas	1191.7	5839.3	14.9	104.0	6.8	18.3	27.0	294.3	1240.3	6255.9
California	-	-	24.3	170.1	5.1	13.8	17.5	190.8	46.9	374.7
Delaware	247.7	1213.7	1.3	9.2	0.2	0.6	-	-	249.2	1223.6
Florida	119.9	587.5	10.7	75.2	2.0	5.4	-	-	132.6	668.1
Georgia	1229.7	6025.5	20.8	145.4	7.9	21.3	-	-	1258.4	6192.2
Illinois	-	-	3.6	25.3	0.4	1.1	2.9	31.6	6.9	58.0
Indiana	-	-	23.0	161.3	5.6	15.2	13.5	147.2	42.2	323.6
Iowa	-	-	31.1	217.4	6.7	18.1	7.8	85.0	45.6	320.6
Kentucky	208.2	1020.2	3.8	26.4	1.8	4.9	-	-	213.8	1051.5
Maryland	283.3	1388.2	3.4	23.7	1.1	2.9	0.6	6.5	288.3	1421.3
Michigan			6.3	44.1	1.3	3.5	2.7	29.4	10.3	77.0
Minnesota	44.2	216.6	12.5	87.4	3.3	8.8	43.5	474.2	103.5	786.9
Mississippi	739.9	3625.5	6.6	46.2	3.1	8.5	-	-	749.6	3680.2
Missouri	240.0	1176.0	6.7	46.7	1.4	3.8	22.0	239.8	270.1	1466.2
Nebraska	3.4	16.7	11.8	82.9	2.1	5.5	-	-	17.3	105.1
New York	2.1	10.3	4.2	29.6	1.4	3.7	0.5	5.3	8.2	48.9
North Carolina	698.4	3422.2	11.0	77.2	5.5	15.0	44.0	479.6	759.0	3993.9
Ohio	45.7	223.9	29.1	203.9	6.7	18.0	4.7	51.2	86.2	497.1
Oklahoma	223.1	1093.2	3.9	27.1	1.3	3.4	-	-	228.2	1123.7
Oregon	-	-	2.9	20.4	0.8	2.1	-	-	3.7	22.5
Pennsylvania	133.3	653.2	24.2	169.3	6.4	17.2	9.8	106.8	173.6	946.4
South Carolina	196.8	964.3	5.3	37.1	1.5	4.1	9.5	103.6	213.1	1109.0
South Dakota	-	-	2.2	15.3	0.3	0.9	4.2	45.8	6.7	62.0
Tennessee	151.3	741.4	1.2	8.7	0.8	2.2	-	-	153.4	752.3
Texas	551.0	2699.9	18.7	130.6	6.3	16.9	-	-	575.9	2847.4
Utah	-	-	3.2	22.2	0.7	1.8	-	-	3.8	24.0
Virginia	264.9	1298.0	3.4	23.6	0.9	2.5	24.0	261.6	293.2	1585.7
Washington	-	-	4.9	34.2	1.8	5.0	-	-	6.7	39.1
West Virginia	91.3	447.4	1.0	7.0	0.7	2.0	4.5	49.1	97.5	505.4
Wisconsin	32.8	160.7	4.4	31.1	1.3	3.6	-	-	38.6	195.5
Other States	525.2	2573.6	21.6	151.6	4.9	13.2	31.9	346.7	583.6	3085.1
U.S.	8262.6	40486.9	322.2	2255.4	94.4	254.9	270.5	2948.4	8949.7	45945.6

[a] Includes laying hens and pullets of laying age.

[b] Adapted from USDA, 2001.

[c] Broiler manure based on 4.9 kg dry manure/bird/year (Sims et al., 1989).

[d] Layer manure based on 7.0 kg manure/bird/year (Sims et al., 1989).

[e] Pullets manure based on 2.7 kg manure/bird/year (Sims et al., 1989).

[f] Turkey manure based on 10.9 kg manure/bird/year (Sims et al., 1989).

Mg is megagrams.

Table 1.3 Numbers of Chickens Produced in the State of Oklahoma from 1990-2000[1]

Year	Layers[3]	Pullets	Broilers	Total Birds
------------------------1000 Birds------------------------				
1990	3,725	875	142,200	146,800
1991	3,720	1,020	155,800	160,540
1992	4,003	877	157,800	162,680
1993	3,620	1,040	175,200	179,860
1994	3,730	925	185,800	190,455
1995	3,860	1,060	198,300	203,220
1996	3,660	1,160	204,000	208,820
1997	4,075	1,320	197,400	202,795
1998	4,040	1,120	216,000	221,160
1999	4,000	1,070	216,400	221,470
2000[2]	3,870	1,250	223,100	228,220

[1] Adapted from Oklahoma Agricultural Statistics 1991-2000.
[2] Adapted from USDA Agricultural Statistics, 2001.
[3] Includes Pullets of laying age.

Over the past several years, broiler production in Oklahoma has been rapidly increasing (Eaton, 1999). According to the Oklahoma Department of Agriculture's agricultural statistics, in 1990 142.2 million broilers were produced in Oklahoma, increasing to 223.1 million birds in 2000 (Table 1.3). Sharpley et al. (1998) stated that in several states (such as Mississippi, Oklahoma), income from poultry and swine production had more than doubled in the previous five years.

The top four counties in the state based on poultry production are Le Flore, McCurtain, Delaware, and Adair, which account for 81% of total production. This concentration has led to increasing and largely localized stocks of broiler litter that are threatening the safety and quality of both surface and ground water. The Oklahoma poultry industry produces about 1.1 million tons of litter every year (Table 1.2). The main problem is the lack of proper ways to dispose of this huge amount of litter.

Objectives

The general objective of this research is to enhance rural economic development, benefit the environment and maximize profits of poultry producers. The specific objective is to calculate the maximum processing cost that would permit a profitable investment in a new generation cooperative to produce methane biogas and fertilizer from poultry litter.

Poultry Litter Composition and its Current Use

Before discussing the current use of poultry litter, it is important to define the relevant terms. Moore (1998) defines poultry manure, poultry litter and bedding material as follows: *Poultry manure* is a mixture of poultry feces and urine. *Poultry litter* is a mixture of manure, bedding material, feathers, wasted feed, and soil (usually inadvertently included during the cleanout operation). *Bedding materials* are used to absorb the liquid fraction of the excreta. Materials typically utilized for bedding include wood shavings, sawdust, rice hulls, peanut hulls, and oat straw (Carpenter, 1992). Litter associated with broiler production, manure generated from laying operations (hens and pullets), and dead birds are the three wastes of primary concern in poultry production (Edwards and Daniel, 1992). The majority of poultry manure (about 84%) produced in the U.S. is in the form of broiler litter (Table 1.2).

In most states, the litter in broiler houses is totally removed once a year, normally in April or May. In Oklahoma, a total clean out of the poultry houses is also performed once a year. However, partial clean outs occur after every five to six flocks. In these clean outs, after a flock of birds is harvested, the top layer of hardened manure, which is referred to as cake, is removed using a "de-caker" which is pulled behind a tractor (Eaton, 1999).

Poultry litter has a diverse number of uses. This diversity of use stems primarily from the complex set of components found in litter (Peel, 2000). The components in poultry litter include macronutrients, micronutrients, and organic matter. The macronutrients contained in 1 ton of poultry litter are roughly 51 lbs nitrogen, 13 lbs ammonia nitrate, 64 lbs phosphorus, and 48 lbs of potash. Poultry litter also contains substantial quantities of boron, calcium, copper, iron, magnesium, manganese, sulphur and zinc (Stephenson et al., 1990). Factors that affect the mineral composition and quality of litter include bedding used, housing and rearing facilities, type of feed, number of birds in the house, type of litter treatment being used, manure storage practices, and climate (Karlen et al., 1998; Eaton, 1999).

Broiler litter has been used as a cattle feed ingredient for over 35 years without harmful effects to humans (Peel, 1996). Peel reported that as a feed source, poultry litter has met with both good and bad reviews. The predominantly organic composition of litter, combined with limited amounts of inorganic nitrogen, makes it a potential feed for ruminant animals. Poultry litter is an excellent source of protein, energy and minerals when fed to stocker cattle and brood cows (Ruffin and McCaskey, 1991). However, the experience and comfort of the animal industry with the use of litter for feed is limited in Oklahoma, hence only a small amount of litter is used for animal feed in Oklahoma. The cattle industry, fearing adverse public reaction, is unwilling to support increased litter use for feed (Peel, 1996).

Poultry litter can also be used as a source of energy. Litter is often cited as potential biofuel source but little has been used for this purpose in the U.S. (Peel, 2000). Several researchers have looked at the economic feasibility of generating renewable energy from livestock waste including poultry litter, but early findings did not find this feasible (Willis and Christensen, 1977). Willis and Christensen argued that renewable energy generation from litter would be feasible only if energy prices increased considerably. Some writers have reported that renewable energy production from litter has become feasible due to the availability of modern and improved litter processing technologies.

Bulk land application of raw litter is likely the simplest and least cost use of litter. Poultry litter is generally considered the most valuable animal manure for use as a fertilizer because of its low water content (Karlen et al., 1998). Poultry litter is a valuable, natural soil amendment that adds macronutrients and micronutrients as well as organic matter to increase soil fertility in cropland or pastureland. Organic matter improves the soil's ability to hold water and nutrients. It also improves the soil structure and binds soil particles together thereby reducing soil erosion. Historically, poultry litter has been used principally as a fertilizer and for its soil amendment value. Bulk land application has been the predominant use of litter in Oklahoma and is likely to remain so (Peel, 1996).

The problem has been that litter application has been confined to areas near poultry production. Carpenter (1992) reported that except for small amounts of poultry manure used in animal feed and other uses, the major portion (>90%) is applied to agricultural land [within a few miles from where it is produced (Moore et al., 1995)]. Bosch and Napit (1992) reported that poultry are produced in spatially concentrated areas to minimize feed and poultry transportation costs. They noted that this concentration of poultry production may result in high ratios of poultry litter to available nearby cropland, and litter may be applied at higher rates than required by crops. Unused nutrients in litter potentially can contaminate surface water and groundwater through runoff and leaching. Unused nutrients also represent an economic loss to poultry growers (Bosch and Napit, 1992). While the practice of bulk land application of manure will continue, alternative uses are needed, especially where sufficient cropland or pastureland is not readily available.

Poultry Litter Processing

Numerous litter-processing technologies have been developed. Since litter is highly unstable, some processing is done to stabilize litter and some is done to produce a value-added product such as fertilizer or biogas.

The method of processing employed to stabilize poultry litter has an impact on the quality and quantity of litter available for end use (Eaton, 1999). Composting is one of the most popular processing techniques. It is a controlled biological degradation of organic material by microorganisms such as bacteria and fungi. The resulting product is stable and more economical to transport and spread (Barker), although composting results in a loss of nitrogen. Composting is generally conducted under aerobic conditions.

A second method of stabilizing litter is by ensiling or anaerobic fermentation. This is probably the most common (Peel, 1996). This occurs when litter is deep stacked and left for a period of time. The deep stacking process allows for a natural heating and fermentation process that stabilizes the litter. The end result is a product that is slightly drier, slightly denser and slightly lower in quality, primarily from loss of nitrogen through volatilization.

Since both of the above processes result in considerable loss of nitrogen via volatilization, if weather conditions permit, direct application of manure and/or litter is preferable to deep stacking or composting. Moore (1998) states that although composting of poultry litter has received a tremendous amount of attention in recent years, it is a waste of time, money, and nutrients, unless the litter is being used as a feed supplement. Composting of dead birds, on the other hand, provides a fairly economical solution to a major waste product.

Pelleting is a third common method that is purely mechanical. Dry pellets are more convenient and economical when compared to traditional raw litter. The advantages of pelleting are that pellets are stable, and lower in moisture, and are easier to haul, store and handle. The dry pellets are also easier to apply and can be broadcast more evenly through spreaders than can raw litter. The disadvantages are the high costs of pelleting and transporting to a pelleting site and some loss of quality (mostly nitrogen). Pelleting litter without a well-defined market justification in terms of storage, hauling or handling is not feasible (Peel, 1996).

There are a small number of relatively high value processed products made from poultry litter. The majority of these are fertilizer products for indoor and outdoor use. Litter can also be processed into biogas such as methane for use as a fuel. Methane can also be used to run turbines for electricity generation. Various technologies have been developed to process litter into methane, two of which are anaerobic digestion (which is the most common), and pyrolysis.

Environmental Concerns of Poultry Litter in Oklahoma

Since bulk land application of litter is the most common use of poultry litter in Oklahoma and elsewhere, and that application occurs within a few miles from where it is produced, the result has been excess application of litter on the same land posing a threat to the environment. Animal manure can be a valuable resource if managed properly by using cost-effective best management practices. In many areas, manure applications have improved soil structure and increased vegetative cover, thereby reducing runoff and erosion potential. However, in areas of intensive confined animal operations, where manure production exceeds local crop nitrogen and phosphorus requirements, agricultural, environmental and economical interests are often opposed to one another (Sharpley et al., 1998). The U.S. Environmental Protection Agency (EPA) says that hog, chicken, and cattle waste have polluted 35,000 miles of rivers in 22 states and contaminated groundwater in 17 states (Paudel and McIntosh, 2000). In 1994, the U.S.

EPA reported that water quality problems in over 70% of surveyed rivers and lakes resulted from agricultural nonpoint sources of pollution (U.S. EPA, 1994). Principal pollutants of concern from animal agriculture are: organic matter and oxygen-demanding substances, pathogens, plant nutrients (nitrogen and phosphorus), salts and toxic materials.

Continual application of manure at rates providing more N and P than removed by crops can increase soil nitrogen and phosphorus to levels that are of environmental rather than agronomic concern (Sharpley et al., 1998). The number of soils with plant-available phosphorus (soil test phosphorus) exceeding levels required for optimum crop yields has increased in recent years in areas of intensive animal production (Alley, 1991; Sims, 1992). In 1989, several state soil test laboratories reported the majority of soils analyzed had soil phosphorus levels in the high or very high categories, and require little or no phosphorus fertilization (Sharpley et al., 1998). Willet et al. (2001) reported that in a number of southern states with large poultry industries, the problem of poultry litter disposal and its contribution to excessive phosphorus loading of surface water is considered to be an important concern. A range of policy options designed to address this concern have been examined. Govindasamy et al. (1994) examined two policies, one of which restricts litter applications on soils with elevated phosphorus levels and another option based on a tax levied on every unit of phosphorus applied.

The heavy concentrations of poultry farms in eastern Oklahoma and plans for even more expansion in this area have prompted a number of environmental concerns. The large supply of waste, specifically poultry litter, produced by these operations has spawned fears of water pollution from runoff and leaching (Peel, 1996). In Oklahoma, animal waste nutrients are a major concern in phosphorus threatened watersheds (Lake Eucha, Illinois River, and Wister Lake) (Eaton, 1999). The city of Tulsa in particular is concerned about its Lake Eucha water supply reservoir in Delaware County, located in a major poultry watershed. Much of the focus is on phosphorus runoff and how to reduce it by limiting the amount of litter spread in the affected watersheds (Britton, 1998).

Potential Problems Associated with Land Application of Poultry Litter

Potential problems associated with land application of poultry litter can be divided into two categories: production problems and environmental problems (Moore, 1998). The production problems associated with poultry litter include salinity damage to crops, grass tetany in cattle, copper toxicity in sheep and ammonia volatilization.

Salinity Damage to Crops. Under certain conditions, nitrogen and potassium salts may build up from excessive poultry litter applications, causing salinity damage to crops (Moore, 1998). Hileman (1971) and Weil et al. (1979) observed that reduced germination, leaf burn, stunted root growth, and decreased production were among the damage due to excess salinity.

Grass Tetany in Cattle. Moore, (1998) reports that due to excessive litter applications an imbalance of calcium, magnesium and potassium in soils are typical in areas of the U.S. where concentrated poultry production and cattle production are linked, such as northwest Arkansas. This results in high levels of potassium in forage causing grass tetany in cattle.

Copper Toxicity in Sheep. Poultry litter has been successfully used as cattle feed for many years (Peel, 1996). Approximately 4% of the poultry litter produced in the U.S. is fed to cattle (Carpenter, 1992). Although disease problems have not been reported from feeding manures to animals under acceptable conditions (Moore, 1998), copper toxicity has been reported to be a problem in sheep (Fontenot et al., 1971). Most poultry producers feed an excess of copper sulfate (Moore, 1998).

Ammonia Volatilization. Ammonia volatilization from poultry litter causes both production and environmental problems. The production problems are: (1) high levels of atmospheric ammonia in poultry houses, posing a health hazard to both farm workers and birds, and (2) ammonia volatility results in nitrogen loss from litter, which reduces the fertilizer value of the litter. As stated earlier, poultry houses in the U.S. are normally cleaned out only once a year. The accumulation of poultry litter through several flocks results in tremendous amounts of ammonia volatilization. Research on the effects of high ammonia levels on poultry has shown it causes decreased growth rates, decreased egg production, reduced feed efficiency, and damage to the respiratory tract, among others (Moore, 1998).

Potential environmental problems associated with poultry litter include leaching of substances into groundwater, surface runoff of pollutants, and ammonia volatilization.

Leaching of Substances into Groundwater. Nitrate leaching into the groundwater is a potential threat to human health from land application of poultry litter. Infants less than three months old drinking water contaminated with high levels of nitrate are susceptible to blue-baby syndrome (Hubbard and Sheridan, 1989; Bouwer, 1990). Several authors have shown that excess application of poultry litter has caused elevated levels of nitrate in soil solutions and groundwater (Adams et al., 1994; Kingery et al., 1993; Ritter and Chirnside, 1982; Weil et al., 1979).

Surface Runoff of Pollutants. Nonpoint source runoff from agricultural lands is now believed to be responsible for the water quality problems in over 70% of the lakes and rivers in the U.S. (U.S. EPA, 1994). Potential contaminants in runoff water from fields fertilized with poultry litter include bacteria, carbon compounds, metals, pesticides, and phosphorus (Moore, 1998).

Bacteria and Carbon. Several researchers have pointed out that poultry manure contains many pathogens that are responsible for human diseases (Bhattacharya and Taylor, 1975; Fontenot and Webb, 1975; McCaskey and Anthony, 1979). Also, Edwards and Daniel (1992) indicated that carbon runoff from poultry litter could negatively impact aquatic life by decreasing dissolved oxygen levels in waterways.

Metals and Pesticides. Poultry feed has been found to contain heavy metals, such as arsenic (As), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), selenium (Se), and zinc (Zn), which are added by the poultry industry (Tufft and Nockels, 1991). Kingery et al. (1993) found elevated levels of copper and zinc in soils heavily fertilized with poultry litter.

Moore (1998) reports that pesticide contamination of surface and groundwater is not normally associated with poultry production. However, there are a few pesticides used by the poultry industry, mainly to kill flies and litter beetles, which have been reported contaminating surface and ground water.

Phosphorus. Phosphorus, unlike nitrate, is not toxic to human (Moore, 1998). Equally, phosphorus normally does not have a direct negative impact on land to which it is applied, if it is applied in excess, though it can adversely impact surface waters if it is moved off-site by runoff or erosion (Sharpley and Menzel, 1987). Phosphorus is considered to be the primary element of concern with respect to eutrophication of freshwater system (Schindler, 1977, 1978). Eutrophication is derived from the Greek word meaning well nourished, and describes a condition of lakes or reservoirs involving excess algae growth, which may eventually lead to severe deterioration of the body of water (Moore, 1998). This increases the cost of cleaning and purification of water for drinking purposes.

Recent studies have shown extremely high phosphorus concentrations in the runoff water from pasture receiving low to moderate levels of poultry litter (Edwards and Daniel, 1992; Edwards and Daniel, 1993; Shreve et al., 1995). The majority (80-90%) of the phosphorus in the runoff water is water soluble, the form that is most readily available for algal uptake (Sonzogni et al., 1982). Since the plants can utilize more nitrogen than phosphorus (Moore, 1998), the soil test phosphorus level in these soils builds up and after many years far exceeds that required for 100% sufficiency of many crops (Sims, 1992; Sims, 1993; Wood, 1992). Sharpley, Smith and Bain (1993) conducted a similar study in which they studied 12 Oklahoma soils applied with poultry litter over a long time. They found that phosphorus accumulated in the surface meter of treated soils to a greater extent than nitrogen. This reflects the differential mobility, absorption, and plant uptake of nitrogen and phosphorus in soil (Moore, 1998).

Ammonia Volatilization. Another negative environmental impact associated with poultry litter is ammonia volatilization, which enhances atmospheric acid deposition and helps contribute to eutrophication (Moore, 1998). Ap Simon et al. (1987) indicated that atmospheric ammonia pollution plays a very important role in acid rain in Europe. Ammonia loss also causes low N/P ratios in litter, which increases the likelihood of excessive phosphorus runoff into adjacent water bodies, thus increasing eutrophication (Moore, 1998).

In Oklahoma, before poultry litter is applied on land a soil sample test must be done. The Department of Agriculture needs to know the source and amount of litter to be applied, the name of the farmer applying the litter, and the applicator. A permit is then given. With increasing poultry production, as noted above, this requirement has resulted in a surplus of poultry litter, posing a threat of nutrient leaching. To avoid the dangers of polluting the environment with this excess byproduct, farmers, especially in the eastern part of Oklahoma, have tried to market litter outside the production region. But their endeavors have met a number of challenges. The economic costs of remedial strategies to environmental problems of poultry litter are the crucial issues facing farmers trying to efficiently utilize litter.

The Litter Market

The failure of a more efficient litter market in Oklahoma has been attributed to several factors. First, and probably most important, is a lack of demand. The causes of poor demand are many. Peel (2000) reported that many potential users of litter are simply unaware of the potential value (and in some cases of the availability) of litter. The complex composition of litter increases the difficulty of understanding its value for various uses. This is further exacerbated by the fact that litter varies considerably from sample to sample and thus the user is often uncertain about exact composition. Hence lower prices than the true value of litter have been offered to poultry farmers (Peel, 2000).

The second factor limiting the litter market is the lack of market infrastructure. This includes lack of storage facilities and handling equipment, which limit timely application of litter and inability to utilize commercial hauling (especially backhauls) due to lack of facilities and equipment for fast and timely loading. In some cases, poor quality of rural roads and bridges limits access for large trucks (Eaton, 1999).

The third factor limiting the litter market relates to transportation costs. Due to the low nutrient content of litter, and thus the high volume required, it is not economical to transport poultry litter long distances for use as a source of plant nutrients (Paudel and McIntosh, 2000). Moore (1998) reported that in most cases, the land base available for application of manure is limited due to restrictions imposed by the high cost of transporting manure long distances.

The fourth factor limiting the litter market relates to supply limitations. The supply problem is not the amount of litter produced per se, which clearly is sufficient to support a sizeable market but rather producers' unwillingness to sell litter (Peel, 2000). There are numerous instances where potential users with willingness to buy litter (at some price) have reported difficulty in finding anyone willing to sell litter to them. The problem likely has economic, financial and social roots. The problem could be economic in that the current price may simply not be high enough to lure litter away from its present use. There is, however, evidence that litter is not currently valued anywhere near its potential value (Peel, 1996; Eaton, 1999; Wimberly and Goodwin, 2000). It appears that litter is often held off the market for financial rather than economic reasons. In some cases, litter producers may use litter for fertilizer rather than sell it and buy a more appropriate (and perhaps economical) mixture of commercial fertilizer simply to avoid reduced cash flow and perhaps to reduce credit needs. In other instances, litter producers may use litter as a barter item with neighbors to acquire needed services or products, again avoiding reduced cash flow and credit needs (Peel, 2000).

Finally, social attitudes towards dealing with third parties may limit marketing opportunities. Producers are often suspicious about marketing agents (middlemen) and fear being taken advantage of when selling litter (Peel, 2000).

A number of researchers have tackled the various problems associated with poultry litter marketing (Donald and Brake, 1990; Bosch and Napit, 1992; Peel, 1996; Eaton, 1999; Wimberly and Goodwin, 2000). Issues they have examined in greater detail are quantity and quality of litter market information, management, transportation and processing, value-added options, regionally coordinated litter markets, and market infrastructure (i.e. handling and storage facilities for litter).

Peel reported that litter could be hauled farther and in more diverse types of equipment if moisture can be reduced by drying. Drying could also stabilize litter to facilitate storage. Bosch and Napit studied the economic viability of transporting broiler litter from counties of surplus to counties of deficit supply. They first looked at a situation where litter was applied to all crop and pasture land. They also examined a scenario where litter is applied to 50 percent of the total crop area available. The results of this study showed that the value of litter as a fertilizer was higher than the costs associated with the transfer of litter even to a distance of 50 miles.

Currently, economics indicate that poultry litter can be trucked up to 100 miles from the point of sale if used for fertilizer and up to 300 miles if used as feed. This assumes 20-ton truckloads carrying litter costing $5.00-10.00 and a transportation cost of $1.00-1.25 per mile. It is also based on a litter value of $22.00 per ton if used as fertilizer or $40.00 per ton if used as feed (Donald and Brake, 1990).

The studies reported above have all been done to help protect the environment from further pollution from the continual increase in poultry litter generated from commercial poultry production. There still exists a need to identify other avenues of recycling poultry litter that are environmentally sound, economically and technically feasible, and socially acceptable. This research conducts a break-even analysis for a cooperative value-added enterprise that aims at processing poultry litter into methane biogas and a byproduct that might be used as a fertilizer. This study aims at providing information that can be used in future feasibility studies of similar technologies that process poultry litter into gas and fertilizer.

Objectives

The general objective of this research is to enhance rural economic development, benefit the environment and maximize profits to poultry producers. The specific objective is to calculate the maximum processing cost that would permit a profitable investment in a new generation cooperative to produce methane biogas and fertilizer from poultry litter.

CHAPTER II

LITERATURE REVIEW

Introduction

The purpose of this review is to highlight important aspects of a successful cooperative business venture in methane production. Since the investment is potentially risky, aspects of business planning in a risky environment are reviewed. This review is divided in three sections. The review begins by looking at economic analysis of methane production from biomass, livestock waste and municipal wastes. The various pieces reviewed have looked at the economics of producing methane at small- and large-scale operations. On-farm production of methane for energy production has also been considered in the review.

The second section reviews the formation of cooperatives, cooperative theory and development, and the cooperative business as a firm. Some aspects of successful cooperation are also considered.

The third section of the review considers important aspects of business planning and feasibility analysis. Topical issues for a complete and thorough business plan and feasibility analysis are highlighted in this section. The section includes risk analysis in the business plan. Since the business of methane production is considered to be risky due to variable energy prices and the importance of continuous availability of the major input (poultry litter), business planning with risk considerations is an important part of this section. The review ends by summarizing the overall contribution of the various articles and books reviewed and then sets a stage for this paper's research.

The Production of Methane

Treatment of manure, an organic material, usually falls into three major categories: physical, biological, and chemical. Physical treatment of livestock manure or litter is accomplished with solid-liquid separation by sedimentation and various methods of screening or centrifuging. Other physical treatments include drying and incineration but increasing fuel costs have diminished interest in these methods (Day and Funk, 1998). Pyrolysis is another physical treatment of livestock manure and litter. Biological degradation of litter is a natural process that has occurred since the beginning of time, as manure is a good substrate of microorganisms. Biological treatment of livestock manure or litter includes anaerobic treatment (without oxygen), aerobic treatment (with oxygen) and composting. Livestock manure and/or litter can be chemically treated; this includes manure additives for odor control and other chemical treatments.

Two processes in treatment of livestock manure and/or litter that generate methane are anaerobic treatment and pyrolysis. The production of methane gas from anaerobic digestion of livestock and poultry wastes is one alternative energy source that has been explored in some depth since the energy crisis developed in the early 1970s. But earlier reports showed that this process was not economically feasible (Jones and Ogden, 1986). Anaerobic digesters decompose manure in airtight chambers while producing onsite fuel (biogas). The biogas is composed of 60% methane and 40% carbon dioxide with trace amounts of hydrogen sulfide and hydrogen gas. The disadvantages are the initial cost of the digester and the operational management required are high. The other disadvantage is that manure must be collected, transported, and fed into the digester; and the accumulating sludge must be disposed of routinely (Day and Funk, 1998).

The initial stage in anaerobic digestion involves hydrolysis of the organic matter by enzymes. The second stage involves manure being broken down into a series of fatty acids by acid-forming bacteria, called the acid-forming stage. In the third stage, methane-forming bacteria convert the acids to methane gas and carbon dioxide (Jones and Ogden, 1986). Fulhage et al. (1993) says that methane-forming bacteria are strict anaerobes and cannot tolerate oxygen in their environment. They function best at 950 ^{0}F; therefore to obtain maximum gas production, heat usually must be added to a digester. Anaerobic digestion is believed to be the most feasible process for converting manure into energy (Jones and Ogden, 1986).

Anaerobic digestion has not been widely utilized in agricultural settings due to technological failure and lack of economic feasibility (Miranowski et al. 1999). Most technologies that have been developed have had mechanical failure even before payback period was over. Those technologies that have performed with minimal mechanical failure have fallen short of any kind of reasonable economic payback (Miranowski et al. 1999). Smith (1978) found that the cost of producing methane using an anaerobic digester was twice the market price of methane. He concluded that it was not economical in most developed countries to produce methane with an anaerobic digester.

Pyrolysis is defined as incineration under anaerobic conditions; it has high-energy efficiency. Organic material may be pyrolyzed by holding it at 250-1000°C (480-1830°F) in an oxygen deficient atmosphere (Day and Funk, 1998). It produces a gas composed of hydrogen, water, methane, carbon monoxide, carbon dioxide and ethylene (White and Taiganides, 1971). It also produces solid residue composed of ash and carbon and an oil-like liquid.

The Current Uses of Methane

Methane gas can be used as a fuel for boilers or to replace natural gas in cooking, fuel oil, or LP gas for other uses on the farm like water heating, space heating, air conditioning, refrigeration. The gas can also be used to power engine generators to produce electricity for on-farm operations or possibly for sale to electric utilities in some states (Jones and Ogden, 1986). A big challenge comes on how best to handle or use gas generated from manure. Methane does not liquify under reasonable pressures and temperatures. Methane gas is not practical as a mobile fuel due to the high pressure needed to keep it in liquid form, and the high cost of compression makes it very expensive to store for future use (Jones and Ogden, 1986). Fulhage et al. said that methane is impractical to store in large amounts, hence most storage applications would likely involve only short-term accumulations of methane. They suggested the best way to use the gas is for home heating and generation of electricity.

Jones and Ogden (1986) found that economic feasibility of methane generation would be greater for farms that utilize high cost fuel and electricity that could be replaced. They also found that additional investment tax credit or other government subsidies would of course increase the economic feasibility of methane generation from the farmers' standpoint and might lead to greater self-sufficiency in energy production.

Storage of manure is an important aspect in manure processing. Manure can be stored in pits, bunkers, or stacks if dry, or in holding tanks, ponds, or lagoons if liquid (Jones and Ogden, 1986).

In order to benefit from economies of scale a regional approach might be a better option in the litter management i.e. several farmers coming together to form a cooperative. This might agree and fit well with what Jones and Ogden (1986) found. But the question is, "Is a cooperative the best business form or structure for a feasible methane production or could it be equally feasible on individual commercial poultry farms?" The next section analyses a cooperative business firm.

The Cooperative Business

The development of cooperatives in the U.S. dates back to about a century ago. Most U.S. agricultural cooperatives originated in the early 1900s because of a combination of economic, farm organization, and public policy factors (Cook, 1995). At least three purposes of economic organization can be identified: making profits, providing services, and realizing meaning (Torgerson et al., 1990). Predominant cooperative organizations are located within the service purpose i.e. a focus on serving the greatest numbers of people over the longest period of time. Agricultural marketing cooperatives tend to be found between the service and profit purpose orientation, with new generation cooperatives attempting to preserve earnings benefits for a defined membership over time. Cooperative organizations typically contain elements of all three tendencies (Torgerson et al., 1990). Torgerson et al. (1990) also reported that agricultural cooperatives provide many services that the market either does not provide, or does so only in limited quantity or quality. The reason a cooperative provides an otherwise unmet service is because its purpose is to serve the interests of members in enhancing the profitability of the individual enterprises (Torgerson et al., 1990).

The evolution of agricultural marketing cooperatives has its roots in the emergence of commercial agriculture in the nineteenth century and subsequent refinements honed by the development of two distinctly American schools of thought (Torgerson et al., 1990). As a self-help business form, agricultural cooperation was designed to move product to market and influence price and other terms of trade – consistent with market supply and demand conditions – while providing fair treatment and other benefits to members (Torgerson et al., 1990). A number of writers have reported that the primary motive of cooperative formation is to capture benefits for the members. Torgerson (1977) stated that the changing market structure of agriculture, a prime motivator in early organizing efforts associated with the emergence of commercial agriculture, remains the underlying rationale for cooperative efforts by farm operators. Recent studies continue to document that market failure (excessive transaction costs, discriminatory treatment of contract growers, and increased monopsony in buyer markets) lead to group action by producers (Torgerson et al., 1990). Cook (1995) reported that one of the two economic justifications for forming cooperatives is that individual producers need institutional mechanisms to countervail opportunism and holdup situations encountered when markets fail. He says that often cooperatives formed on this economic justification survive and become successful in correcting, or at least ameliorating, the negative economic impacts of market failures. Generally, the first stage in the formation of a cooperative is viewed as defensive in nature. Several papers have suggested that alliance formation is also driven by the goal of managing risk (Knoeber and Thurman, 1995). Risk shifting of output price and, sometimes, input prices is provided through contract payments to growers in a vertical alliance. Westgren (2000) states that one interesting characteristic of agricultural alliances is that they typically have a horizontal dimension, as well as vertical dimension. That is, several agricultural producers will combine around common assets to attempt to mimic scale advantages of large organizations.

Besides benefiting the cooperative members, cooperative formation has also benefited the rural sector and contributed to economic growth and development. Weingast (1995) stated that the evolution of cooperative and coalition institutions has a decisive impact on economic growth and development. Agricultural cooperatives can be regarded as rural infrastructure/institutions. In this regard, the nature of the organization empowers rural people generally and specifically rural communities (including farmers). Due to the economic impact brought about by operation of agricultural cooperatives, they can be viewed as a public developmental good at the grass roots level (Torgerson et al., 1990). Stafford (1990) argued that economic development needs to focus on encouraging reported that one of the two economic justifications for forming cooperatives is that individual producers need institutional mechanisms to countervail opportunism and holdup situations encountered when markets fail. He says that often cooperatives formed on this economic justification survive and become successful in correcting, or at least ameliorating, the negative economic impacts of market failures. Generally, the first stage in the formation of a cooperative is viewed as defensive in nature. Several papers have suggested that alliance formation is also driven by the goal of managing risk (Knoeber and Thurman, 1995). Risk shifting of output price and, sometimes, input prices is provided through contract payments to growers in a vertical alliance. Westgren (2000) states that one interesting characteristic of agricultural alliances is that they typically have a horizontal dimension, as well as vertical dimension. That is, several agricultural producers will combine around common assets to attempt to mimic scale advantages of large organizations.

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A Cooperative Defined. A cooperative can be defined as an economic organization whose residual claims are restricted to the agent group that supplies patronage under the organization's nexus of contracts (i.e., the member-patrons) and whose board of directors is elected by this same group. Most cooperative organizations have decision specialists who are not residual claimants (Vitaliano, 1983). Rhodes defines a cooperative as a special type of business firm owned and operated for mutual benefit by the users (member-patrons). Actual management is by salaried professionals. An elected board of directors represents the interests of the members.

A cooperative is a form of an organization. Fama (1980) defined an organization as a nexus of contracts between individuals; economic agents who supply resources to a productive economic activity in exchange for various claims on the cash flows the activity generates. Contracts specify (1) the nature of the residual claims, and (2) the allocation of the decision process among agents. Residual claims are usually exchanged for capital resources, and an organization's residual claimants are the agents that bear the financial risk of the organization's activities. Agency theory and the institutional discussion of property rights often describe "residual claimants" as being the beneficiaries of joint action whether it is in an investor-owned firm or a cooperative. The organization is viewed as a nexus of contracts or collaborative effort among participating units or agent groups, each reaching for their rewards from the organizational endeavor (Torgerson et al., 1990).

Is a Cooperative Organization a Firm? The resource-based theory of strategy states that organizational capital is one of the basic categories of firm resources for successful cooperation. The other categories of capital resources are physical and human. The theory argues that the way the firm or cooperative is organized to use the available scarce resources will determine its success to achieve the intended goals. Westgren (2000) argues that market returns (i.e. economic rents) are effectively payments to the resources used in production of the products. Westgren also argues that above-normal rents are realized when the combination of physical, human, organizational and financial capital resources gives the best strategy.

Helmberger and Hoos (1962) adopted an organizational approach to the study of the cooperative association. Based on Chester Barnard's definition of an organization as a system of consciously coordinated activities of two or more persons, they defined a firm as a cooperative system consisting of an organization, persons who contribute activity to the organization, and privately-owned physical plant; and in which (1) economic resources are mobilized, (2) goods and services are produced for sale, and (3) primary reliance is placed on the proceeds from the sale of the product to meet production costs. They stated that organization could emerge only when (1) persons contribute activity to the system, (2) participants share one or more common goals, and (3) communication among participants is present.

They concluded that a cooperative enterprise can legitimately be viewed as a firm, since it (1) embodies persons and privately owned physical plant; (2) mobilizes factors of production, produces goods and services, and relies primarily on the proceeds from the sale of its product to meet the costs, which it incurs. Gherty (1991) suggested that a cooperative must first and foremost be a business organization. The basic underlying objective of every cooperative should be to improve the returns of its farmer-owners, to maximize the return on their investments, to achieve industry-competitive economic performance, and to maintain a strong balance sheet.

Farmer Cooperatives in the Market. Of particular interest in the cooperative literature is the procompetitive impact of cooperatives on rural communities (Sexton, 1990). Market power is a significant issue at various stages of many agricultural markets, and cooperatives, actively or potentially, play an important role in these concentrated markets (Sexton, 1990). Cooperatives may countervail buyer market power in concentrated markets through the yardstick of competition effect espoused originally by Nourse (1922) and recorded in Torgerson et al., (1990).

Cooperatives from a public policy perspective are seen as procompetitive market instruments. Producer members respond to improved prices by producing more since members individually determine their production decisions (Torgerson et al., 1990). Empirical evidence suggests that consumer prices are generally lower in markets with a substantial cooperative presence (Rogers and Petraglia, 1994). Sexton (1990) wrote that the goal of competition policy regarding cooperatives should be to facilitate their opportunity to address market failure and countervail market power, while limiting the opportunity for cooperatives themselves to exercise market power. Sexton (1990) argued that marketing cooperatives are generally ill suited to the exercise of market power for two fundamental reasons: (1) most marketing cooperatives' output levels are determined implicitly by the levels of production chosen by their farmer members. Individual farmers are perfect competitors. Cooperatives may have restrictions on member deliveries – hence supply control; (2) membership in cooperatives in market economies is voluntary, and seldom does any single cooperative control the complete market supply of a product. Cooperatives may also control supply by restrictions on membership. A simulation analysis conducted by Hoffman and Royer (no date) suggested that the existence of competitive yardstick effect is not universal with respect to various scenarios regarding market structure and behavior. In particular, cooperative processors did not always have a substantial or positive effect on industry output or economic welfare.

Cooperatives represent one of the few options that farm entrepreneurs have for surviving in a more concentrated and integrated global agriculture. As an off-farm extension of the farm firm, the essential function of agricultural cooperatives is to perform vertical integration (Torgerson et al., 1990). Cooperatives harmonize transactions and in so doing lower transaction costs, reducing the margin between the farm and retail prices. Farm operators are better able to deal with market power of processors by using vertical integration through cooperatives and provide themselves with direct economic benefits (Torgerson et al., 1990).

Vertical integration can be defined as the combination of two or more stages of a production-marketing chain under single ownership. Vertical integration reduces transaction costs and the amount of technological inputs (den Ouden et al., 1996). As stated earlier farmer-owned cooperatives were traditionally formed to join forces and offset bargaining power of the more concentrated supplying or marketing stages. Cooperatives are familiar, widespread, and particular forms of vertical integration in agriculture (den Ouden et al., 1996).

A number of factors have been indicated as explanations for cooperatives' failure to integrate forward into high-margin, value-added activities to a greater degree. Most of the suggested explanations are related to the principal characteristics of cooperative ownership, capitalization, and governance that distinguish cooperatives from other business forms (Royer, 1995). Royer suggested that due to the nature of cooperative organization, raising of equity capital is a factor limiting their vertical expansion. Cooperatives are committed to returning their earnings to producers on the basis of patronage and not ownership of capital stock.

Diaz-Hermelo et al. (2001) studied member responses to the farmer-owned cooperative's alternative capital management strategies. The results suggested that decreasing cash patronage to increase equity redemption is a poor strategy. Members preferred the strategy of using debt to increase equity redemption. Royer (1995) also suggested that cooperatives might be reluctant to invest in value-added processing activities because of the increased risk associated with the establishment and management of a new and unfamiliar business. The third suggestion is that firms may have incentives to integrate vertically because of the existence of technological economies, transactional economies, or market imperfections that may not apply to cooperatives. On the other hand, Peterson (1993) wrote that if a cooperative is to compete successfully for both member patronage and capital, then its business goals must focus on finding an optimal mix between (1) earning competitive returns on the cooperative's own assets and (2) generating returns on members' farm assets that exceed those realized when members deal with noncooperative firms.

A question might arise as to whether a cooperative could increase its market share to a dominant level within a competitive market. Rhodes (1983) examines advantages and disadvantages of large cooperatives as competitors in oligopolistic settings that include investor-owned firms (IOF). He argued that cooperatives could likely enter and even dominate high-margin, concentrated markets. He reported that cooperative market shares would increase at the expense of the IOF's market share as long as (a) the market prices are the same for similarly regarded services and (b) the net earnings of cooperatives are large enough to permit distribution of significant patronage dividends. He reported that cooperatives are constrained from pursuing profit opportunities that would appeal to IOFs because they are farmer-member oriented. Garoyan (1983), on the other hand, argued that theoretically the operational features of cooperatives and IOFs are similar - there appear no unique features resulting from form of organization. He wrote that the decision process is the most significant distinction between the two types of firms.

Several authors have written on efficiency measures of cooperative businesses. Ariyaratne et al. (1997) analyzed efficiency of midwestern agricultural cooperatives and found that a cooperative is more likely to reduce costs by focusing on technical or allocative efficiency than by adjusting scale. They concluded that, in general, larger cooperatives have higher technical, allocative, and scale efficiencies, and are overall more efficient than smaller cooperatives.

The "New Generation" or "New Wave" Cooperatives. Since 1990 "New Generation" cooperatives have developed allowing producers the opportunity to forward integrate into processing and marketing activities while retaining the anti-trust exemptions granted to cooperatives by the Capper-Volstead Act of 1927. One of the five factors that Fulton (1990) argued would contribute to the potential success of cooperatives is the development of new generation or new wave cooperatives. She reported that the recent activity associated with the development of new generation cooperatives suggests that the cooperative form of business organization is important and will survive. She further argued that, in many cases, farmers with experience in cooperatives are realizing the potential of new organizational structure to vertically integrate and move into value-added processing. In other cases, producers who have not traditionally been involved in cooperatives are finding the cooperative organizational structure useful in vertically integrating.

Fulton noted, however, that new generation or new wave cooperatives have some specific challenges to face. The first challenge is survival in extremely competitive business sectors in which failure is a common occurrence. The second challenge is the complexity of these business organizations. She notes that one of the important features of new generation or wave cooperatives is that they are closed-membership. The other two distinguishing features of the new generation cooperatives are the tradable shares and the long-term contractual agreements for supply of raw materials. The final challenge is that the manner in which decision makers react to the failures when they occur will be an important factor in the long-term success or failure of this new form of business organization.

Several authors have reported on issues pertaining to closed and open membership cooperatives. Helmberger (1964) concluded that a closed-membership cooperative could produce "socially undesirable" market performance by restricting output to a level less than that associated with a profit-maximizing monopsony. In a spatial oligopsony analysis, Sexton (1990) found that a closed-membership cooperative could result in poorer performance than an industry consisting entirely of profit-maximizing processors. Sexton (1990) reported that open membership cooperatives are procompetitive forces whose presence mitigates for-profit firms' opportunities to exercise monopoly or monopsony power. Le Vay (1983) challenged Helmberger's conclusions about the socially undesirable effects of a closed-membership cooperative. Le Vay (1983) maintained that an open-membership cooperative overproduces by accepting whatever quantity of raw product members choose to supply. Hence an open-membership produces at a level beyond the social optimum. Closed-membership cooperatives also emphasize quality of their produce. Besides meeting the quantity requirements of the demand for their products they also ensure that quality standards of their products are maintained. Consequently, they are more than able to survive market competition.

One of the challenges faced by both open and closed membership cooperatives is the need to unite their members with divergent goals. Members in a coalition differ in their preferences; consequently they are faced with many decisions. According to Friedman (1986), a coalition is a subset of players that is able to make a binding agreement. As a coalition, cooperatives are faced with many decisions that include the pricing of different services to members, including the possibility of differential pricing based on members' patronage; the location of facilities; and the allocation of overhead costs and pool receipts (Staatz, 1983).

Cooperative game theory is usually used to model situations where joint action by a potential coalition of players produce gains, but the players must bargain among themselves about how the net benefits of the joint action are to be shared. Game theory assumes that a player evaluates various outcomes in terms of the utility derived from them. Application of the theory of cooperative games offers promise as a way of modeling how farmer cooperatives can allocate costs and benefits among diverse membership while preserving the incentives of the members to patronize the organization (Staatz, 1983).

In a new generation cooperative, producers purchase equity shares, which imply their membership delivery rights and obligations. The total quantity of delivery rights that the cooperative sells to producers depends on the processing capacity of the cooperative's operations. Staatz (1983) states that failure to agree on an allocation of net benefits among players prevents the coalition from forming. Cooperative game theory will not be used in this paper since it is not within the scope of this paper. It has been referred here as a way to manage the diverse and sometimes conflicting interest of members in a cooperative.

Since a cooperative can be viewed a business firm, several factors have to be considered in planning a business to avoid unnecessary costs and loss of profits. The following section deals with business plan and factors to be considered before venturing into a new business.

Business Planning and Risk

Several authors have argued that prior to initiating any new enterprise or method of producing and marketing a product, it should be determined whether the proposed venture is financially viable (i.e. has a profit potential) (Schermerhorn, 1991; Williamson and Stegelin, 1987; Schermerhorn and Makus, 1987). Schermerhorn (1991) stated that one purpose of conducting a feasibility analysis is to avoid costs associated with making a wrong decision. Also, it provides a valuable planning tool to implement the new business venture.

A feasibility study can be divided into two major phases: an analysis of directly influencing factors, and an analysis of environmental conditions (Schermerhorn, 1991). Analyses of directly influencing factors include market determination, raw product supply, and production process. It analyzes factors that directly affect the success of the operation

Market determination involves determining current and potential consumption of the product, types and location of available markets, types of distribution systems available, ways the market can be entered, types of buyers within the market, types of selling arrangements used, and prices charged for the product. Market determination also involves determining levels of available competition in the market as well as market trends.

Raw product supply analysis determines availability of raw product inputs for the proposed enterprise. Four factors included in this analysis are: (1) minimum facility size; (2) plant requirements; (3) availability of required inputs in the needed quality and at an affordable price; (4) assurance of future input supply. In the raw product supply stage, Williamson and Stegelin (1987) suggested including charges to cooperative members for services or inputs.

The production process assesses the production component of the production proposed activity. It assesses specific facility needs, capital requirements (equity and borrowed capital), cost and quantity of labor needed, necessary financing, and the potential costs and returns associated with the business venture. This stage also includes management requirements; value of land, buildings and equipment and preparing expense, for beginning operations; and additional capital necessary to support working capital (Williamson and Stegelin, 1987).

The second major phase in feasibility analysis is the analysis of environmental conditions. A complete feasibility study analyzes the availability of facilities and services that the firm believes are essential to create an acceptable environment in which the plant can operate and its management and labor force can live (Schermerhorn, 1991). These factors are considered after the general location, as affected by supply of raw product and availability of markets, is determined.

Once a feasibility analysis has shown that the business venture is feasible, a complete and comprehensive business plan needs to be done. A business plan aids in financial planning (especially when seeking loans through lending institutions). It also serves as a guide, which the business operators use to monitor their progress towards achieving the intended objectives to reach the final goal of the business. With a business plan on hand it is easier to monitor whether the business is on track or not, and remedial measures can be put in place before major losses are incurred.

One of the major concerns associated with business ventures, especially agribusiness ventures, is the risk attached to them. Many times business owners are confronted with the question of decline in the value of portfolio over a given time period as well as income variability. What would happen to the investment if the input prices went up and/or output prices declined? Nelson (1997) stated that uncertainty or risk is what makes decision-making both challenging and frustrating. The key to success is to take the right risks. Some of the primary sources of risks to be considered as reported by Nelson are production risk, market risk, and financial risk. Branch (1991) wrote that risk appears to be more important at farm level than at processing or wholesale level. He said that as you move up the marketing ladder the risk associated with any produced commodity declines because the commodity generally accounts for a smaller proportion of the entire marketing level.

Nelson (1997) wrote a logical procedure for making risky decisions: (1) analyze decisions in terms of alternative actions, possible events, and payoffs (the pay off matrix); (2) estimate the odds (probabilities) associated with the events affecting the decision payoffs; (3) consider the business's financial position and the manager's attitudes about taking risks (risk preference); (4) adopt management strategies to control or counteract risk.

Sporleder and Goldsmith (1990) reported that forward contracting, inventory management and vertical integration are some of the strategies used to manage or mitigate risk. They wrote that pooling, usually accomplished through member obligation delivering to the cooperative, has both a theoretical and empirical basis for risk mitigation. Empirical results have shown that pooling results in a greater efficiency of equity capital through greater total assets controlled by equity owners per unit of equity capital. Clearly, this is firm level risk mitigation from pooling which allows the marketing cooperative to function more efficiently in the long run.

Simon (1996) wrote that recent interest in risk management has centered on a new approach called value at risk. Essentially, value at risk poses the question: "Over a given period of time with a given probability how much could the value of the portfolio decline?" Value at risk is one of the ways of measuring risk, it stands high in financial management. It is most useful in measuring short-term risk of traded instruments in normal market conditions.

CHAPTER III

CONCEPTUAL FRAMEWORK

Production Process and Break-Even Analysis

A cooperative enterprise can legitimately be viewed as a firm or business organization. According to Nicholson (1998), a firm is an association of individuals who have organized themselves for the purpose of turning inputs into outputs. A cooperative embodies labor and management and has privately owned physical plant. It also mobilizes factors of production (i.e. inputs) to produce goods and services (i.e. outputs). A cooperative relies primarily on the proceeds from the sale of its output to meet the costs and provide residual claims to its members. The basic underlying objective of every cooperative is to improve the returns of its farmer-owners, to maximize the return on their investments, and to compete favorably within the industry for successful economic performance.

Since a cooperative is a firm that seeks, among its objectives, to maximize returns to its member-owners, it is therefore viewed here as a profit-maximizing firm. A profit-maximizing firm chooses both its inputs and outputs with the sole goal of achieving maximum economic profits. In other words, the firm seeks to make the difference between its total revenues and its total economic costs as large as possible (Nicholson, 1998). The economic cost of an input is the remuneration the input would receive in its best alternative employment.

The purpose of this study is to provide a basis for feasibility analysis of investment in production of methane and fertilizer from poultry litter. The study attempts to determine the conditions under which such an investment will be profitable. One of the ways to analyze the profitability of an investment is through cost-benefit analysis.

Investment Analysis. The profitability of an investment is measured as:

3.1 $\text{Profit} = \text{Total Revenue} - \text{Total Cost}$

3.2 $\text{Profit} = \sum \alpha_i Y_i - [\sum \delta_j X_j + \sum FC_k + \sum VC_l]$

subject to

3.3 $\sum X_j \leq CAP$ (capacity constraints)

The variables are defined as:

α_i = price per unit of output Y_i

Y_i = quantity of output i obtained from a processing plant
Note that the plant is assumed to produce four outputs i.e. methane and fertilizer elements i.e. nitrogen, phosphorus and potassium.

δ_j = transportation cost per ton of litter X_j hauled from poultry farm j to a processing plant

X_j = amount of litter in tons hauled from poultry farm j to a processing plant with constant capacity (CAP)

FC_k = fixed cost k associated with investing in the processing plant

VC = variable cost associated with operating the processing plant to produce outputs

CAP = capacity of the processing plant

$\sum X_j$ = total supply of litter from all poultry farms

The plant's revenue comes from sale of four products: methane gas, nitrogen, phosphorus and potassium fertilizers. The fertilizers would be formed from a by-product of ash from methane production. Both manufactured inorganic fertilizer and the methane gas will be sold at existing market prices, presumably in a competitive market. The costs are divided into fixed and variable costs, where,

Fixed Costs = cost of land + cost of building + cost of equipment + plant installation cost + insurance cost + interest + depreciation + taxes + general office expense + management salaries

and,

Variable Costs = maintenance and repair costs + cost of raw materials (including poultry litter) and supplies+ advertising costs + sales promotion costs + energy cost (kwh x electric rate) + cost of non-energy utilities + labor cost + litter transportation cost

Investment analysis requires that all costs and benefits be represented. Unfortunately, due to confidentiality requirements by data providers, it was impossible to adequately represent non-transportation costs. Consequently, the analysis was changed to a break-even analysis. In this break-even analysis the result is a dollar value that is the maximum amount that all non-transportation costs can total for the investment to break-even (achieve zero profit).

Break-Even Analysis. Moore (1971) presents a simple break-even equation as:

3.4 Break-Even Revenue = Variable Expenses + Fixed Expenses

For a firm to attain profits, or positive returns to its costs, the following equation must be true:

3.5 Profit = Income – Costs (Fixed & Variable) > 0

Since there are known and unknown costs, equation 3.6 can also be written as follows:

3.6 Profit = Income – Known Costs – Unknown Costs

If profit is zero,

3.7 Unknown Costs = Income – Known Costs

If unknown costs are greater than income minus known costs, then profit will be negative. On the other hand, if unknown costs are less than income minus known costs, then profit will be positive. The research here calculates income minus known costs to determine the break-even point of the investment. This number gives the maximum the enterprise can afford to pay for all unknown costs and still break-even.

Model Assumptions. (1) The firm/cooperative operates in a competitive industry; (2) The price of output is given by the market (i.e. the cooperative is a price taker and its production does not affect the market price); (3) The prices of inputs used (both fixed and variable) are true competitive prices, that is the cooperative pays economic values of the inputs; (4) All required inputs are available at the right price, right time, right form and in required quantities; (5) The technology used in the production process of the two outputs does not become obsolete within the life span of the equipment; (6) All members of the cooperative are willing and committed to supply poultry litter to the processing plant at a given price.

CHAPTER IV

DATA SOURCES AND PROCEDURES

Data Sources

The major part of the data used in the research was provided by the Oklahoma Department of Agriculture. The data included location of poultry farms in each county, types of birds produced, total number of birds on each farm, and number of poultry houses on each farm. Duplicate entries in the data were deleted. After cleaning the duplicate entries, out of 1,260 farms in the original data obtained from the Department of Agriculture, 928 unique farms remained. Due to confidentiality of the data from the Oklahoma Department of Agriculture it has not been presented in the report, but a summary of the data by county has been presented in the table below.

Table 5.1 gives the number of birds, number of poultry houses, and amount of litter produced per year by counties in eastern Oklahoma. About 365,000 tons of litter per year are produced eastern Oklahoma.

A consultant hired by the poultry producers to help in planning and forming the cooperative provided the financial part of the data. The data provided included the price of natural gas in terms of Million British Thermal Units ($3.00 per MBTU). He also provided the heating value of a pound of poultry litter in terms of BTU upon conversion to methane gas, and quantities of nitrogen, phosphorus and potassium that can be produced from a ton of poultry litter. These data are not presented here due to a confidentiality agreement with the providers. The prices of nitrogen, phosphorus and potassium were obtained from 2001 USDA data available online (USDA, 2001). The prices used were $0.131, $0.106, and $0.084 per pound of nitrogen, phosphorus and potassium, respectively.

Table 5.1. Total Birds and Poultry Litter Produced in Eastern Oklahoma By County

County	Total Birds	Number of Houses	Poultry Litter Produced in tons
Le Flore	17,136,894	791	81,482
McCurtain	15,886,755	852	63,581
Delaware	13,553,080	816	52,001
Adair	9,495,300	607	34,734
Haskell	4,238,598	190	19,968
Ottawa	2,924,100	158	14,627
Cherokee	2,062,100	174	8,313
Mayes	1,380,500	75	5,513
Craig	721,000	32	3,894
Sequoyah	533,343	38	2,448
Choctaw	228,000	12	1,491
Muskogee	456,200	21	1,449
Latimer	167,000	11	876
Pittsburg	70,000	3	756
McIntosh	65,000	7	358
Pushmataha	30,000	3	231
Total OK	68,947,870	3,790	291,722

Procedures

Estimation of Poultry Litter Produced. One approach to calculate litter per farm is to divide number of birds per farm by number of poultry houses per farm to get birds per poultry house. Number of poultry houses on a farm would then be multiplied by amount of litter produced per poultry house to get litter per farm. However, since number of birds per farm is not the same from one farm to another, the resulting litter per farm numbers are unreliable.

The second best alternative to estimate poultry litter produced on each farm was to use dry manure produced per type of bird per year as given by Sims et al. (1989), and multiply by number of birds of each type on a particular farm. According to Sims et al. (1989), broilers produce 4.9 kg dry manure per year; layers produce 7.0 kg dry manure per year; pullets produce 2.7 kg dry manure per year; and, turkeys produce 10.9 kg dry manure per year. Each of these numbers was multiplied by the number of each type of bird to estimate manure produced per farm.

The problem with this procedure is that it underestimates the total litter produced per poultry house since it uses dry poultry manure and not poultry litter produced. As defined earlier in this report poultry manure is a mixture of poultry feces and urine. Poultry litter is a mixture of manure, bedding material, feathers, wasted feed, and soil (usually inadvertently included during the cleanout operation). It is believed that the non-manure particles in poultry litter makeup about 20% of the weight of poultry litter. Consequently, the estimates of poultry manure per farm were adjusted upwards by 20% to account for the non-manure particles in poultry litter.

Estimation of Transportation Cost. The Oklahoma Department of Agriculture data along with a geographical information database, and program (see below), was used to estimate travel distances from each poultry farm to a plant sites in the city of Jay in Delaware County and the city of Watts in Adair County. These travel distances are actual road miles, rather than straight line "as the crow flies" distances. The following is the information that was used in the estimation process: section data; township number; township direction; range number; and range direction. This information was used to calculate the shortest available road distance from each farm to Jay in Delaware County. To successfully solve the problem three sets of data were used: a TIGER-based road network for eastern Oklahoma without a mileage attribute; the township and range sections in a polygon shape file; and, the input dataset of poultry farm locations and litter amounts.

The following software were used: (1) ArcView with the Network Analyst extension and two additional scripts/extensions as mentioned above (2) Access for the multi-key database, and excel for the final calculation all available from ESRI (Environmental Systems Research Institute, Inc.). The first task included adding two additional features to ArcView, the Centroid calculator and the LengthCoordTools.avx file. Second, the mileage attribute was calculated and added to each route section of the TIGER-based road network. Third, the section polygons were converted to centroids (because the network analyst program uses point data, not polygons). Finally, the poultry farm data were attached to the centroids, and over 900 standard shortest path routes (by mileage) were estimated. The result was distances from each farm to a plant location site in Jay and Watts. Figures 4.1 and 4.2 depict the distribution of poultry farms and possible location of poultry litter processing plants in the Eastern Oklahoma region. Note that because Watts is more centrally located the total transportation cost for poultry litter is lower than for Jay, which is further north.

Since the only location information available on each farm was the township, range and section, geo-referencing each farm to the section centroid was the highest accuracy location that could be accomplished. The routes calculated by arcview network analyst were calculated from the plant location to the point on the road network closest to each selected centroid/farm location.

Having obtained shortest routes and distances in miles from each poultry farm to a plant location site, the cost of transporting the poultry litter was calculated using existing market transport prices. A loading cost of $5.00 per ton was used; this cost also covers the first three miles to be traveled. After the first three miles a cost of $0.08 per mile per ton (equivalent to $2.00 per mile per 25-ton truck) was used to calculate the cost of hauling litter for the remaining distance from a poultry farm to a plant site.

Figure 4.1
Chicken Litter Transport Problem
Processing Plant Located in Jay, OK

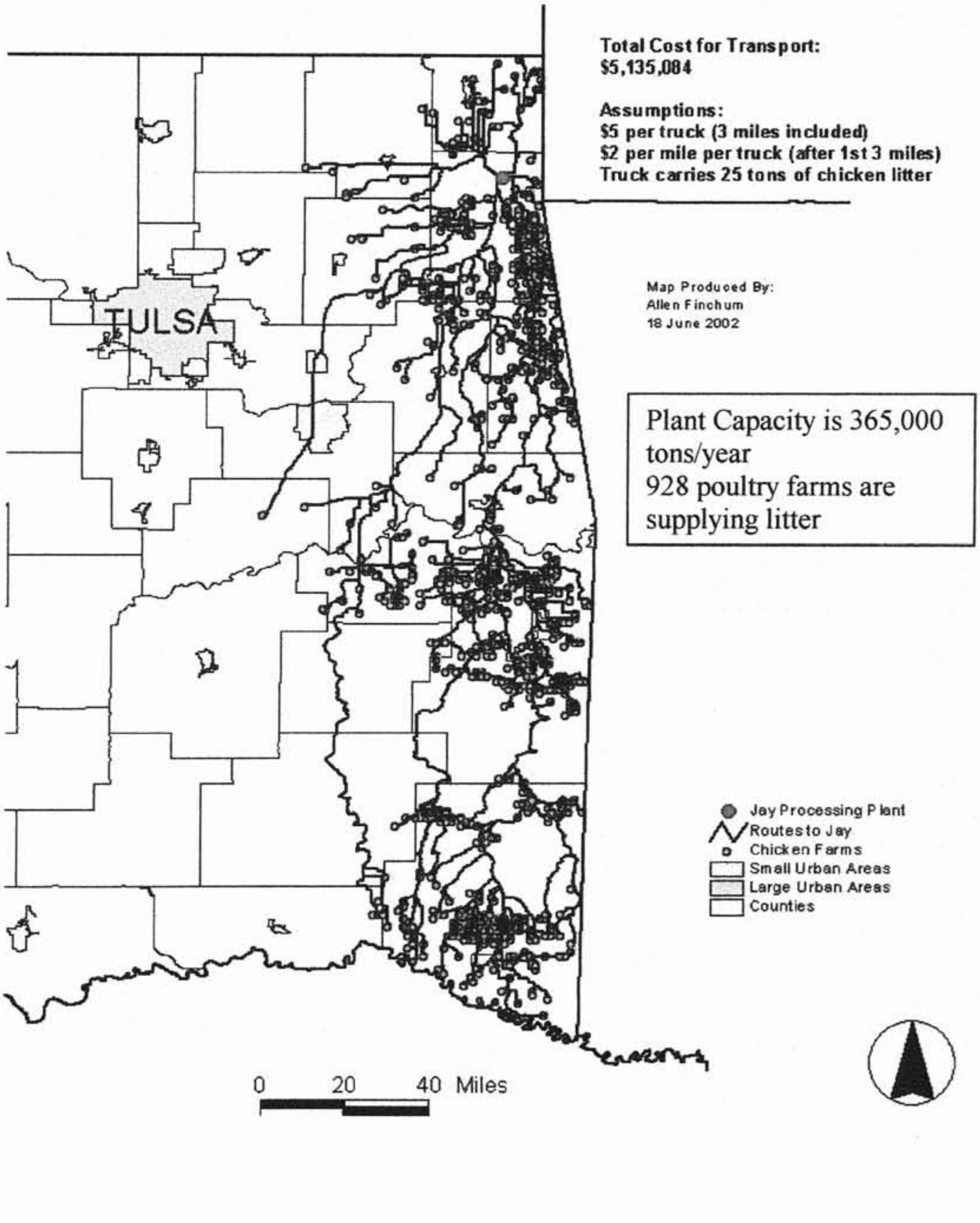
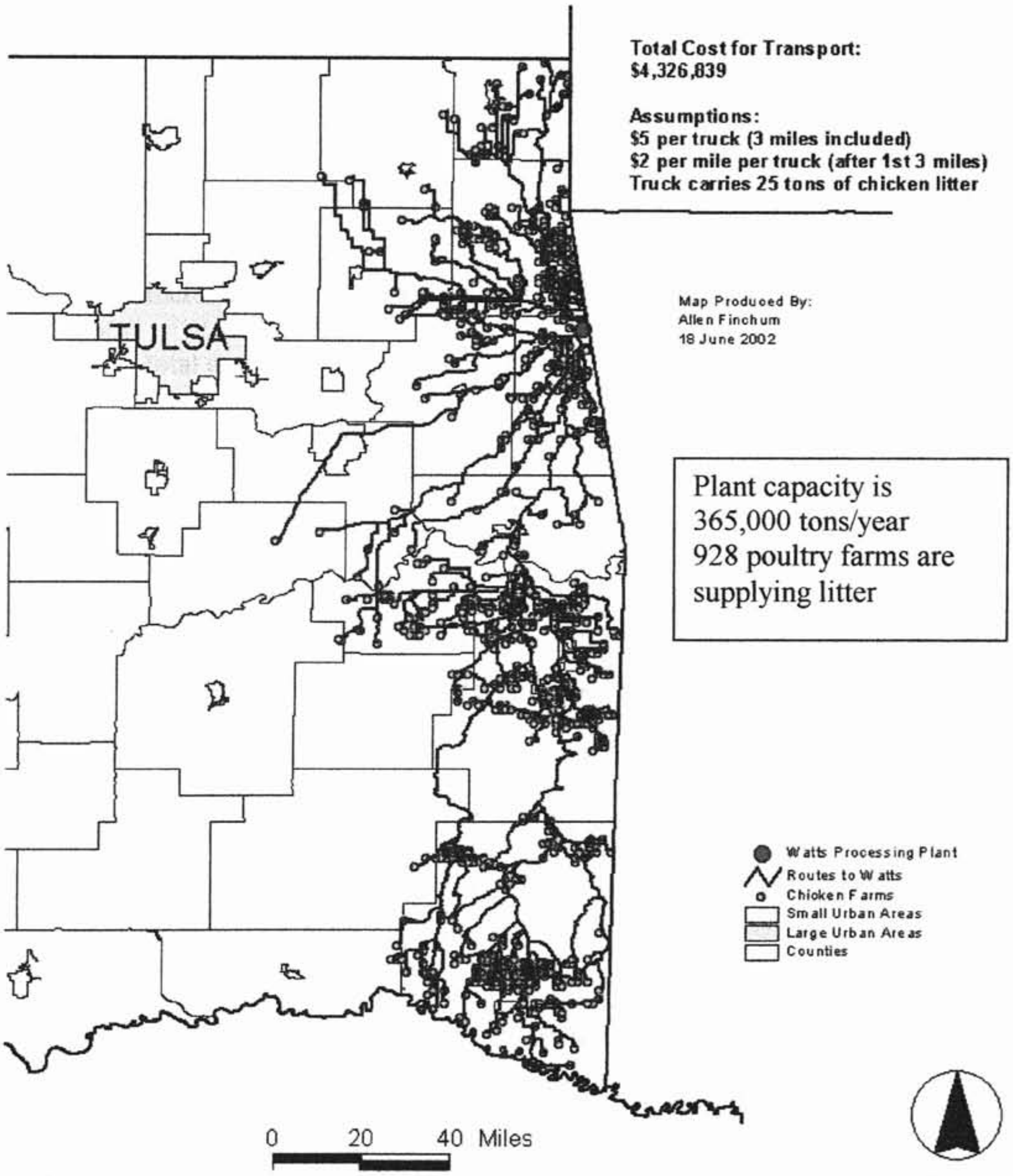


Figure 4.2
Chicken Litter Transport Problem
Processing Plant Located in Watts, OK



Total Cost for Transport:
$4,326,839

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
18 June 2002

Plant capacity is
365,000 tons/year
928 poultry farms are
supplying litter

The calculations of poultry litter transportation were done in Excel by using the following equation. Equation 4.1 is the formula that was used to calculate transportation costs from each farm to a processor.

$$C_j = [\alpha\ T_j + \beta\ (M_j - 3)\ N_j] / T_j \qquad (4.1)$$

The variables are defined as:

C_j = the cost per ton of hauling poultry litter from farm *j* to a processing facility ($/ton)

α = a constant representing a uniform loading charge of $5.00 per ton of litter including first three miles transport

T_j = total amount of litter produced on farm *j* (tons)

β = a constant representing the cost of hauling litter per mile per 25-ton truckload (here $2.00 per mile per 25-ton truckload)

M_j = hauling distance in miles from each poultry farm *j* to the plant location site

N_j = number of 25-ton truckloads hauling litter from each farm *j*

The following are the detailed procedures that were done in Excel to finally get the transportation cost (C_j) from each farm to a plant site:

a) The amount of litter per farm was first converted from kilograms into pounds by multiplying by 2.2046 pounds per kilogram, and then into U.S. tons by dividing by 2000.

b) The amount of litter per farm in tons was divided by 25 tons to obtain the number of 25-ton truckloads to be hauled from each farm.

c) The tons of litter per farm were multiplied by $5.00 to get the total loading cost per farm.

d) Since the loading cost includes three miles of travel, three miles were subtracted from the distance from each farm to the plant location in order to get the remaining distance to be paid for.

e) The distance (from d) was multiplied by \$2.00 per mile per 25-ton truckload to get the travel cost from the farm to the processing plant.

f) The travel cost obtained in e) was multiplied by the number of 25-ton truckloads obtained in b) to get the total cost of hauling one year's production of litter from each farm.

g) The travel cost from f) above was added to the loading cost from c) to get the total cost of loading and transporting litter from each poultry farm to a plant location site. This sum is the "total litter transportation cost" or "transportation cost" for each farm.

h) Finally, the total litter transportation cost per farm found in g) above was divided by the quantity of litter in tons found in a) above to get litter transportation cost per ton for each farm. This is an important aspect of the analysis, especially, when trying to get minimum transportation cost to a particular plant location with a specific plant capacity that needs to be met with the total farm supplies.

The transportation costs obtained above (C_j) were used in a mathematical model in GAMS as the only known cost of processing litter. For cases where the last load of litter shipped from a farm is not a full truckload, the full cost of shipping a 25-ton truckload was allocated over the actual number of tons of litter on that truckload.

Estimation of Heating Value of Litter

The heating value data that was provided in British Thermal Units (BTUs) was converted to million BTUs per ton (MBTU) by multiplying the BTUs per pound by 2000 pounds per ton and dividing the result by 1,000,000 BTUs.

Processing plant capacity was varied in different scenarios from 60,000 tons per year to 120,000 tons per year in increments of 20,000 tons/year. Also, amount of methane gas produced per ton of poultry litter was set at 4.5 on the lower side and 14.5 on the higher side of the baseline estimate of 9.55 MBTU/ton. This was done as a measure of sensitivity of revenue to methane gas production. The baseline estimate, however, is believed to be the best estimate.

The Mathematical Programming Model

Using linear programming in GAMS a mathematical programming model was developed to maximize the returns to unpaid resources taking into account the maximum amount of poultry litter produced from each farm and the capacity of the plant. Choice variables in the model were quantity of litter transported from each farm to the processor in Jay, and quantities of methane gas, nitrogen, phosphorus, and potassium produced at the processor. The objective function for the mathematical programming model is given as:

$$(4.2) \quad \text{Max Z} = \sum_{j=1}^{928} X_j (R_g * P_g + R_n * P_n + R_p * P_p + R_k * P_k) - C_j * X_j$$

The objective function is maximized subject to the following constraints:

(4.3) $X_j - H_j \leq 0$ (quantity limit at each farm)

(4.4) $\sum_{j=1}^{928} X_j \leq CAP$ (processor capacity is not exceeded)

(4.5) X_j, G, N, P, K, CAP ≥ 0 (non-negativity conditions)

The variables in the model are defined as:

X_j = quantity of litter transported from farm j to processor in Jay or Watts (tons),

R_g = heating value of a ton of poultry litter (MBTU),

P_g = price of gas (\$/MBTU),

R_n = nitrogen available in poultry litter (lbs/ton),

P_n = price of nitrogen fertilizer (\$/lb),

R_p = phosphorus available in poultry litter (lbs/ton),

P_p = price of phosphorus fertilizer (\$/lb),

R_k = potassium available in poultry litter (lbs/ton),

P_k = price of potassium fertilizer (\$/lb),

C_j = transportation cost of poultry litter from farm j to processor in Jay or Watts (\$/ton),

H_j = quantity of poultry litter produced at farm j (tons),

G = quantity of biogas produced at processor in Jay or Watts (MBTUs),

N = quantity of nitrogen produced at processor in Jay or Watts (lbs),

P = quantity of phosphorus produced at processor in Jay or Watts (lbs),

K = quantity of potassium produced at processor in Jay or Watts (lbs), and

CAP = capacity of processing plant in Jay or Watts (tons/year)

The objective function for the mathematical programming model is set up to maximize profit by maximizing revenue minus known costs. The known cost is the cost of transporting poultry litter along a network of roads from each farm to meet the demand requirements for a particular capacity at the processing plant. The model subtracts this cost from the revenues obtained by selling biogas, nitrogen, phosphorus, and potassium to obtain profit.

This is not a true profit since the model does not include the fixed and variable costs of processing litter into methane and the fertilizers. Due to this fact the objective function gives returns to resources whose costs are not specified here. Costs not included here are: amortized cost of investment in the plant and other fixed costs, plant operating capital, labor and management cost, cost of raw materials (i.e. payment for poultry litter), and cost of all other inputs into the processing activity.

If the costs not included in the model are greater than the calculated "partial profit" investors will lose money. If the costs not included in the model are less than the calculated partial profit, investors will gain the difference. If costs not included in the model equal the partial profit, investors reach the break-even point, and neither gain nor lose. The partial profit calculated by this model can be viewed as the maximum investors could afford to pay for all non-transportation costs.

CHAPTER V

RESULTS AND IMPLICATIONS

Table 5.1 gives the maximum amount of money that can be spent on capital equipment and other inputs not accounted for in the model, such as labor, price of manure and chemicals, etc for the investment to break-even. This amount appears in the table as the break-even (B-E) value. Note that these values are provided for plants at various capacities (i.e. 60,000, 80,000, 100,000, and 120,000 tons per year) in both Jay and Watts. Although the assumed amount of methane produced from a ton of poultry litter using the available data was 9.55 MBTU per ton of poultry litter, that amount is varied from 4.5 to 14.5 MBTUs to measure the effects on the break-even point of alternative levels of productivity. From the table it can be observed that the break-even values for Jay and Watts are slightly higher than those for Jay. This is because the cost of transporting litter from poultry farms to a plant in Watts is lower than that of transporting to a plant in Jay.

At each plant capacity (i.e. 60,000; 80,000; 100,000; 120,000 tons of poultry litter per year) the total amount of poultry litter shipped from the farm to the processing plant location was equal to the capacity of that particular plant in each of the two plant locations. At each plant capacity, poultry litter from farms with lowest transportation costs was shipped first, followed by farms with higher transportation costs, until the capacity of the plant was achieved. At each plant capacity all the farms that were selected by the model to transport poultry litter shipped all the litter except that the last farm transported only a fraction of its litter to completely meet the plant's specified capacity.

All farms that were selected to ship poultry litter to a plant of capacity 60,000 tons of poultry litter per year were also selected to ship litter to all plants of higher capacity (i.e. 80,000; 100,000; 120,000 tons of poultry litter per year) in addition to others that were selected for plants with higher demands. This is consistent with the model selecting farms in order to minimize cost of transportation (i.e. shipment was done starting from closest farms with lowest transportation costs until the plant capacity was reached).

Table 5.1. The Per Year Break-Even Value of Capital and Other Inputs and the Quantities of Gas and Fertilizer Produced from Poultry Litter for Different Sized Plants

Plant Location	Plant Size (Tons)	Methane (MBTU/ton of Litter)	B-E Value (Million Dollars)	Gas (Thousand MBTUs)	Nitrogen (Million lbs)	Phosphorus (Million lbs)	Potassium (Million lbs)	Total Farms	No. of Farms Shipping Litter	No. of Farms not Shipping
Jay	60,000	4.50	1.538	270	3.636	3.456	3.066	928	136	792
Jay	60,000	9.55	2.447	573	3.636	3.456	3.066	928	136	792
Jay	60,000	14.50	3.338	870	3.636	3.456	3.066	928	136	792
Jay	80,000	4.50	2.028	360	4.848	4.608	4.088	928	186	742
Jay	80,000	9.55	3.240	764	4.848	4.608	4.088	928	186	742
Jay	80,000	14.50	4.428	1160	4.848	4.608	4.088	928	186	742
Jay	100,000	4.50	2.504	450	6.060	5.760	5.110	928	232	696
Jay	100,000	9.55	4.019	955	6.060	5.760	5.110	928	232	696
Jay	100,000	14.50	5.504	1450	6.060	5.760	5.110	928	232	696
Jay	120,000	4.50	2.969	540	7.272	6.912	6.132	928	259	669
Jay	120,000	9.55	4.787	1146	7.272	6.912	6.132	928	259	669
Jay	120,000	14.50	6.569	1740	7.272	6.912	6.132	928	259	669
Watts	60,000	4.50	1.562	270	3.636	3.456	3.066	928	120	808
Watts	60,000	9.55	2.471	573	3.636	3.456	3.066	928	120	808
Watts	60,000	14.50	3.362	870	3.636	3.456	3.066	928	120	808
Watts	80,000	4.50	2.062	360	4.848	4.608	4.088	928	175	755
Watts	80,000	9.55	3.274	764	4.848	4.608	4.088	928	175	755
Watts	80,000	14.50	4.462	1160	4.848	4.608	4.088	928	175	755
Watts	100,000	4.50	2.552	450	6.060	5.760	5.110	928	228	700
Watts	100,000	9.55	4.067	955	6.060	5.760	5.110	928	228	700
Watts	100,000	14.50	5.552	1450	6.060	5.760	5.110	928	228	700
Watts	120,000	4.50	3.030	540	7.272	6.912	6.132	928	284	644
Watts	120,000	9.55	4.848	1146	7.272	6.912	6.132	928	284	644
Watts	120,000	14.50	6.630	1740	7.272	6.912	6.132	928	284	644

With a plant capacity of 60,000 tons/year about 84% of the total litter available (364,652 tons) remain unused. For a capacity of 80,000 tons/year 78% of the litter is unused, for 100,000 tons/year 73% is unused, and for 120,000 tons/year 67% of poultry litter available is unused.

Assuming that the amount of methane gas produced from a ton of litter is 9.55 MBTU/ton of poultry litter, Table 5.1 shows that for a plant of size 60,000 tons of poultry litter per year the maximum expenditure on capital equipment, working capital and other costs must not exceed \$2.45 million per year for a plant at Jay and \$2.47 million per year for a plant located at Watts for the investment to break even. For a plant of 80,000 tons of poultry litter per year the maximum expenditure on capital equipment, working capital and other costs must not exceed \$3.24 million per year for a plant at Jay and \$3.27 million per year for a plant located at Watts for the investment to break even.

For a plant of 100,000 tons of poultry litter per year the maximum expenditure on capital equipment, working capital and other costs must not exceed \$4.02 million per year for a plant at Jay and \$4.07 million per year for a plant located at Watts for the investment to break-even.

Finally, for a plant of 120,000 tons of poultry litter per year the maximum expenditure on capital equipment, working capital and other costs must not exceed \$4.79 million per for a plant at Jay and \$4.85 million per year for a plant located at Watts for the investment to break-even. These figures indicate that the maximum expenditure to break even for Jay and Watts are not substantially different.

Table 5.2 shows the total and average transportation cost incurred in shipping poultry litter to plants of each capacity in both Jay and Watts. For both Jay and Watts, average transportation cost increases with larger amounts shipped since larger amounts shipped require shipment from greater distances.

Figures 5.1 and 5.2 plot average transportation cost versus size of plant. Note that for both Jay and Watts, average transportation costs are increasing with increased plant capacity. This is because as the size of plant increases more litter is required to be transported from farms located farther away from the plant location. This results in diseconomies of size with regard to poultry litter transportation cost. The graphs are plotted based on the data provided in Table 5.2.

Not all farms are able to ship poultry litter to the plant. In order to transport all poultry litter produced in eastern Oklahoma to the plant, a plant with a capacity of at least 365,000 tons poultry litter per year is required. It should be noted that such a large plant will have high running costs and it will incur high costs of transporting litter from all poultry farms.

Table 5.2. Total Transportation Cost, Average Transportation Cost and Plant Capacity at Jay and Watts

Plant Location	Plant Capacity (tons/year)	Total Transportation Cost (Dollars)	Average Transportation Cost ($/ton)
Jay	60,000	371,980	6.20
Jay	80,000	518,600	6.48
Jay	100,000	679,610	6.80
Jay	120,000	850,580	7.09
Watts	60,000	348,210	5.80
Watts	80,000	485,340	6.07
Watts	100,000	631,250	6.31
Watts	120,000	789,990	6.58

Figure 5.1. Average Transportation Cost Against Plant Capacity at Jay

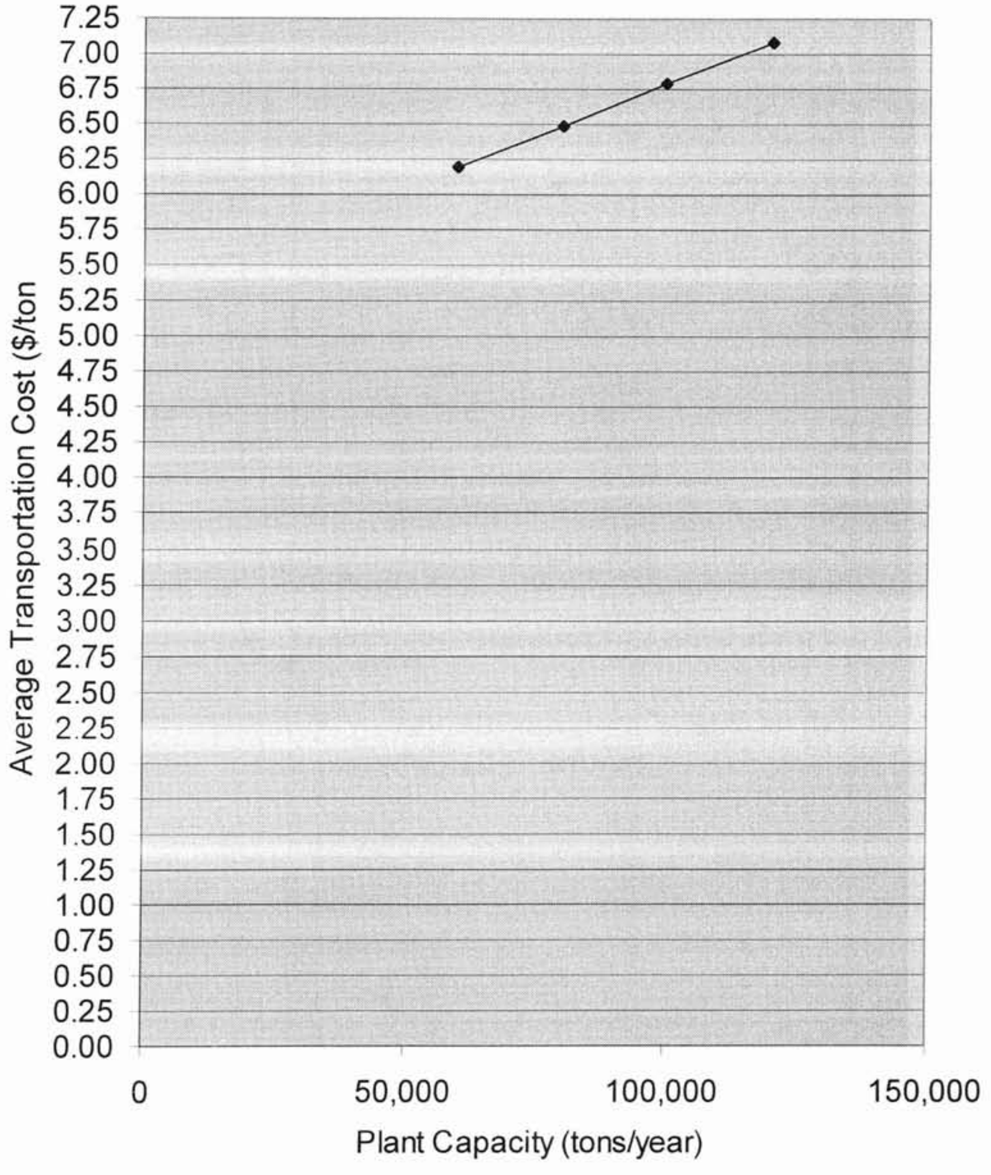
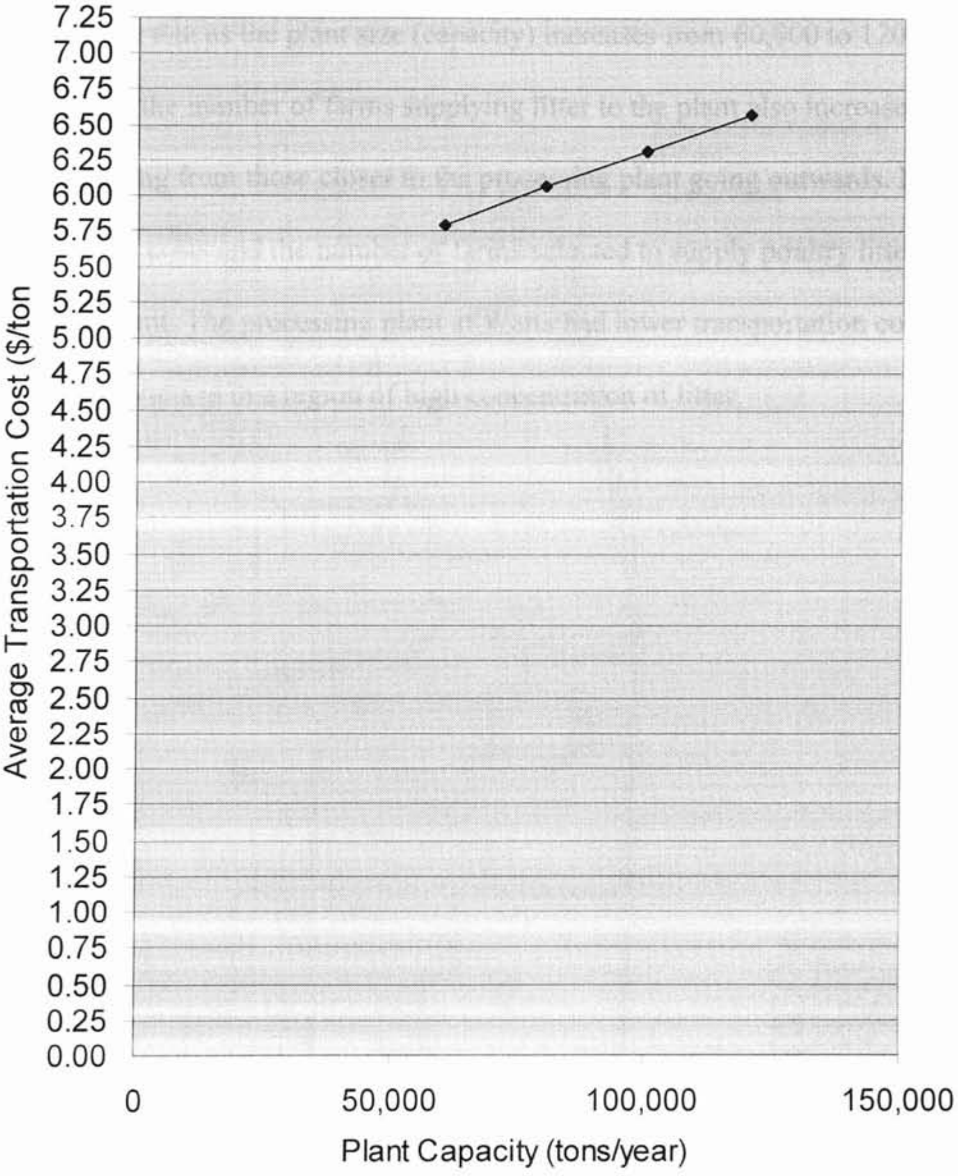


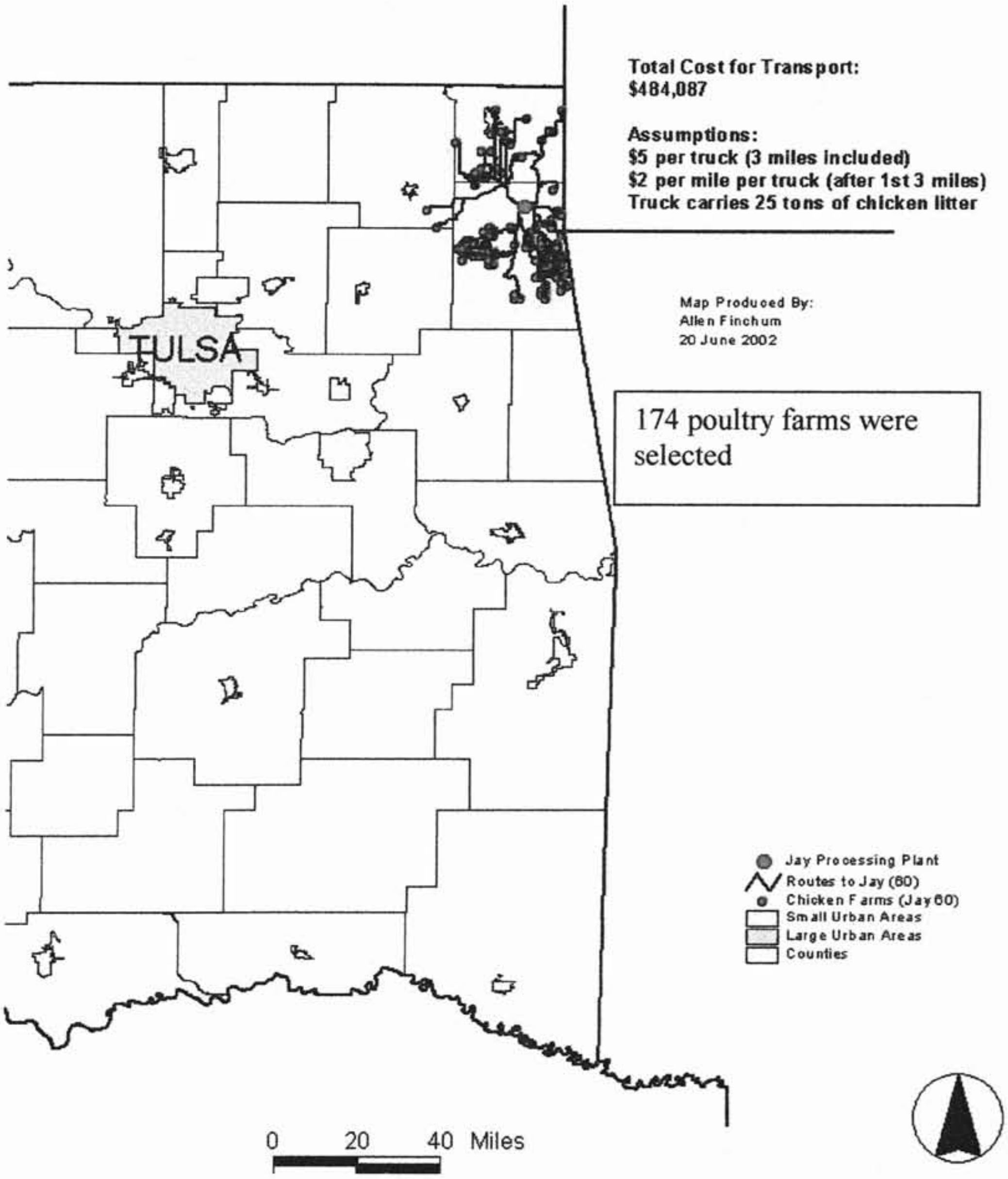
Figure 5.2. Average Transportation Cost Against Plant Capacity at Watts



Figures 5.3 to 5.10 below show the number of farms that were selected to supply poultry litter to a processing plant of a given capacity in each plant site i.e. Jay and Watts. The plant capacities are 60,000, 80,000, 100,000 and 120,000 tons of litter per year.

Notice that as the plant size (capacity) increases from 60,000 to 120,000 tons of litter per year the number of farms supplying litter to the plant also increases, but they increase starting from those closer to the processing plant going outwards. Note the transportation costs and the number of farms selected to supply poultry litter to the processing plant. The processing plant at Watts had lower transportation costs than that at Jay because Watts is in a region of high concentration of litter.

Figure 5.3
Chicken Litter Transport Problem
60,000 Ton Per Year
Processing Plant Located in Jay OK



Total Cost for Transport:
$484,087

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

174 poultry farms were selected

Figure 5.4
Chicken Litter Transport Problem
80,000 Ton Per Year
Processing Plant Located in Jay OK

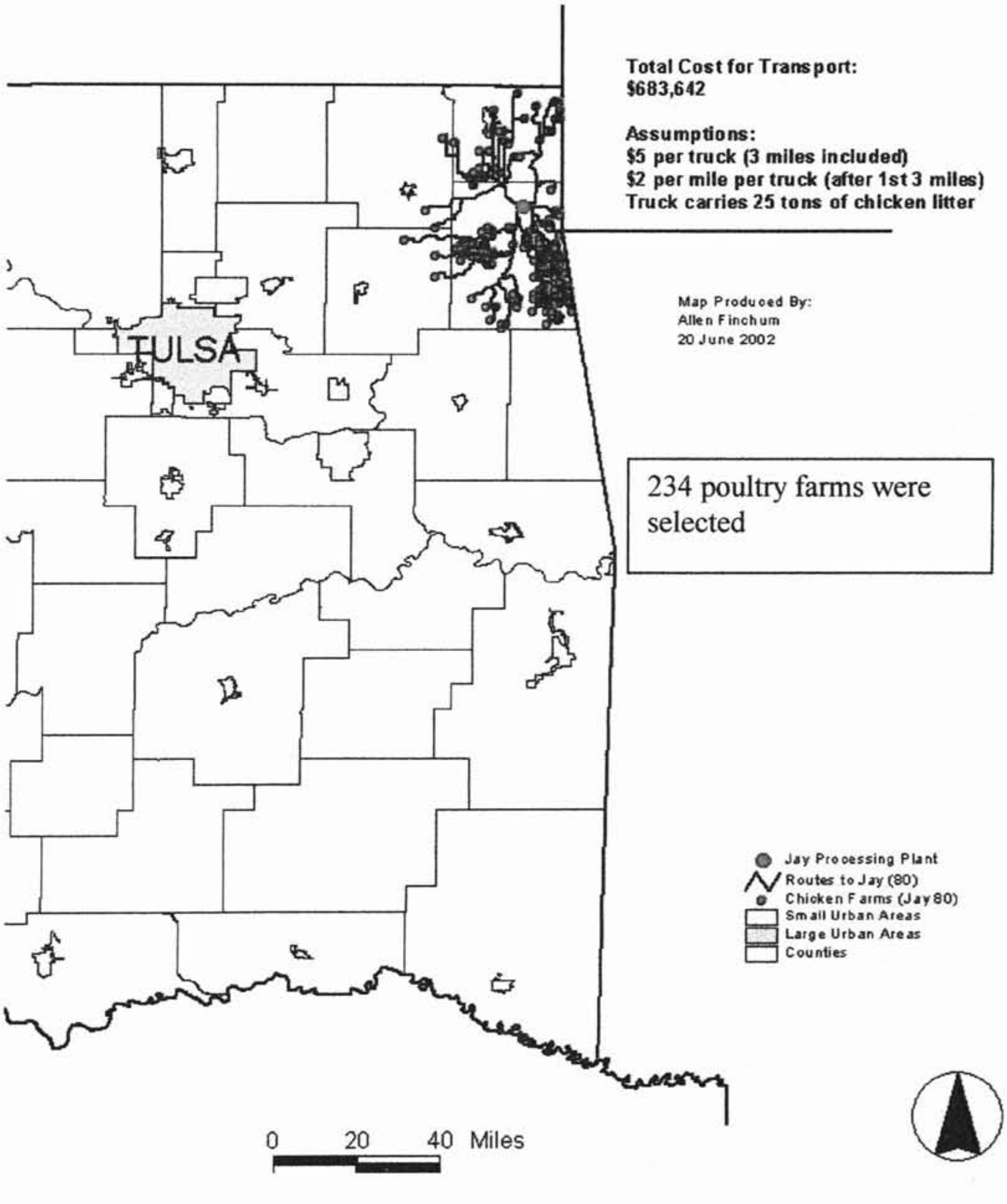
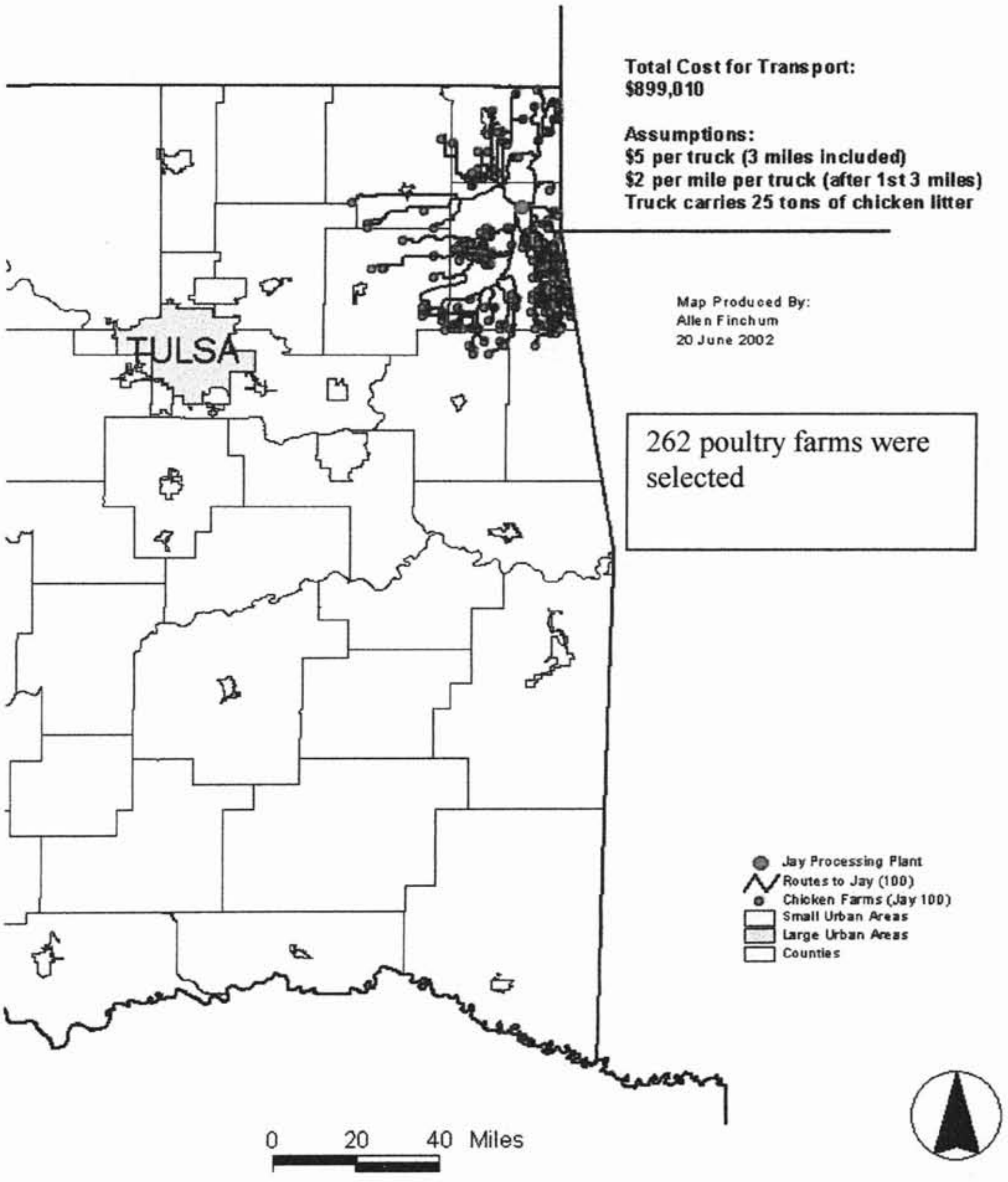


Figure 5.5
Chicken Litter Transport Problem
100,000 Ton Per Year
Processing Plant Located in Jay OK



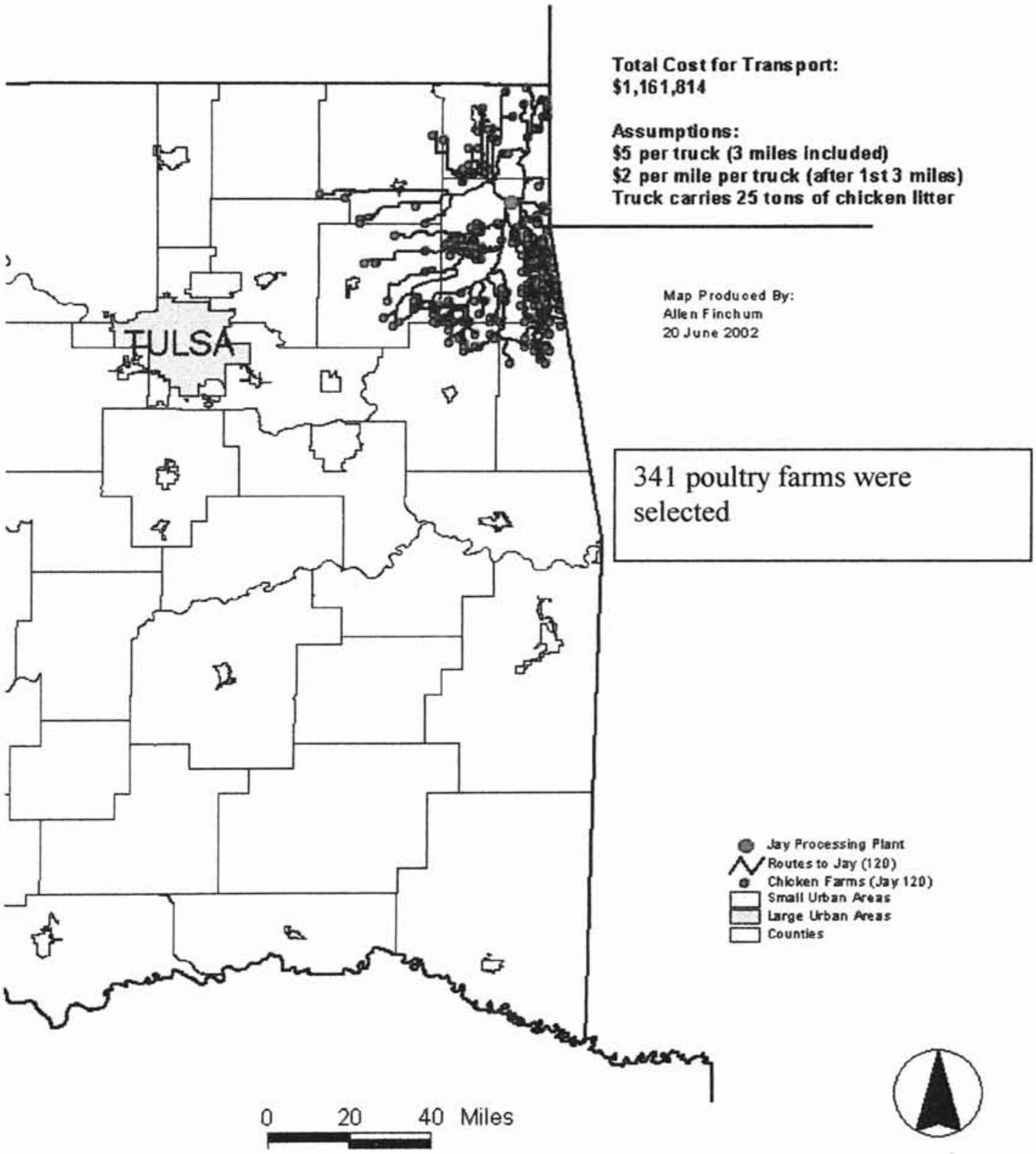
Total Cost for Transport:
$899,010

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

262 poultry farms were selected

Figure 5.6
Chicken Litter Transport Problem
120,000 Ton Per Year
Processing Plant Located in Jay OK



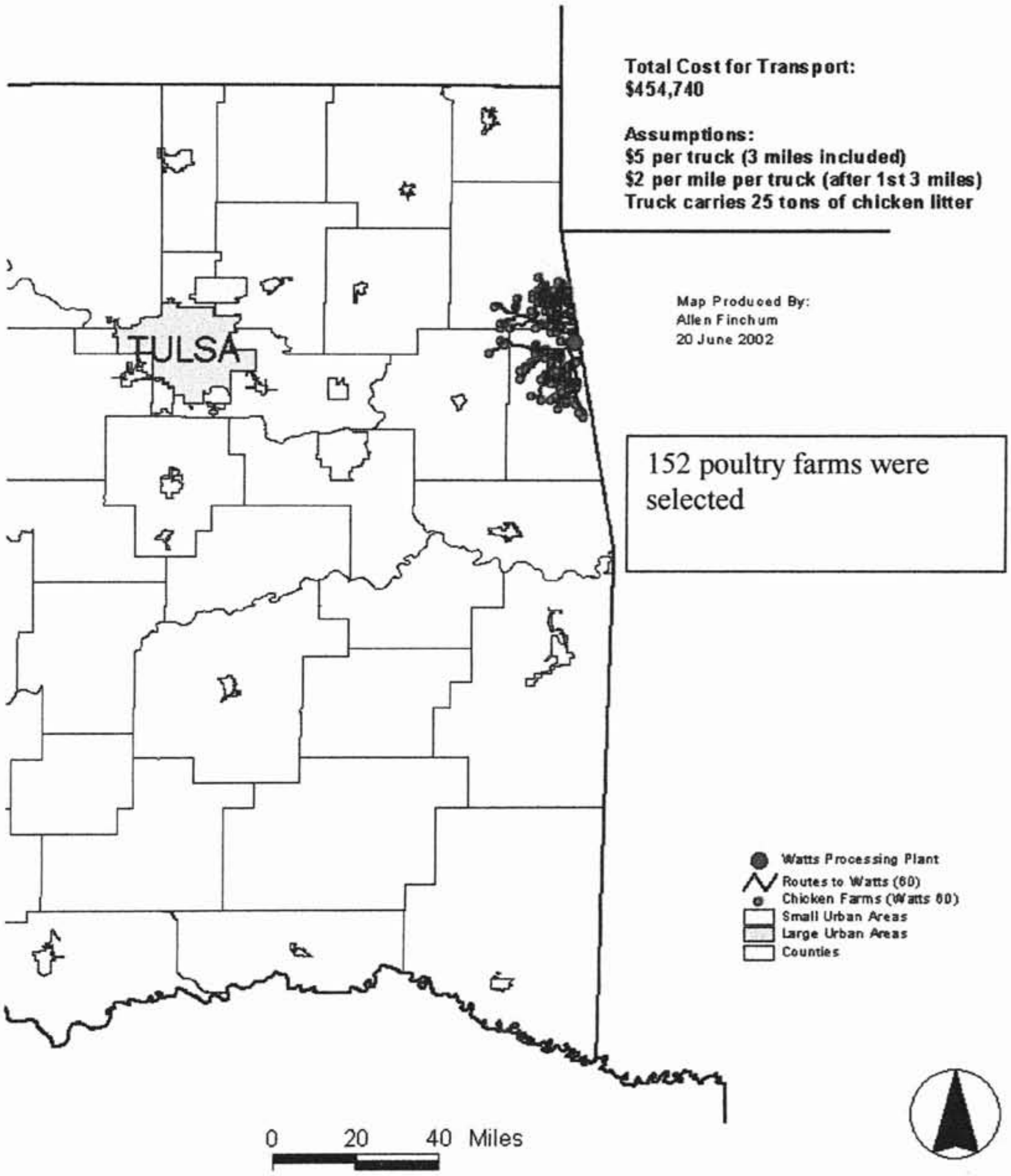
Total Cost for Transport:
$1,161,814

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

341 poultry farms were selected

Figure 5.7
Chicken Litter Transport Problem
60,000 Ton Per Year
Processing Plant Located in Watts OK



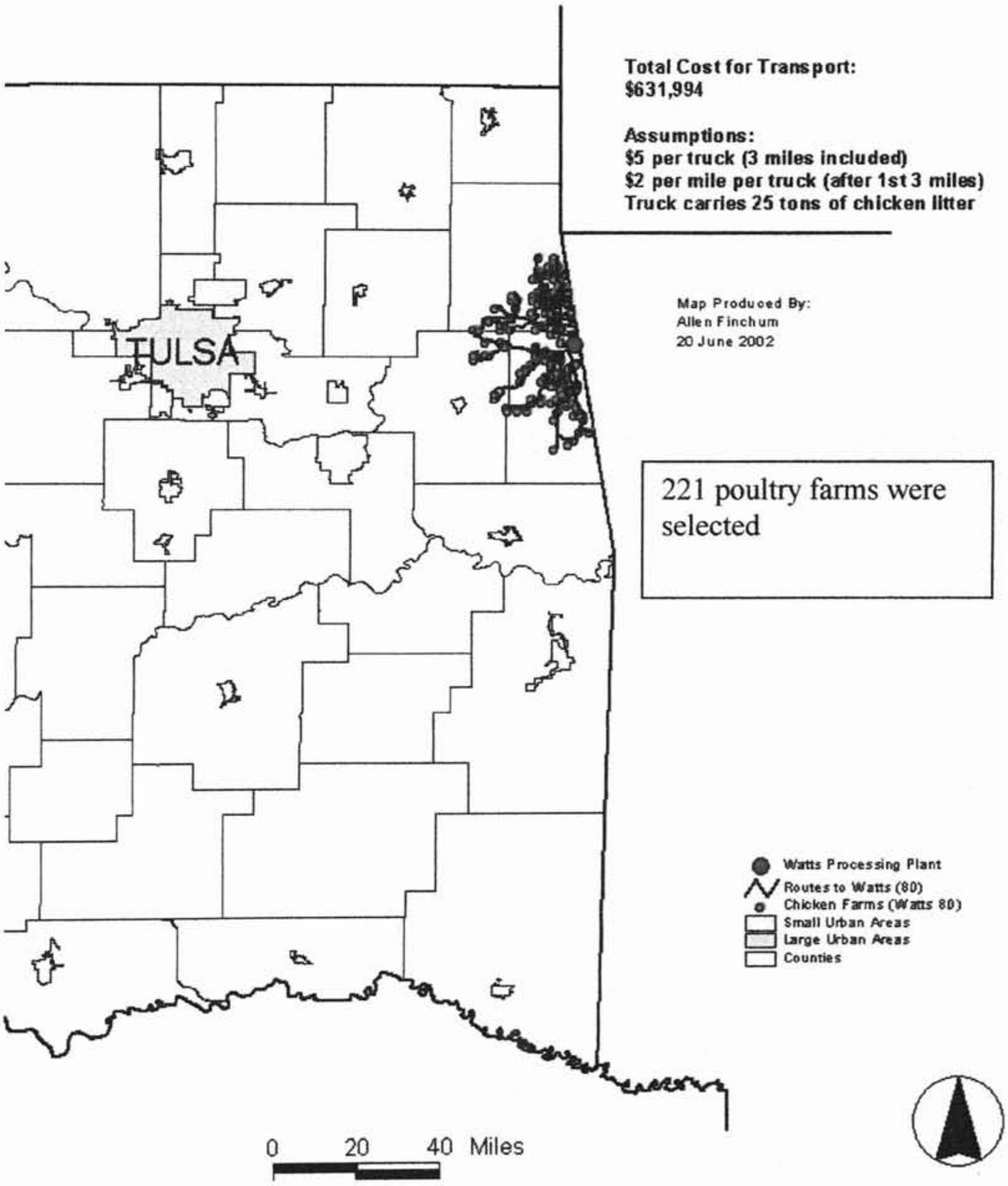
Total Cost for Transport:
$454,740

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

152 poultry farms were selected

Figure 5.8
Chicken Litter Transport Problem
80,000 Ton Per Year
Processing Plant Located in Watts OK



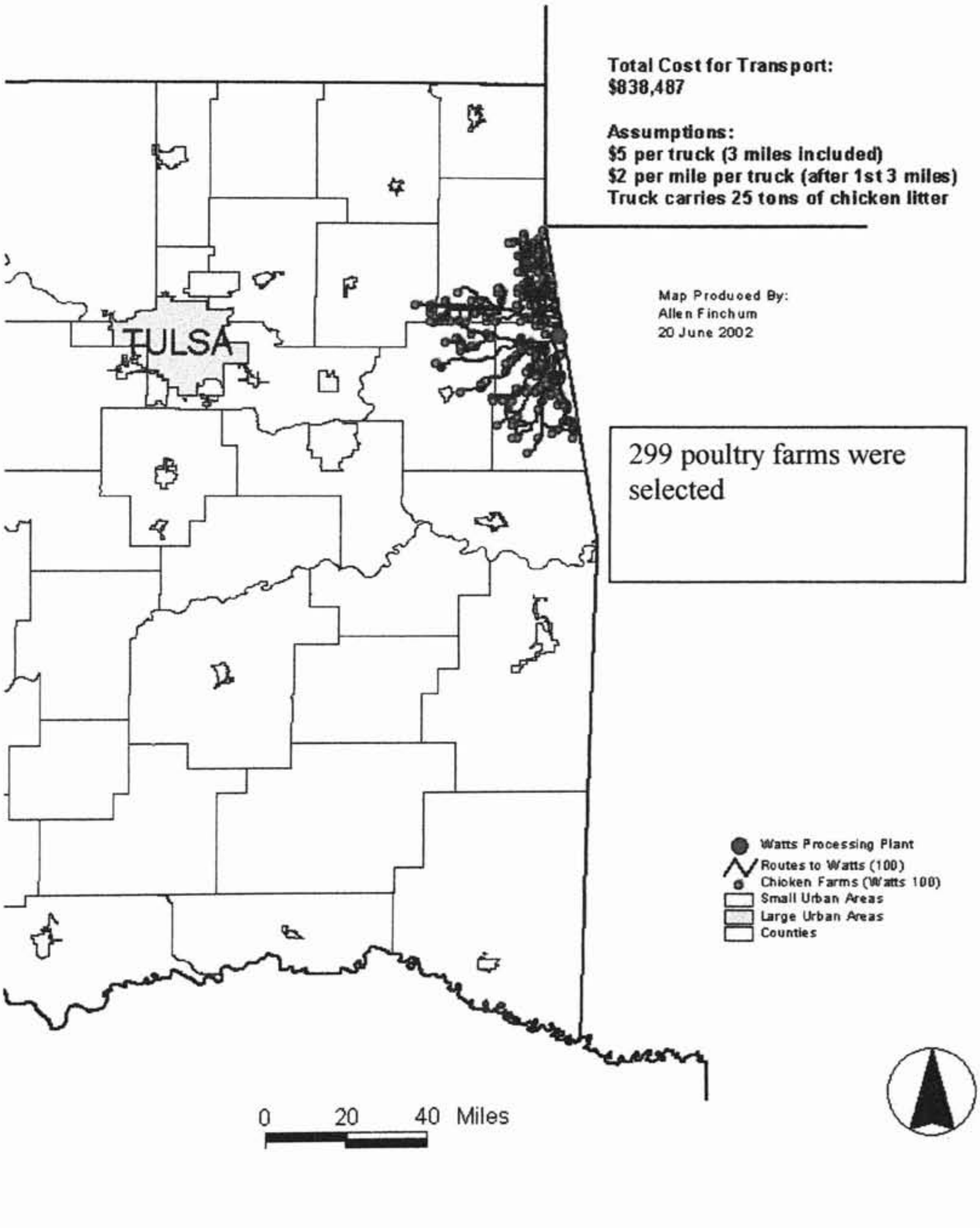
Total Cost for Transport:
$631,994

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

221 poultry farms were selected

Figure 5.9
Chicken Litter Transport Problem
100,000 Ton Per Year
Processing Plant Located in Watts OK



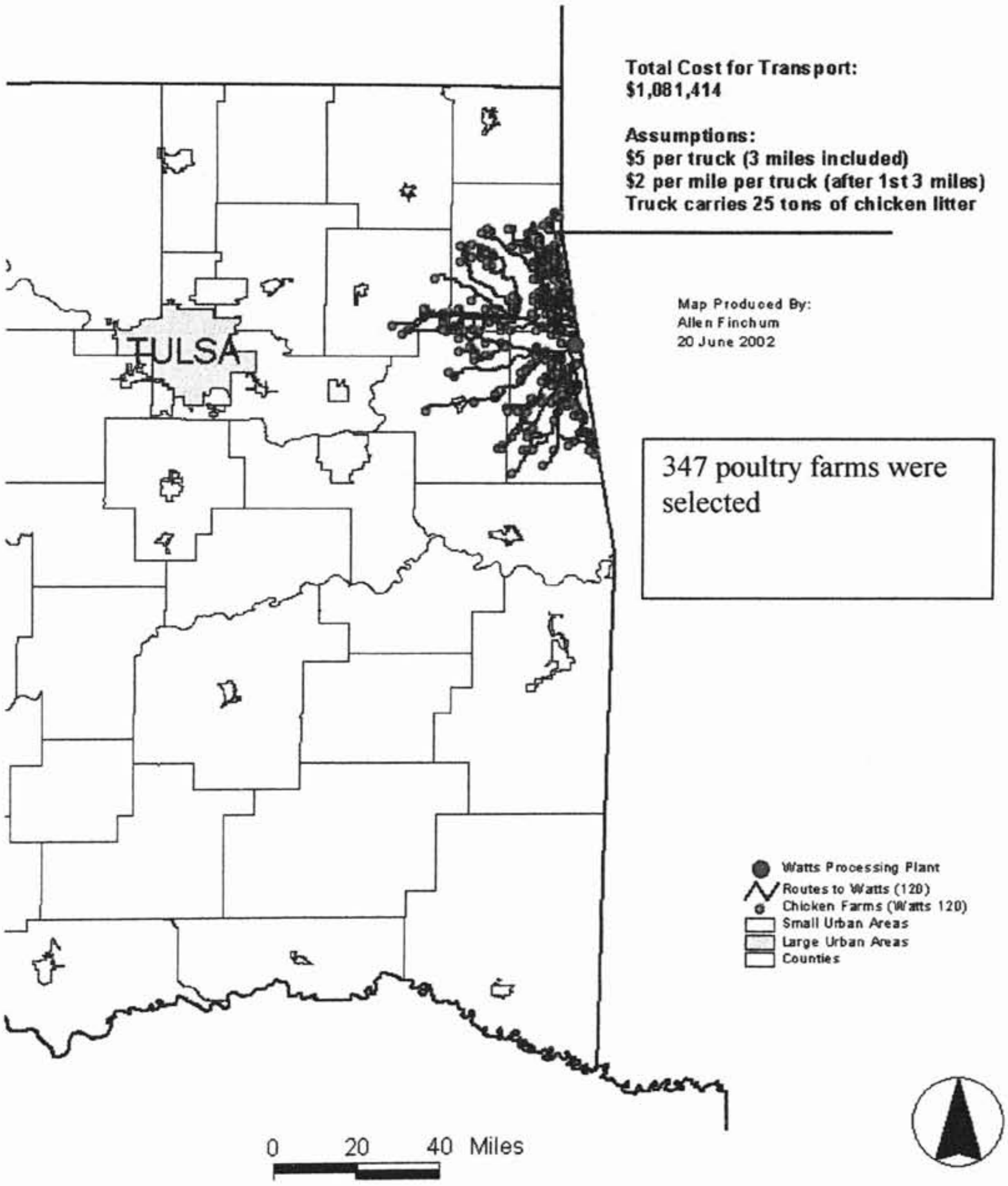
Total Cost for Transport:
$838,487

Assumptions:
$5 per truck (3 miles included)
$2 per mile per truck (after 1st 3 miles)
Truck carries 25 tons of chicken litter

Map Produced By:
Allen Finchum
20 June 2002

299 poultry farms were selected

Figure 5.10
Chicken Litter Transport Problem
120,000 Ton Per Year
Processing Plant Located in Watts OK



Figures 5.11 graphs plant capacity shadow prices against plant capacity. As plant capacity increases from 60,000 to 120,000 tons per year the shadow price of additional capacity decreases from about $40.39 to about $38.69. With higher plant capacity, marginal revenue of additional units of litter is constant and greater than the transportation cost of additional units of litter. However, as capacity increases, additional units of litter are transported at higher and higher per unit costs because of increasing transport distance. Constant marginal revenue and increasing marginal cost of transport combine to result in declining shadow prices of capacity.

Figure 5.12 graphs plant capacity shadow prices against methane yield. At a given plant capacity, shadow prices of additional units of capacity increase with higher yields of methane gas since the value of each ton of litter is more valuable when more methane gas is derived from it.

Figure 5.11. Capacity Shadow Prices Against Plant Capacity

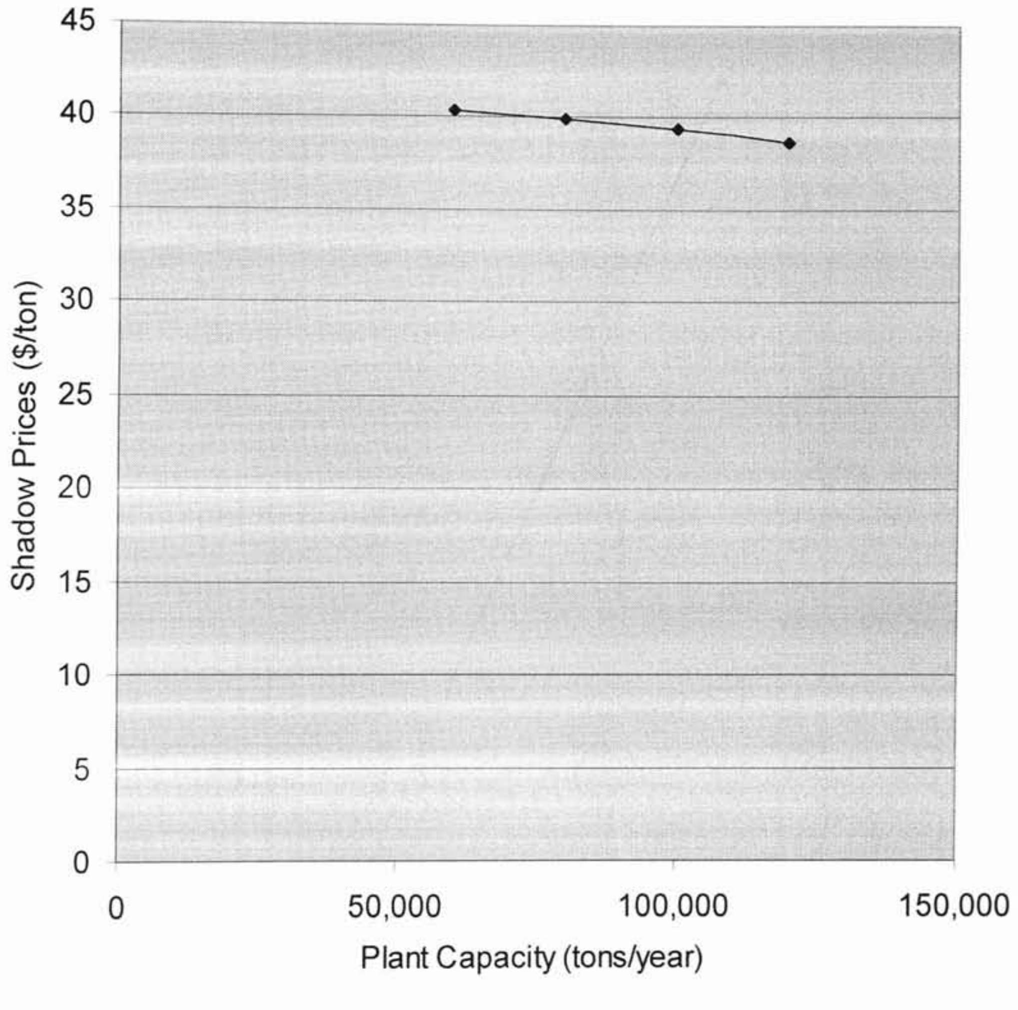
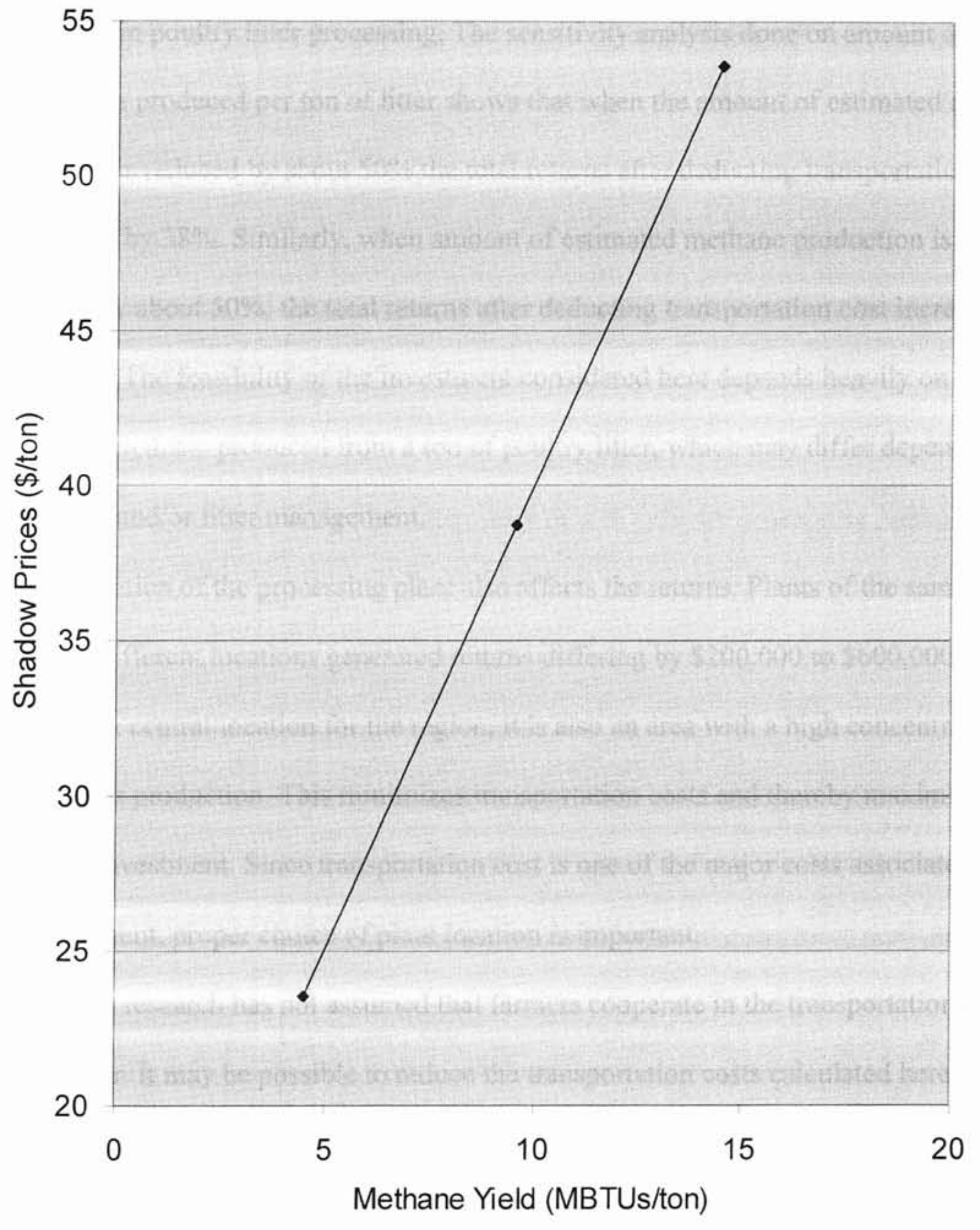


Figure 5.12. Shadow Prices vs. Methane Yield of Plant Capacity of 120,000 tons/year



Implications

The results presented in this chapter have some implications for the proposed investment in poultry litter processing. The sensitivity analysis done on amount of methane gas produced per ton of litter shows that when the amount of estimated methane production is reduced by about 50% the total returns after deducting transportation cost are reduced by 38%. Similarly, when amount of estimated methane production is increased by about 50%, the total returns after deducting transportation cost increase by about 37%. The feasibility of the investment considered here depends heavily on the amount of methane produced from a ton of poultry litter, which may differ depending on technology and/or litter management.

Location of the processing plant also affects the returns. Plants of the same size located at different locations generated returns differing by $200,000 to $600,000. Watts is not only a central location for the region, it is also an area with a high concentration of poultry litter production. This minimizes transportation costs and thereby maximizes returns to investment. Since transportation cost is one of the major costs associated with this investment, proper choice of plant location is important.

This research has not assumed that farmers cooperate in the transportation of poultry litter. It may be possible to reduce the transportation costs calculated here if some institutional issues could be resolved. For example, if poultry litter owners are paid for litter by weight, the may prefer to weigh the litter once it is on the truck to be sure they are paid the full amount. This may keep costs high by preventing a truck from hauling form more than one farm on a delivery route.

Also, there may be an opportunity to save transportation costs by using backhauls, perhaps with chicken feed. But this would require an agreement between feed suppliers and either the farmers or the cooperative, or both. Additional savings may be achieved if the cooperative can schedule cleanouts by each member so that truck routes can be concentrated in specific regions at a time. Processing costs, which are not considered here would also be reduced by scheduling litter deliveries from each farm to coincide with processing demands.

The maps for the whole region (Figure 4.1 and 4.2) clearly show three pockets of high concentration of poultry and poultry litter production. Any useful plant location model should account for these pockets in order for the investment to minimize transportation costs. It is likely that economies of size exist for processing, which is at least potentially offset by diseconomies of size for transportation cost. Further information about processing and investment costs are necessary to find the optimal size and number of plants and their optimal location.

The results here show that returns to investment are directly or indirectly affected by the location of the processing plant, optimal number of plants available in the poultry production region, size (capacity) of the processing plant, and quantity of methane gas produced per ton of litter.

These results are an important contribution to investment analysis in poultry litter processing facility. The results could be used in feasibility analysis, profitability analysis, and detailed and complete break-even analysis in the area of poultry litter processing into methane gas and fertilizers. As stated earlier on the results in this research serve as a basis to detailed and complete investment analysis of poultry litter processing technology that is planned to be undertaken by a cooperative in the eastern Oklahoma region.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Significant increases in poultry production over the last two decades have resulted in a large increase in production of poultry manure. Over 45 billion kg of poultry manure and/or litter are produced each year in the U.S. Since the poultry industry is geographically concentrated, certain areas produce a large amount of manure.

The state of Oklahoma is one of the largest poultry-producing states in the country. The poultry industry in Oklahoma is concentrated in the eastern part and produces broilers, layers, pullets, and turkeys. Of these, broiler production is the largest in terms of animal numbers, revenue generated, and the amount of litter produced.

The Oklahoma poultry industry produces about 1.1 million tons of litter every year. The main problem is the lack of proper ways to dispose of this huge amount of litter. Bulk land application of raw litter is the most common use of poultry litter due to its simplicity, low cost of use, and the benefits of litter as an organic fertilizer for pasture and crop production. The problem with bulk land application of litter is that continual application on the same land results in accumulation of salts in the soil. Unused nutrients in litter can contaminate surface water and groundwater through runoff and leaching.

Potential problems associated with land application of poultry litter are production problems and environmental problems. The production problems associated with poultry litter include salinity damage to crops, grass tetany in cattle, copper toxicity in sheep and ammonia volatilization. Potential environmental problems associated with poultry litter include leaching of substances into groundwater, surface runoff of pollutants, and ammonia volatilization. To circumvent the problems of high amounts of litter several attempts to develop an efficient and competitive litter market in Oklahoma have been made. Numerous litter-processing technologies have been developed. The failure of such a market in Oklahoma has been attributed to lack of demand, lack of market infrastructure, uneconomical transportation costs, supply limitations, and social attitudes of farmers towards marketing agents.

Since litter is highly unstable some processing is done to stabilize litter and some is done to produce a value-added product such as fertilizer or biogas. To date, most of the value-added technologies have not proven to be profitable. There is a need for technologies that will process litter into value-added products that can solve the problem of water pollution and at the same time enhance poultry farmers' profitability.

This research conducted a break-even analysis for a cooperative value-added enterprise that aims at processing poultry litter into methane biogas and fertilizer byproducts. The study aimed at providing information that will be used in future feasibility studies of similar technologies that process poultry litter into gas and fertilizer. The specific objective was to calculate the maximum processing and capital cost that would permit a profitable investment in a new generation cooperative to produce methane biogas and fertilizer from poultry litter.

A linear programming model was solved using GAMS to maximize the returns to unpaid resources taking into account the maximum amount of poultry litter produced from each farm and the capacity of the plant. An important feature of the analysis is that, using a Geographic Information System, transportation cost was calculated using actual road miles from each farm to the proposed processing site.

The maximum processing and capital cost at breakeven point that has been calculated apply to any technology that will produce the amounts of gas and fertilizer assumed here. According to the results, the investment can be profitable if all the costs unaccounted for are less than the breakeven point calculated by the model in this research.

Research Limitations

The break-even analysis done in this research has not been done in great detail. If all the necessary data were available, a complete break-even analysis, including break-even output level, would be useful. A feasibility analysis that compared different technologies that produce methane gas and fertilizers would be very useful.

The eastern Oklahoma region that produces large amounts of poultry litter borders with the western side of Arkansas. The counties in western Arkansas also produce a substantial amount of poultry litter, which should be included in the investment analysis for a poultry litter processing plant in the Eastern Oklahoma region.

Finally, risk and sensitivity analysis are some of the major important components of any particular investment. Due to the scope of this study risk was not considered. Risks that might affect the feasibility of an investment in a litter-processing plant include risks of insufficient amounts of poultry litter to achieve capacity utilization, higher transportation costs, variable prices for outputs and inputs, competitor response, and variation in process yield and productivity. Further research that would incorporate these risks would be a major contribution.

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VITA 2

Lawrence Daniel Mapemba

Candidate for the Degree of

Master of Science

Thesis: METHANE AND FERTILIZER PRODUCTION FROM POULTRY LITTER: TRANSPORTATION COST AND BREAK-EVEN ANALYSIS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Blantyre, Malawi, on June 3, 1969, the son of Lawrence and Margaret Mapemba.

Education: Graduated from Salima Secondary School, Salima, Malawi in June 1984; received Bachelor of Science degree in Agriculture from University of Malawi, Lilongwe, Malawi in September 1993. Completed the requirements for the Master of Science degree with a major in Agricultural Economics at Oklahoma State University in December, 2001.

Experience: Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, January 2001 to December 2002; Senior Agricultural Economist, Planning Division, Ministry of Agriculture and Irrigation, 1997 to present, Lilongwe, Malawi; Farming Systems Economist, Estate Land Utilization Study, 1995 to 1997, Lilongwe, Malawi; Secondary School Teacher, St. John's Secondary School, 1993 to 1995, Lilongwe, Malawi.

Professional Membership: Southern Agricultural Economics Association