ECONOMIC ANALYSIS OF GEORGIA STATE BROILER LITTER TRANSPORTATION

by

ULUGBEK BEKCHANOV

(Under the Direction of Jeffrey D. Mullen)

ABSTRACT

The profitability of using broiler litter as a source of crop nutrients was calculated using phosphorus based poultry litter application. A cost-minimizing phosphorus-consistent transportation model developed to meet the nutrient needs of 142 application counties in Georgia revealed that not all of the litter can be utilized in the state. The analysis indicates that a ton of litter can cost effectively be transported up to 151 miles from the production facility. The total cost increased when transportation of the litter out of the heavily surplus counties was equivalent to complete litter disposal from the originating region. Total litter use was minimally affected by changes in chemical fertilizer prices. Shadow prices indicated the robustness of the model.

INDEX WORDS: Broiler litter; Optimization; Priority-based model; Phosphorus based litter application; Transportation costs

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

"*We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect" – Aldo Leopold*

The value of manure as an organic fertilizer and a source of plant nutrients has been recognized for centuries. Poultry manure fertilizer contains all the essential nutrients required for crop production. Even with its beneficial effects on plant growth, manure constitutes only a small percentage of the nutrients applied to cropland when compared to commercial fertilizer.

According to Cooperative Extension Service at the University of Georgia, there are several reasons why poultry fertilizer is not used to its full potential. Among these are (1) lack of information on the value of manure as a source of plant nutrients, (2) failure to recognize how and where to use it, and (3) lack of recognition of its economic value (Ritz and Merka, 2004).

1.1 Background

The poultry and egg industry is Georgia's most valuable agricultural sector and leads the nation in the poultry production. The poultry industry has dramatically increased in size over several decades with more than 2/3 of the state's 159 counties involved in production. On an average day, Georgia produces 24.6 million pounds of chicken and 14 million eggs (http://www.georgiaencyclopedia.org). Major poultry processors based in Georgia include Pilgrim's Pride, Fieldale Farms, Claxton, Mar-Jac, and Cagle's. Poultry products, including turkeys, earn more than any other Georgia crop. The statewide economic impact of the industry is close to $20 billion annually. According to *Farm Gate Value Report* (2006), poultry industry producers and processors directly employ 51,515 workers in Georgia which include full-time and part-time jobs. Indirect employment (those relying on the poultry industry) provides an additional 50,132 jobs. This group includes those who provide supplies and inputs to the poultry industry, such as poultry equipment and feed (McKissick, 2007).

The poultry industry is responsible for 50 percent of the total GDP generated from agricultural enterprises in Georgia. One hundred counties in Georgia produce poultry products worth more than one million dollars (Figure 1.1). With this large amount of poultry production comes problems in disposing of the by-products: litter and dead chickens. The Georgia poultry industry produces close to two million tons of litter every year (Table 1.1). The main problem associated with these by-products is the lack of proper ways to dispose of this huge amount of litter.

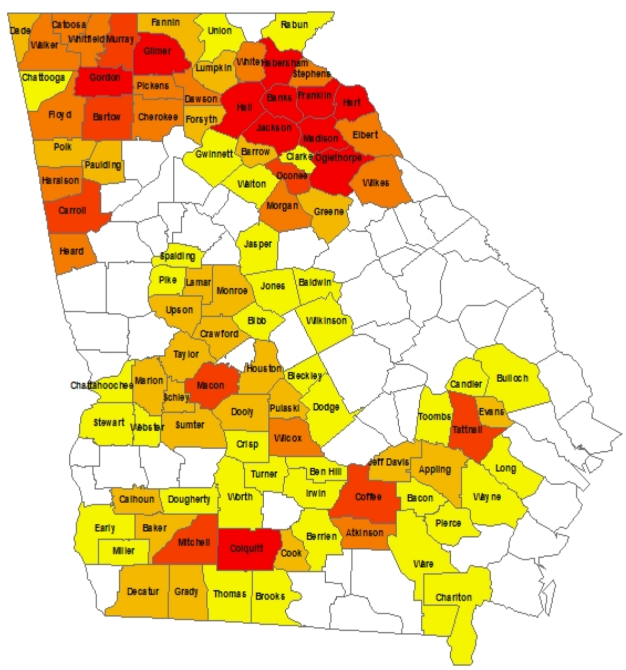

Figure 1.1 Counties in Georgia that Collect More Than Million Dollars Annually from the Poultry Industry

1.2 Problem Statement

The poultry industry in Georgia includes the production of broiler, layers, pullets, and turkeys. Of these, broiler production is the largest in terms of bird numbers, revenue generated, and the amount of litter produced. Ritz and Merka (2004) state that Georgia's yearly production is estimated at 1.3 billion broilers, 12 million commercial laying hens, 11.8 million broiler breeder hens and 12 million replacement pullets. The manure produced by these birds is a valuable by-product, with a potential gross value over $60 million dollars (Ritz and Merka, 2004). Thus in this study we will focus our analysis on the broiler litter disposal.

Table 1.1 Poultry Birds, Their Numbers, and Total Litter Produced in Georgia, 2007

Type of Poultry	Number (1,000)	Litter per bird[a] (Pounds)	Approximate nutrient content (N-P_2O_5-K_2O)[b]	Total litter produced (Tons)
Laying Chicken	13,843	40	38-56-30	276,860
Broiler	1,394,661	2.5	64-54-48	1,743,327
Turkey	261.96	31	57-72-40	4,060.38
Replacement Pullet	85,878	8	38-56-30	343,512

[a]Source: (Vest, L., J. Dyer, and W.I.Segars., 1994)

[b]Source: North Carolina State University Department of Biological and Agricultural Engineering; The University of Georgia Agricultural and Environmental Services Laboratory.

The broiler industry generates 37.4 percent of total GDP in the state of Georgia. The top five counties in the state, based on the sale of broilers, are Franklin, Madison, Habersham, Banks, and Gilmer. More than 45 percent of the total broiler production is concentrated in an eight-county-area of the central Piedmont region of Georgia. The absence of proper disposal facilities for the litter can cause air and water-quality problems. Even this has led to an ever increasing and fairly localized stock of broiler litter that threatens the safety of both surface and ground water. The locally concentrated production of poultry waste is a problem to both private and public sectors in this region. The long-term environmentally consistent alternative utilization of poultry waste will determine the profitability and stability of poultry farms in this concentrated production area. There is also a positive benefit associated with poultry litter as there exists a potential profitable opportunity for the processing and marketing of this by-product.

Geographically, major poultry producing counties and crop producing counties divide the Georgia into two so-called "surplus regions", north part of Georgia with high poultry production, and "application", south part of Georgia with major crop producing counties. However, crops such as corn, wheat, and soybean are also grown in "surplus" counties. However, excessive poultry production threatens this and adjacent regions with respect to air- and water-quality pollution.

The P-index measurement takes into consideration the factors such as phosphorus generated in poultry litter and phosphorus removed by crops in the county. According to Georgia statewide pilot poultry litter transfer program created by Natural Resource Conservation Service (NRCS) in 2005, 15 targeted counties were distinguished based on P-index. Among them Cherokee, Forsyth, Habersham, Hall, Gilmer, Banks and Lumpkin counties were the most risky counties with 50 points (the highest P-index coefficient).

The transfer of litter from counties with an excess to areas where litter can be used as a source of crop nutrients in an environmentally responsible way minimizes water- and air-quality deterioration in the region. This study identifies a strategy, not only for Georgia, but also for other states with concentrated broiler production, to achieve optimum distribution of broiler litter that minimizes crop nutrient costs and promotes air and water quality.

Poultry litter is rich in the major plant nutrients: nitrogen, phosphorus, and potassium. Poultry litter can, therefore, be used as a substitute for chemical fertilizers in the production of row crops and pasture grasses. The substitution of poultry litter for chemical fertilizers can provide benefits in three ways: it retains water, provides needed plant nutrients, and has the potential to increase soil productivity due to continuous addition of an organic source of nutrients. Since most of the nutrients applied by poultry litter are not extracted in the same year as applied, the carryover of nutrients from one year to another must be considered. In this study, we will compare the costs of applying poultry litter versus chemical fertilizers in the production of the major row crops, such as cotton, corn, wheat, peanuts, and soybeans grown in Georgia. Hay production will also be taken into consideration, because in most of the "surplus" counties, the poultry litter is widely used in hay production.

Phosphorus is a primary element of concern in assessing surface water quality since it is generally considered a limiting nutrient for eutrophication[1] in fresh water. Broiler litter contains high level of water-soluble phosphorus, making it environmentally damaging due to runoff. In the past, researchers have considered nitrogen management to be a major agricultural issue (VanDyke, L.S., Bosch, D., Pease, J.W., 1999; Reinhard, S., Lovell, C.A.K., Thijssen, G., 1999; Piot-Lepetit, I., Vermersch, D., 1998). Phosphorus, however, has emerged as a serious concern in areas where animal operations predominate and there is major land application of manure (Boland, M.A., Preckel, P.V., Foster, K.A., 1998; Goetz, R.U., Zilberman, D., 2000; McCann, L.M.J., Easter, K.W., 1999). Most optimal control policies for addressing phosphorus pollution

[1] Eutrophication means an increase in chemical nutrients – typically compounds containing nitrogen or phosphorus – in an ecosystem. It may occur on land or in water.

have focused on its externality aspects. Other studies have emphasized the economics of restricting phosphorus and taxing its application to avoid the eutrophication problem.

For an effective phosphorus-based analysis to be calculated, the likelihood of broiler litter being applied as a crop nutrient source, the area where it can be applied, and each county's potential for producing and utilizing the litter must be known. The use of phosphorus-based analysis helps in determining these parameters. Specifically, it establishes the maximum amount of litter that can be utilized in crop-producing areas relative to broiler-producing areas. These critical pieces of information are necessary to design of phosphorus based policy tools that promote air and water quality through the optimum utilization of broiler litter as a crop nutrient source.

The phosphorus-based analysis is applied using the criterion that a farmer pays the minimum cost to meet the total nutrient needs of the selected major crops grown in Georgia when phosphorus is the binding constraint. The phosphorus-based analysis is defined as the application of litter based on the rate of phosphorus-recommended for a crop in state by the Cooperative Extension Service.

Other alternative uses of poultry litters include its use as a livestock feed, as a fuel source and as a plant bedding material. But in this study, we will only deal with nutrient characteristics for row crops of poultry litter.

1.3. Objectives

The main objective of this study is to achieve optimum distribution of broiler litter subject to transportation costs, environmental regulations, and industry requirements. To accomplish the main objective, the following sub-objectives will be analyzed:

1. Conduct a fertilizer cost analysis on broiler litter as a crop nutrient compared to commercial fertilizers to see if the broiler litter is economically feasible and environmentally sustainable with regard to nutrient replacement;
2. Develop a transportation model to find the most efficient solution for litter transfer to meet the crop nutrient demand in the state;
3. Develop a production function that (1) estimates the yield response of selected row crops (cotton, corn, wheat, peanuts, soybean) to poultry litter applications; (2) determines the application rate of poultry litter that maximizes net returns to each crop; (3) estimates the amount of litter demanded by row crop producers in application counties under current cropping patterns; and (5) estimates the size of subsidy needed to ensure all the excessive poultry litter in the state is applied to row crops.

1.4 Organization of the Study

This thesis work is composed of five chapters. Chapter 2 provides a literature review on the poultry industry in Georgia and its consecutive effects, broiler litter as a crop nutrient source, land application potential in Georgia, and several statewide, or other states research works and programs. Chapter 2 also provides a short review on the federal and state governmental policies and regulations on animal waste and poultry litter use with regard to environmental protection. Chapter 3 explains the data and methodology used in this study. Chapter 4 reports the results and analysis. A Summary and discussion of conclusions are provided in chapter 5.

CHAPTER II

LITERATURE REVIEW

This chapter reviews the literature on (1) the poultry industry in the state as well as the use of poultry litter as a fertilizer and its land application potential with selected row crops in Georgia; (2) Federal and state rules and regulations with Animal Feeding Operations (AFO) permit requirements, and poultry litter in terms of pollution; and (3) summaries of several state programs on poultry litter use and transfer across the nation; and finally (4) a brief theoretical description of linear programming.

2.1 Poultry Litter Production in Georgia and Boiler Litter as a Crop Nutrient Source

The quantity of poultry litter produced can be estimated using county poultry production data from the *GA Poultry Facts 2007.* Although the poultry industry is spread throughout the state, it is highly concentrated in North Georgia. Nearly 2,000 of the state's 4,139 poultry farms are located in the Piedmont Region. According to *Georgia Statistics Service 2007* (www.georgiastats.uga.edu), these "surplus" counties account for 47.2 percent of Georgia's broiler production. Franklin is the number one county in Georgia in broiler production and farm cash receipts from poultry. The second-ranking county for broiler production is Hall with more than 488 million pounds of production. The top 25 broiler-producing counties and their respective state share are shown in table 2.1. The data clearly show the dominance of the "surplus" counties in Georgia poultry production. Nevertheless, significant poultry production occurs in the other counties of the state as well.

Table 2.1 Georgia Poultry Production[1], 2007

County	Value of Broiler Production ($)	% of the state total
Franklin	$299,930,908	6.36%
Madison	$243,157,138	5.16%
Habersham	$222,021,145	4.71%
Banks	$211,646,325	4.49%
Gilmer	$209,379,584	4.44%
Jackson	$185,017,620	3.92%
Hart	$170,956,281	3.63%
Hall	$170,216,211	3.61%
Colquitt	$166,204,614	3.52%
Oglethorpe	$162,444,282	3.45%
Gordon	$161,601,328	3.43%
Tattnall	$138,800,058	2.94%
Carroll	$124,019,624	2.63%
Coffee	$119,466,861	2.53%
Whitfield	$110,576,937	2.35%
Macon	$101,673,234	2.16%
Mitchell	$89,172,117	1.89%
Murray	$87,189,554	1.85%
Oconee	$86,802,659	1.84%
Bartow	$84,558,834	1.79%
Elbert	$74,840,178	1.59%
White	$72,277,912	1.53%
Atkinson	$58,766,870	1.25%
Pickens	$56,982,912	1.21%
Morgan	$55,416,864	1.18%
Georgia	**$4,715,194,764**	**100%**

[1]Counties with significant proportion of state production

Source: www.georgiastats.uga.edu

Poultry Litter Production

Major poultry processors based in Georgia include Pilgrim's Pride, Fieldale Farms, Claxton, Mar-Jac, and Cagle's. These vertically integrated companies combine all the phases of the business – raw materials, processing, and distribution – within a single company. Although based elsewhere, a number of other poultry companies also operate in Georgia, including Tyson, Con-Agra, and Continental Grain. These companies contract with growers who operate on short-term contracts. The companies typically own the birds and the feed. Growers own the poultry houses and manage bird production. The growers are also responsible for disposing of dead birds and litter, and for purchasing poultry bedding. The growers are typically paid based on how much weight the birds gain relative to how much they are fed.

The number of birds grown per house varies widely based on the capacity of the house. In some cases, the grower is allowed to decide when litter cleanout is conducted. In other cases, poultry integrators mandate when the houses are cleaned out. Studies indicate that houses are typically cleaned out once per year (Evers, 1998). However, this practice varies widely, and producers in Georgia clean houses at a frequency that varies between once per flock to once every five years. Turkeys produce considerably more litter than broilers per bird, and this increased litter production also affects cleaning rates. Bedding material typically consists of pine shavings or peanut hulls. The amount of bedding spread in a house varies depending on grower preference and bedding costs, and the type of bedding chosen is based on price and availability. Growers cite little or no preference between the two bedding types, other than the perceived appeal of peanut hulls in poultry litter used for cattle feed. When the house is cleaned out, the poultry litter consists of poultry excreta, feathers, wasted feed, and bedding materials (Evers, 1998).

Growers may clean out the houses themselves, or permit others to clean their houses. If someone else cleans the house, the common exchange is to receive the poultry litter in return for the cleaning service. The houses are cleaned using equipment such as a skid loader or a tractor outfitted with a scraping device. A lot of literature (Poultry Waste Management Handbook, 1999; Parker, D. and Li, Q., 2006) indicates that if the poultry grower cleans out the house, the poultry litter has been typically sold for $12-15 per ton for feed or $3-6 per ton for fertilizer (depending on season). Typically, turkey litter is only suitable for fertilizer while most broiler litter may be also suitable for livestock feed. However, nearly all broiler litter is currently used for fertilizer. Poultry litter used for livestock feed should be very low in moisture and granular in consistency. Litter not used for feed is typically removed from the house in a process called caking. According to various producers, litter should then be deep-stacked in storage sheds for at least seven days to kill bacteria in litter with heat.

Over 95% of poultry litter produced in the United States is applied to agricultural land as fertilizer (Evers, 1998). Poultry litter as a fertilizer has several desirable attributes in addition to nitrogen, phosphate, and potash nutrients. These attributes include slower nitrogen release, which reduces leaching; potassium and calcium content, which reduces soil acidity; and organic matter, which improves the water and nutrient holding capacity of the soil (Evers, 1998). As with commercial fertilizer, poultry litter should be applied at rates appropriate for the soil type and crop. Timing of any fertilizer application is also extremely important in order to avoid nitrogen losses and to assure nutrient availability at the appropriate time. Failure to consider proper application rates and timing can result in leaching and runoff of nitrogen and phosphorous. These nutrients, although valuable to plants at appropriate levels, pose potential environmental hazards if they reach surface or ground water.

Table 2.2 indicates the estimated amount of poultry litter produced in Georgia during 2007 based on the poultry production shown in Table 2.1. For these calculations, broilers were assumed to produce 1.25 tons of manure per thousand birds (Ritz and Merka, 2004). When the poultry litter for the "surplus counties" are summed, the region alone accounts for almost 50 percent of the total poultry litter produced in Georgia.

Table 2.2 Georgia Poultry Litter Production, 2007

County/*Region*	**Broiler Litter Produced (tons)**	**Share in Total (%)**
Removal Counties	822,959	47.21%
Franklin	110,892	6.36%
Madison	89,901	5.16%
Habersham	82,087	4.71%
Banks	78,251	4.49%
Gilmer	77,413	4.44%
Jackson	68,406	3.92%
Hart	63,207	3.63%
Hall	62,933	3.61%
Gordon	59,748	3.43%
White	26,723	1.53%
Pickens	21,068	1.21%
Dawson	19,037	1.09%
Heard	15,840	0.91%
Catoosa	14,729	0.84%
Cherokee	13,617	0.78%
Lumpkin	10,325	0.59%
Forsyth	8,782	0.50%
Application Counties	920,368	52.79%
Georgia Total	**1,743,327**	**100.00**

Source: www.georgiastats.uga.edu

Poultry Litter Nutrient Content

Poultry litter contains nitrogen, phosphorus, and potassium compounds as well as small amounts of some micronutrients. The form of the major nutrient compounds are nitrogen (N), phosphate (P_2O_5), and potash (K_2O). Typical concentrations of these nutrients in Georgia poultry litter are shown in table 2.3.

Table 2.3 Average Nutrient Composition of Poultry Manure on an As-Received Basis

Manure Type	**Total N**	**Ammonium NH_4**	**Phosphorus P_2O_5**	**Potassium K_2O**
	lb/ton			
Broiler litter	64	10	54	48
Stockpiled litter	36	8	55	35
Breeder manure	31	7	40	35
Layer manure				
Highrise cleanout	40	18	94	58
Lagoon sludge	26	8	92	13
Lagoon effluent	62	42	59	37

Source: North Carolina State University Department of Biological and Agricultural Engineering; The University of Georgia Agricultural and Environmental Services Laboratory.

The concentrations shown in table 2.3 are recommended by Cooperative Extension Service of the University of Georgia's College of Agricultural and Environmental Sciences for the Georgia farmers in nutrient management plans (NMP). However, there are some other nitrogen concentration averages used in various works. For example, data from North Carolina and Pennsylvania (Carter, 1999; Poultry Waste Management Handbook, 1999) indicate that the nitrogen concentration of broiler litter is often closer to 70 pounds per ton. Analysis of unpublished Virginia litter tests from 1998-99 indicate average total nitrogen concentrations of 71.6 pounds per ton. However, since our study area is the state of Georgia, the estimate of 64 and

54 pounds of nitrogen and phosphorus per ton of broiler litter respectively, was used in this study.

Table 2.4 Broiler Litter Nutrients, 2007

County/*Region*	**Nitrogen (N), thousand lbs**	**Phosphorus (P_2O_5), thousand lbs**	**Potassium (K_2O), thousand lbs**
Removal Counties	52,669,367	44,439,778	39,502,025
Franklin	7,097,090	5,988,170	5,322,817
Hall	5,753,685	4,854,672	4,315,264
Madison	5,253,557	4,432,688	3,940,168
Habersham	5,008,063	4,225,553	3,756,048
Banks	4,954,427	4,180,298	3,715,820
Gilmer	4,377,964	3,693,907	3,283,473
Jackson	4,045,239	3,413,170	3,033,929
Hart	4,027,727	3,398,394	3,020,795
Gordon	3,823,878	3,226,397	2,867,908
White	1,710,270	1,443,040	1,282,703
Dawson	1,348,353	1,137,673	1,011,265
Pickens	1,218,356	1,027,988	913,767
Cherokee	1,013,772	855,370	760,329
Heard	942,630	795,344	706,973
Catoosa	871,488	735,318	653,616
Lumpkin	660,799	557,549	495,599
Forsyth	562,068	474,245	421,551
Application Counties	58,903,533	49,699,856	44,177,650
GEORGIA	**111,572,900**	**94,139,634**	**83,679,675**

Source: www.georgiastats.uga.edu

Using Georgia poultry litter production shown in table 2.2, and nutrient concentrations found in table 2.3, it is possible to estimate nutrient production for the "surplus" and "application" poultry producing counties in Georgia. Nutrients produced by broilers are shown in table 2.4.

Poultry Litter as Fertilizer

The alternative use of poultry litter is as a source of plant nutrients. Poultry litter can be considered the most valuable of animal wastes because of its low moisture and high nutrient content. The average amount of nitrogen, phosphorus and potassium (N-P-K) in broiler litter was estimated to be 3-3-2 (Wood, 1992). The average amounts of major nutrients (N-P-K) present in the different classes poultry litter are shown in table 1.1. Significant amounts of secondary plant nutrients are also found in broiler litter. Any kind of poultry litter can be used as a source of plant nutrients although broiler litter is by far the most plentiful.

The value of broiler litter in crop production is generally based on nitrogen content. Most of the nitrogen in poultry litter is not immediately available to plants because it exists in an organic form. Nitrogen gets carried over even two years after poultry litter application. When litter is applied according to the nitrogen requirement of the crop, phosphorus gets over-applied. This results in potential leaching of nitrogen and leaching and runoff of phosphorus which are harmful to surface and ground water quality. However, if litter is applied according to the phosphorus requirements of the crop, both problems can be ameliorated (Paudel, Adhikari and Martin Jr., 2004). If litter is applied to match the phosphorus needs of the crop, then remaining amount of nitrogen not supplied by poultry litter could be supplied using inorganic fertilizers. The most economical nutrient management strategy is applying poultry litter based on the minimum amount of the major nutrient needed for crop production. Paudel *et al.* (2004) state that a phosphorus-consistent analysis has been implemented in Texas where the threshold phosphorus concentration in the soil is set at 200 part per million (ppm). At levels beyond this threshold, phosphorus application is based on the amounts of major nutrients that the crop takes out of the soil during the growing season.

According to Paudel *et al.* (2004), due to the low nutrient content of litter and the high volumes required to supply adequate crop nutrients it is not economical to transport poultry litter long distances for use as a source of plant nutrients. Therefore, most of the litter produced in Georgia is currently applied to pasture or row crops located near the poultry production facilities. As shown in the Figure 1.1, poultry production occurs in almost every county in the state, although a higher concentration occurs in the northern part of the state. Carpenter (1992) states that more than 90 percent of all poultry wastes are directly land applied. Another option for processing and disposal of litter would be to compost the litter. The problem with composting is that the process results in a loss of nutrients, especially nitrogen. This loss in nutrient content effectively reduces the value of the litter and makes composting unprofitable for broiler producers. This view is supported by Vervoort and Keeler (1999) who found that unless environmental constraints are considered, it is not profitable to compost poultry litter.

The most environmentally benign and economically relevant disposal option for poultry litter is that of land application based on soil phosphorus levels and plant phosphorus needs. A relevant question, therefore, is how far poultry litter can be transported to apply as sources of plant nutrients based on the phosphorus need of a crop. Bosch and Napit (1992) studied the economic viability of transporting broiler litter from counties of surplus to counties of deficit supply. They first look at the situation where litter is applied to all crop and pasture land. They also examine a scenario where litter is applied only in 50 percent of total crop area available. The results of this study show 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. Additional savings could be obtained if poultry litter is applied according to phosphorus content.

Donald *et al.* (1994) used the rule of thumb and estimated the amount of litter produced by broilers to around 0.5 to 0.7 pounds per pound of meat produced. Under Alabama growing conditions, they found that broilers produced 0.52 pounds of litter per pound of meat. With a total of 9.21 billion pounds of broilers produced in Georgia during 2007, this would equal 4.79 billion pounds of litter.

Currently, poultry litter is applied to about half of the crop production area in north Georgia (Givan, B., through Paudel, K., 2004). The total crop land acreage in Georgia was 4.68 million acres in 2002 (http://www.ers.usda.gov/StateFacts/GA.htm). Pasture and range land account for 8.1 percent of the total land acreage in the state (table 2.5).

Table 2.5 Land Use Pattern in Georgia 2002 **(***Total Acreage=10,744,239***)**

Land use	**Percentage of total acreage**
Crop land	43.5
Woodland	39.9
Pastureland and rangeland	8.1
Other land	8.5

Source: 2002 census of agriculture - state data, GA

Both pasture and crop lands are currently receiving applications of poultry litter. According to *Givan* (through Paudel, K. 2004) almost all poultry producers use poultry litter to fertilizer their land. The amount of litter application per acre is traditionally based on nutrient content in the litter.

The nutrient content of litter varies due to moisture, temperature, amount and kind of litter, the amount of soil picked up in cleaning up houses, the number of flocks of broilers fed on the litter and the conditions under which manure was stored and handled before spreading.

Mitchell *et al.* (1992) analyzed samples of poultry litter with 20 percent moisture content obtained from 147 broiler house over 11 years and found the percentage of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) to be 3.9, 3.7, and 2.5 percent, respectively.

Based on this result, the fresh sample of broiler litter will contain 3.1-3.0-2.0 percent or 60:60:40 pounds of N-P_2O_5-K_2O per ton of poultry litter. As stated before, not all nutrients are available to the crop when broiler litter is applied. Here, we will assume that broiler litter is broadcast applied to the crop or field. When litter is applied this way, only 75 percent of the inorganic nitrogen (ammonium nitrogen) is available to crop. We assume the inorganic nitrogen content in the litter to be around 2.2 percent while the organic nitrogen is about 0.9 percent (Mitchell, C.C., Donald, J.O., Payne, V.W.E., 1992). We also assume that only 50 percent of the organic nitrogen from litter is available in the first year, 12 percent in the second year, and 5 percent in the third year. In addition, it is assumed that phosphorus and potassium are available only 75 percent of the original application amount. These assumptions are consistent with the previous studies (Mitchell, C.C., Donald, J.O., Payne, V.W.E., 1992; Hammond, 1993).

Due to the concern over phosphorus runoff and eutrophication, litter should be applied to crops based on the phosphorus content of the litter and soil, and the phosphorus needs of the crop. This will help to overcome the criticism of poultry litter application and its link to phosphorus pollution in nearby water sources.

Land Application Potential in Georgia

Cotton, peanuts, corn, wheat and soybean are the major row crops in Georgia. They account for, including all other crops, 14.5 percent of total GDP generated by agricultural enterprises in the state. Where cotton itself accounts for 8 percent of total GDP, continuous application of chemical fertilizer and conventional tillage has reduced the productivity in cotton in Georgia (Paudel, 1999). Poultry litter application helps to enhance soil productivity as it is a source of organic matter in the soil. Continuous application of poultry litter can enhance the productivity of soil and help to maintain a favorable soil structure. To examine the economics of applying litter to selected row crops, and because of a three-year assumption for complete nutrient recovery, crop enterprise budgets were used for a three year application cycle. In addition to utilization of litter, it is suggested that no-till practices be used to reduce phosphorus runoff, especially for cotton (Paudel, 1999). We analyze net returns and breakeven transportation distances under two scenarios – application of broiler litter consistent with phosphorus levels and application of chemical fertilizer.

It is assumed that counties have all necessary farm machinery and equipment. Litter transportation cost in the surplus region, especially in the Piedmont area, is $3.50 per mile (EQIP, 2006). The cost of litter is $10 per ton (GASS, 2006). The University of Georgia Cooperative Extension Service recommends that nitrogen, phosphorus, and potassium in the Piedmont region for dryland cotton be applied at the rate of 70:50:80 pounds per acre of N-P_2O_5-K_2O.

If it is assumed that poultry litter supplies nutrients as well as improves soil structures due to increase in organic matter, soil productivity should increase if poultry litter is applied continuously at a responsible rate. Paudel (1999) reports that an increase in organic matter by 1 percent increases input efficiency which boosts yield by 3 percent. Assuming that organic matter in the surplus counties is, at present, at one percent, continuous application of poultry litter has the potential to increase yield up to 12 percent above the current levels. However, Paudel (1999) also states that even with no-till and continuous poultry litter application, the maximum organic matter level that can be attained in Piedmont soils is 2.5 percent. It takes about 300 years for organic matter to reach that level (Paudel, 1999). Increases in organic matter help to improve soil tilth and decrease the soil erosion by increasing infiltration. If poultry litter were applied to all cotton acreage in Georgia, this would utilize approximately 1.66 million tons of litter. However, the major cotton growing area in the state is in the coastal plains region where cotton is grown under irrigation. Given the distance from the major poultry producing counties (region) transportation costs become an issue.

While cotton is the major field crop, there are other crops grown within reasonable distances of the major poultry litter producing region. Within 200 miles surrounding the major poultry litter producing area, crops such as corn and winter wheat are grown extensively. The use of broiler litter in these two crops could provide an alternative solution of poultry waste disposal problems in the Piedmont area. Figure 2.1 shows the picture of counties' location with respect to acreages of selected crops' production and the number of broiler production. Total poultry use based on the phosphorus requirements of above mentioned three crops (both irrigated and dryland) are presented in table 2.6. The total acreage (irrigated and dryland), recommended amount of major plant nutrients, and phosphorus consistent poultry litter application rates for cotton, corn, and wheat are shown in table 2.6. The nutrient needs not met by poultry litter are assumed to be supplied through application of chemical fertilizers.

Total potential amount of litter utilized in the production of cotton, corn, wheat and (using phosphorus consistent application rates) can be seen in figure 2.1. If poultry litter were applied to all major crops, approximately 2.4 million tons of broiler litter could be utilized. This amount exceeds the combined production of litter from all poultry sources in the state. It should be noted that in addition to potential use in row crop production, poultry litter is currently applied to 7.5 percent of pasture and range land in the state (Paudel, 1999).

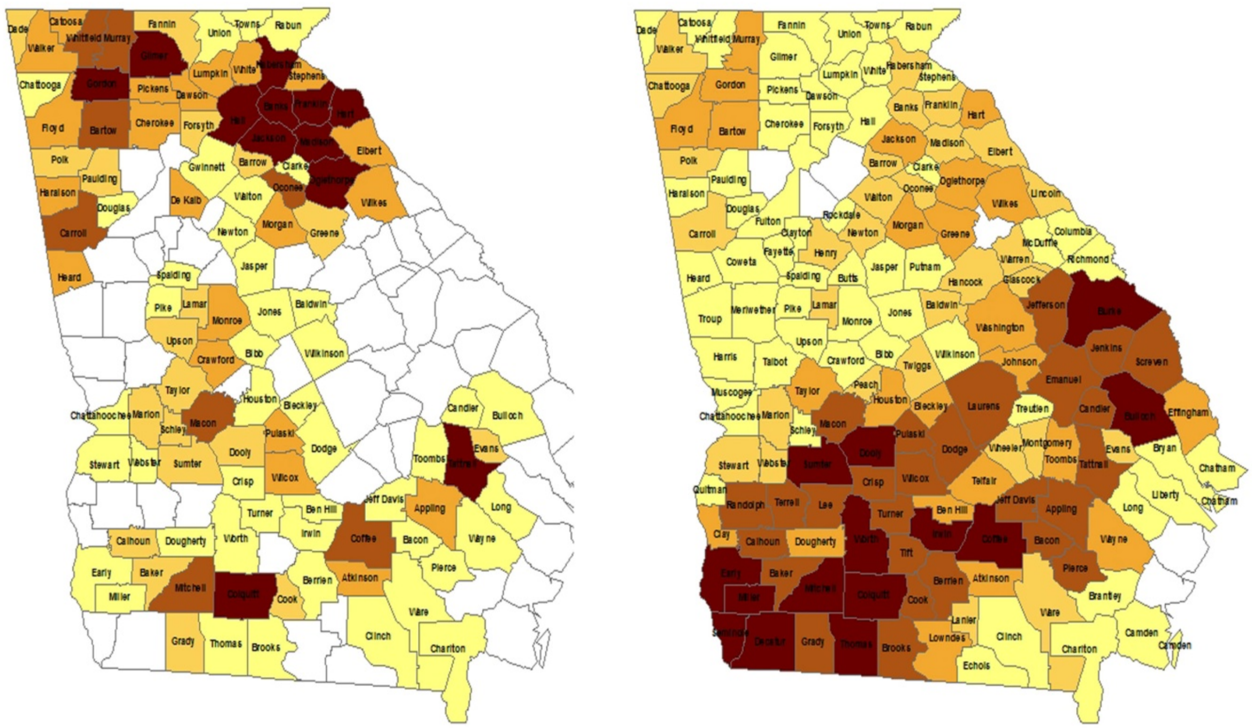

Figure 2.1 Broiler Production (left) and Crop Acreage (right) in Georgia 2007

2.2 Poultry Litter, Regulatory Response and Pollution

As Goodstein (2005) indicates:

"The federal clean water legislation puts responsibility for regulating non-point pollution on the states; the 1987 Water Quality Act requires states to develop so-called 'best-management practices to control runoff from industrial and agricultural sites'. Progress in this area has been slow because the diverse nature of the non-point problem makes centralized, technology-based regulation infeasible".

Table 2.6 Acreage under Three Major Row Crops, the Recommended Fertilizer Rate, and Phosphorus Consistent Poultry Application Rate for Three Years in Georgia (Based on 2007)[a]

Crop[b]	Acreage (1,000)	Recommended NPK, pounds per acre	Phosphorus consistent poultry litter application, tons per acre[c]			
			1st year	2nd year	3rd year	Three years total
Cotton (dryland)	806.27	70:50:80	0.93	0.93	0.93	2.79
Cotton (irrigated)	246.46	90:60:90	1.11	1.11	1.11	3.33
Corn (dryland)	310.72	120:40:40	0.74	0.74	0.74	2.22
Corn (irrigated)	152.78	180:60:80	1.11	1.11	1.11	3.33
Wheat	286.57	80:40:40	0.74	0.74	0.74	2.22

[a]Crop acreage is obtained from Georgia Farm Report/GASS and recommended fertilizer is obtained from the Georgia Cooperative Extension Service.

[b]Soybean (0:40:80 pounds NPK per acre), hay (0:10:40 pounds NPK per acre), and peanuts (0:30:50 pounds NPK per acre) are not included as those crops do not need nitrogen, thus is more profitable and environmentally safe if plant nutrients are applied from chemical fertilizers.

[c]Nutrient level recommended for both irrigated and dryland is the same.

Non-point source pollution created by agriculture is one of the most damaging and widespread threats to a clean environment. Passage of the Clean Water Act 319 in 1987, highlighted a need and established funds to evaluate remedial strategies to minimize non-point source impacts of agricultural production. Disposal of animal waste is often considered a key contributor to agricultural non-point pollution.

The growth of the poultry industry in Georgia has exploded in the early 1980s with an aim to meet the growing demand for poultry meat and eggs. As a result approximately, more than 10 million tons of poultry litter is produced each year in Georgia. The growth of poultry industry has concentrated litter production in some regions where nutrient applications may be in excess of the plant uptake. This can lead to contamination of groundwater as well as surface water in the nearby areas (Govindasamy, I., M.J. Cochran, D.M. Miller, R.J. Norman , 1994b; Govindasamy, I., M.J. Cochran, E. Butchberger, 1994a).

In August of 2003, the Georgia Department of Natural Resources (DNR) approved new Georgia Environmental Protection Division (GaEPD) animal feeding operations (AFO) regulations for some dry manure poultry operations. These new State regulations were passed to meet revised federally mandated AFO rules that brought dry manure poultry operations under permitting requirements. A dry manure poultry operation is one that does not utilize a liquid manure handling system (i.e flush or lagoon system).

Large AFO Definitions. Georgia's new AFO regulations require that large dry manure poultry operations be permitted and regulated by GaEPD. Large dry manure handling AFOs for poultry are defined as a facility that confines or maintains poultry for at least 45 days in any 12-month period in the following numbers:

1. 125,000 or more chickens or broilers (includes pullets and breeders)
2. 82,000 or more laying hens (includes table egg layers and pullets)
3. 30,000 or more ducks
4. 55,000 or more turkeys

Two or more AFOs under common ownership are considered to be a single operation and subject to permitting if they adjoin each other or if they use a common area or system for the disposal of the manure. Operations below the above indicated thresholds are not required to have

National Pollution Discharge Elimination System (NPDES) permits unless they are deemed to be a non-point source of pollution by EPD.

Requirements for Permitting. Requirements for AFO permitting by GaEPD for dry manure handling poultry operations that meet the above definitions are:

a. Owners of existing dry manure AFOs meeting the above definitions must apply for a NPDES permit. Any person who proposes to commence operation of a new poultry AFO that handles dry manure or any person who proposes to expand an existing operation to exceed the minimum number of birds for a permitted AFO must obtain an NPDES permit. Permit applications should be submitted 180 days in prior to beginning operation of the AFO.

b. For existing poultry AFOs, they will not be any discharge of process wastewater pollutants from the operation or manure storage area into surface waters of the State unless a catastrophic rainfall event (25-year, 24 hr storm) occurs. For new or expanded operations there is no discharge of process wastewater pollutants from the operation or manure storage areas into surface waters of the State except when catastrophic rainfall event (100 year, 24 hr storm) occurs.

c. A comprehensive nutrient management plan (CNMP) must be implemented and maintained on the farm and shall not be submitted to GaEPD except upon written request by the Division. The owner of a new AFO shall prepare and implement a CNMP concurrent with the beginning of operation of the AFO. CNMPs for permitted AFOs require assessment of risks related to phosphorus application. In Georgia, the use of a P-index is used to assess site-specific risks for phosphorus application and to identify changes in management practices for high risk sites. For non-permitted poultry operations participating in State's industry-sponsored CNMP program, the use of the P-index is strongly encouraged. For dry manure poultry operations, the CNMP does not have to be prepared by a certified planner but may instead be developed by a person trained in the subject by an academic or trade organization.

d. A setback of 100 feet between waste disposal areas and drainage ditches, surface water bodies or wetlands must be maintained. The owner may, however, substitute a 35 feet wide vegetative buffer as an alternative to the 100 feet setback.

e. Soil samples from the waste disposal fields will be collected and monitored for phosphorus content at a minimum of once every five years.

f. Poultry litter analysis for nitrogen and phosphorus content will be required at minimum on annual basis.

g. Permitted operations must submit an annual report to GaEPD as specified in the permit.

h. For poultry operations which have been excluded from all permit requirements, GaEPD will collect information such as location and industry developed (voluntary) CNMP implementation from the Georgia Department of Agriculture and other organizations.

Complying with this State regulation for AFO permitting for dry manure poultry operations should not be difficult for most poultry producers. Georgia poultry producers have been implementing nutrient management plans on a voluntary basis as part of the Georgia Poultry Federation and University of Georgia CNMP program since 1999. Those individuals implementing these programs should be in good position to meet State permitting requirements. Regardless of whether operations meet the requirements for State permitting, all poultry producers in Georgia should be operating from a comprehensive nutrient management plan. EPD monitors all poultry farms for the implementation of CNMPs.

Poultry Litter and Pollution

The U.S. Environmental Protection Agency (EPA) says that hog, chicken, and cattle wastes have polluted 35,000 miles of rivers in 22 states and contaminated groundwater in 17 states. With an increase number of poultry related factory farms in Georgia, river and groundwater pollution are potentially serious problems. An increasing number of federal and state laws address poultry waste, but environmental regulations are not keeping pace with poultry litter production in Georgia or elsewhere in the USA.

The greatest concentration of poultry in Georgia is in 8 adjacent counties. The cumulative supply of poultry litter located in such a geographically concentrated area poses a serious threat to ground and surface water quality. The nitrogen content of litter is available in organic form such as nitrates. Nitrates are water soluble and thus have the potential to leach into ground water. Contamination of drinking water by nitrogen has been shown to contribute to blue baby disease (Hubbard, R. K. and J. M. Sheridan., 1989; Bouwer, 1990).

Phosphorus is subject to runoff into surface water and hence also poses serious health risks. Current water treatment in the US is done through primary and secondary processes. To remove nitrogen and phosphorus, water should go through the tertiary treatment which may cost as much as six times higher than the current water treatment regimes (Sedlack, 1991).

Nitrogen leaching from poultry litter should not be problem if litter is applied at recommended rates. The EPA has set standards for drinking water such that nitrogen should not occur in concentrations above 10 ppm while the standard for phosphorus is to be 0.05 to 1 ppm for lakes and stream, respectively. Composting of litter works well in reducing the concentration of nitrates being lost, but does not reduce the concentration of phosphorus in the runoff (Radcliff, Cabrera, and Merka, 1996). In addition, since composting lowers the nutrient content of the litter, it also decreases its commercial value (Vervoort and Keeler, 1999)

Various forms of inorganic phosphorus are a source of eutrophication. The concentrations of inorganic phosphorus that will result in problems are those above 0.02 mg per liter (resulting in the potential for algae bloom), and above 0.1 mg per liter in what is termed an excessively enriched region (EPA, www.epa.gov).

Govindasamy *et al.* (1994) examined the implications of phosphorus loading policies for pasture land. They measure the economic opportunity costs of a phosphorus management policy that targets soil with high amounts of phosphorus. The effect of a litter application tax on the optimal allocation of poultry litter is examined. They conclude that restricting litter applications on soils with elevated phosphorus levels will significantly reduce the net return generated from forage production. They also found that the magnitude of the tax, whether small or large, does not affect the level of poultry litter application on per acre basis.

The amount of water soluble phosphorus in litter varies, but fresh broiler litter contains about 0.52 grams of phosphorus per pound of litter (Moore, 1995). Water soluble phosphorus can be reduced substantially with the addition of amendments such as alum, lime, or ferrous products. The application of alum to poultry litter results in lower atmospheric ammonium, and better weight gain and lower energy use by the broilers. Addition of alum can decrease phosphorus runoff from land-applied litter as well as increasing the profitability of poultry production (Moore, 1995). The down-side of adding alum in the production process that it increases the cost of production and the cost of the litter.

The soluble phosphorus from broiler litter is more likely to remain on sandy soils than on clay soils. Soluble phosphorus content is higher on no-till soils than on conventionally tilled areas. However, the runoff of phosphorus is greater in conventionally tilled soil than no-till. Therefore, phosphorus runoff could be minimized if no-till management practices are followed and if litter is applied to clay soils (Cox, 1995). According to Cox (1995), in the beginning of 1990s only 15 percent of total land in cotton cultivation was under no-till management practice.

Williams *et al.* (1998) explored ways to recycle poultry litter that were environmentally sound, economically feasible, and socially acceptable. They found that poultry litter could be used on a commercial basis as an amendment to improve soils contaminated with petroleum hydrocarbons by providing optimum air porosity, carbon co-substrate, and inorganic nutrients for the bio-remediation. Both laboratory and field evaluations showed the significant removal of contamination when poultry litter was used for this purpose.

Poultry litter production and consumption can be restricted by using policy tools such as taxes, subsidies, or environmental standards. Even if markets for poultry litter become well established, farmers have to be aware of the total amount of poultry litter produced so that the total litter production does not exceed the demand from environmentally benign disposal alternatives.

When a standard based tax is imposed at the farm level, such policies tend to be infeasible in controlling non-point pollution (Moxey, A. and White, B., 1994). To control non-point sources of water pollution, alternatives such as emission charges based on estimates, taxes based on inputs or output, cross compliance requirements, marketable permits, deposit refund systems, subsidies for mitigating inputs, legal liability, easements and cost sharing programs should be implemented (McCann, L.M.J., Easter, K.W., 1999).

Another method to limit poultry litter production to environmentally safe levels is to distribute permits to poultry producers. Such permits should be tradable on the open market and should be freely transferable. Several authors report that a permit system is better than the standard based tax system to control either non-point or point sources of pollution. Permits also promote technical change and are easy to implement as one does not have to use trial and error method as in the tax system.

Permits may be the superior policy tool to control poultry litter related pollution in Georgia. An efficient implementation of this system achieves the targeted level of pollution at a minimum resource cost. If a permit system is based on the level of phosphorus in the litter, the permissible levels can be modified after each year depending upon the level of phosphorus in the soil. Therefore, this system has the potential to be efficient even in a dynamic setting. Also the level of information intensity needed for the regulation is minimal. Since the total numbers of permits are initially distributed based on the level of total poultry litter utilized in fertilizer and cattle feed, it is not difficult to set the new standard even in the face of economic change. The advantage of setting the poultry litter production using the permit system is to continuously search for phosphorus reducing technology in poultry litter. Since the permit is considered as the revenue source for the government, it is also a politically attractive tool for operationally regulating poultry litter production.

2.3 Review of Nutrient Transfer Programs in U.S.

Numerous management programs and practices exist with purpose of reducing environmental impacts from agricultural operations. In the poultry industry, there are several such programs that have been strongly promoted and supported throughout the years. One such management program is the application of best management practices on agricultural operations. These practices have been developed by the Natural Resource Conservation Service with detailed specifications and recommendations and can be found in the Field Office Technical Guide (Natural Resource Conservation Service, 2004).

Nutrient management plans are one of the most important programs among best management practices. They have been widely used and are well established as a method for producers to decrease negative environmental impacts and to properly utilize nutrients to enhance farm profits. The United National Strategy that was released on March 9, 1999 by the U.S. EPA and U.S. Department of Agriculture (USDA) set forth a national goal of developing comprehensive nutrient management plans for all AFOs in the United States.

On the basis of Nutrient Management Plans a lot of states (especially those top poultry producing such as Georgia, Arkansas, Alabama, and Virginia.) have initiated nutrient transfer programs taking into consideration the environmental and economic aspects of poultry litter through transporting from poultry producing counties to crop producing areas. Below we will discuss about some of the nutrient transfer programs held by major poultry producing states.

Alabama: Alabama is the third largest broiler producing state in the U.S., and the broiler industry is the largest in the state (www.ag.auburn.edu). This results in a large amount of poultry litter, causing water quality issues as phosphorus is emitted into water bodies from runoff due to excess land application or litter storage. Most of this poultry litter comes from North Alabama, as the Alabama Agricultural Experiment Station (AAES), at Auburn University states, "The four major boiler producer counties (Cullman, Blount, DeKalb, and Marshall) are all located in North Alabama" (www.ag.auburn.edu). AAES researchers divided North Alabama's counties into two groups: surplus and deficit according to the amount of litter generated and crop acreage (www.ag.auburn.edu). As AAES writes, "Surplus counties are those counties where broiler litter produced is in excess of crop nutrients need in the county based on the phosphorus consistent application rate. The deficit counties are those in which litter produced is less than the nutrient needs of the crops grown in the county" (www.ag.auburn.edu). Non-point source pollution, largely from poultry operations, "accounts for approximately two-thirds of the water quality impairments in Alabama's streams and lakes" (www.adem.state.al.us).

In efforts to deal with the water impairment problems, Alabama has developed a poultry litter distribution program that moves poultry litter from areas with high litter concentrations to other areas of the state to be used for land application. According to Mike Rowden of the NRCS, Alabama began to receive 319 funds from the EPA about four years ago (roughly 2003). The transport of litter costs $2 per ton, and all funds toward the program (state and EPA) totaled somewhere from $60,000 to $100,000 (in 2003). Since then, Alabama has made some modifications to the program, mainly using Environmental Quality Incentives Program (EQIP) funds through the NRCS, a USDA agency. The table below shows the funds provided through EQIP by year from 2004 until mid 2007 according to Bill Hughes from NRCS.

Table 2.7 Funds Provided through EQIP by Year from 2004 to mid 2007

Year	Cost Shares by Year
2004	$572,646
2005	$494,468
2006	$459,424
2007	$140,020

Source: www.ag.auburn.edu

The Environmental Quality Incentives Program "was reauthorized to provide a voluntary conservation program … that promotes agricultural production and environmental quality …"

and will provide up to $450,000 for up to 10 years (www.nrcs.usda.gov). The program will pay litter-hauling costs to applicators, as long as litter has not been applied to the land in the last three years (www.aces.edu). The National Resources Conservation Service runs the program, and Alabama counties are free to decide how much EQIP money to designate towards poultry distribution (www.nrcs.usda.gov).

The EQIP project has certain guidelines regarding the transfer of poultry litter. First, the litter must be spread “according to a nutrient management plan” (www.aces.edu). A nutrient management program, or NMP, at the basic level, involves “estimating broiler litter quantities, determining nutrient value of broiler litter, mapping and calculating land area for spreading, and determining target crop and nutrient needs and timing for each field” (http://srwqis.tamu.edu). Secondly, litter must be stored properly until spreading (www.aces.edu). Next, “ten cents per ton per loaded mile … will be paid to the litter receiving party,” and payment will be “according to actual mileage as shown on receiving County Mileage Limit map” (www.aces.edu). Also, litter must be from Alabama and hauled ten miles or more, and, lastly, County Mileage Limits will be doubled during November 15th to February 15th to transport hen litter from North Alabama (www.aces.edu). A Certified Animal Waste Vendor (CAWV) is the person that transports the poultry litter from one area to another. The CAWV must be knowledgeable of practices that relate to waste and its transport, environmental regulations, and “they assume legal liability for any environmental consequences of improper management of application of such wastes” (www.aces.edu).

The vendors are classified by county, and a transfer form should be completed to record litter transport (www.aces.edu). The market for poultry litter is growing in the state, as NRCS reports, “Last year the RC & D program saw the transfer of 6500 tons of litter” (www.nrcs.usda.gov). The Alabama Department of Environmental Management reports that the litter program has already led to environmental benefits, saying, "From October 2001 to July 2002, approximately 6188.82 tons of poultry litter were transported out of the nutrient-rich lands in Cullman County. This translates to approximately 336,000 pounds of nitrogen, 348,000 pounds of phosphorus, and 270,000 pounds of potassium collectively removed from the Duck, Cotaco, and 8-Mile Creek watersheds in the Tennessee Valley region" (www.adem.state.al.us).

Oklahoma: Many of Oklahoma's water sources, particularly Lake Eucha and Lake Spavinaw, have suffered notable water quality problems due to the high concentration of poultry operations in surrounding areas. Large amounts of phosphorus from fertilizers and animal waste have accumulated in Oklahoma watersheds, traveling downstream in runoff from land around the lakes into the water supply of many people. Excess phosphorus in lakes causes high growth rates of certain algae, resulting in odor and taste issues (www.cityoftulsa.org). This has become a problem for Oklahoma residents as several of the watersheds in the state have been designated as litter limited or litter restricted.

One possible solution to the problem is the generation of a litter market through which poultry producers and those who apply it can exchange waste later to be used as fertilizer outside the nutrient limited watersheds. Nutrient trading reduces the transaction costs of hauling litter through subsidies to the litter producers and transporters. The funds for the program to assist in the transport of the waste and use as incentives to litter producers are provided by the U.S. Environmental Protection Agency through the Non-point Source Program, with additional funds from the state of Oklahoma and the poultry industry (www.litterlink.com). As EPA states, "Clean Water Act Section 319 (h) funds are provided only to designated state and tribal agencies to implement their approved non-point source management programs" (www.epa.gov).

There are three incentive or subsidy programs that govern the Oklahoma poultry litter market. The first involves a subsidy to producers for fertilizer and a subsidy to haulers for transport. The Oklahoma Conservation Commission has contracted BMPs, Inc. to manage the program. BMPs, Inc. is a non-profit corporation whose existence was initiated by five poultry companies in northwest Arkansas (www.litterlink.com). As the Oklahoma Cooperative Extension Service reports, "BMPs, Inc. pays poultry producers a minimum of $2 per ton for their litter. Haulers currently receive 5 cents per ton per loaded mile, up to $8 per ton up to 160 miles (www.ok-littermarket.org). According to Sheri Herron at BMPs, Inc., the company manages the litter market for Oklahoma and Arkansas and spends about $300,000 per year on the program. Herron also says that BMPs, Inc. manages EPA funds and that 60% of the $300,000 comes from EPA and 40% from the poultry industry.

Apart from subsides to producers and transporters, two separate programs exist for non-poultry producers; The Environmental Quality Incentives Program (EQIP) and the Oklahoma State Tax Credit. EQIP is operated by the National Resources Conservation Service and grants litter to buyers through a ranking system based on "destination of poultry litter, soil test phosphorus level, and land application technique," Incentive payments to reimburse non-poultry producers for the costs of hauling the litter "range from $4.50 to $12 per ton…" (www.ok-littermarket.org). Applicants to the EQIP program must construct a Nutrient Management Plan and must not have "purchased or applied animal manure on land in the past three years" (www.ok-littermarket.org). Finally, the Oklahoma state tax credit grants litter buyers a tax credit of $5 per ton of litter purchased and transported (www.ok-littermarket.org). To receive the tax break the litter must be "purchased from a registered Oklahoma-based poultry operation located within an environmentally sensitive and nutrient-limited watershed; used or spread in a watershed that is not environmentally sensitive and nutrient-limited, and applied by a certified poultry waste applicator" (www.ok-littermarket.org). Sheri Heron of BMP's, Inc. reports that the tax credit program provides about $50,000 annually.

There are a number of other restrictions contained in the litter market system that deal with location, security, and application. For instance, to be approved by BMPs, Inc., growers must have poultry houses in Oklahoma's Eucha, Spavinaw, Illinois River, or Wister watersheds (www.litterlink.com). In reference to haulers, applicants are required to attend a workshop, have a tractor/trailer license, proof of insurance, and public security liability insurance in the amount of $750,000 with BMPs insured on the policy (www.litterlink.com). As for the buyers, candidates must own land outside the nutrient-limited watersheds that is row crop, pasture, forage, grass, or forestland (www.litterlink.com).

So far, the market for Oklahoma poultry litter has been successful in that there is a demand for litter to be used as fertilizer. As of May 2007, there are approximately 29 sellers, 98 buyers, and 30 service providers listed on the Oklahoma litter market database (www.ok-littermarket.org).

Virginia: The historic Shenandoah River, flowing from Front Royal, Virginia, to Harper's Ferry, West Virginia, is in the heart of Virginia's extensive agricultural industry. It is also "ranked among the state's highest for pollution potential from agricultural land" (http://www.alliancechesbay.org). Poultry production has become a profitable business in Virginia as the Shenandoah watershed is home to "nearly 600 families that raise commercial chickens and another 325 families producing turkeys" (http://www.vapoultry.com). In the state of Virginia as a whole, "six poultry processing companies make about $100 million in annual payments to contract growers in Virginia" (www.vapoultry.com). Expanding agricultural industries, specifically those with poultry operations, have become a problem for water sources as excess nitrogen and phosphorus pollute nearby waters. Agricultural operations in the Shenandoah watershed account for "roughly 60 percent of the nitrogen and 68 percent of the phosphorus entering the Shenandoah river" (http://www.alliancechesbay.org). To combat pollution problems in the Shenandoah watershed as well as in other watersheds across the state, environmental advocates and poultry producers alike have developed programs to redistribute poultry litter from areas with high nutrient concentrations to areas of low nutrient concentrations.

The first program began in 2003 when the Virginia Department of Conservation and Recreation, with support from Virginia poultry companies, "transported approximately 16,000 tons of poultry litter" (www.environmentaldefense.org). Dan Solomon of the U.S. Department of Agriculture (USDA) says the funds for this program came from the EPA. The Natural Resources Conservation Service branch of the USDA launched its own program in 2004, using funds from EQIP (www.environmentaldefense.org). EQIP is the Environmental Quality Incentive Program that offers money to promote both agricultural production and environmental quality. According to Solomon, EQIP funds have been the primary source of money for the program since 2005, using $115,708 in 2005, $350,513 in 2006, and $342,000 so far this year with 64 contracts on about 20,000 acres.

EQIP funds cannot exceed $450,000 over the course of the entire contract, and may pay between "35 to 75 percent to establish conservation practices" (www.privatelandownernetwork.org). The goals of the program are to encourage proper application of poultry litter and to promote nutrient management plans by the end-users of the poultry litter (www.environmentaldefense.org). According to Dan Solomon of the USDA, incentive payments can last up to three years, may not exceed $3000 per year, and are on average about $15 total per acre per county. Also, as Suzy Friedman reports, "Technical Service Providers can receive up to $6 per acre to develop certified nutrient management plans" (www.environmentaldefense.org).

There are certain requirements that have to be met in order to receive EQIP funding for poultry litter hauling. As previously mentioned, end users must develop a current Nutrient Management Plan. Dan Solomon of the NRCS outlines the rest of the requirements:

1. A current soil test must show that the phosphorus levels for field receiving litter is at a "Medium +" saturation level or below according to Virginia Tech criteria.
2. End users must store and apply poultry litter in accordance with state standards.
3. Manure stored for more than 14 days must be put under cover and placed in a manner that runoff will not become a pollutant. Cost-share may be available to construct a temporary storage facility.
4. End users must submit a signed "Poultry Litter Information Form" and bills for payment.
5. Poultry litter must come from one of the following "source" counties: Augusta, Rockingham, Page, Shenandoah, Prince Edward, Amelia, Nottoway, Accomac, Buckingham, and Cumberland.

Also, poultry growers and waste brokers (transfers litter) must keep records of all transactions and the waste must be tracked from starting point to end point (www.deq.state.va.us).

There is also a litter hotline, headed by the Virginia Poultry Federation and the Shenandoah Resources Conservation and Development Council that connects buyers, sellers, and haulers of poultry litter (www.shenandoahrcd.org).

This literature review of state and national regulations regarding the application of poultry litter provides the framework for further economic analysis of the disposal of litter from surplus areas subject to transportation costs and other factors. Linear Programming is an analytical tool used to solve the basic transportation problem subject costs, subsidies and environmental regulations.

2.4 Linear Programming Theory

Dating back to before World War II, Linear Programming (LP) has been used under numerous conditions as a tool for overcoming planning problems. LP is an important tool to know because “it gives an appreciation for the complex manner in which prices; yields; and such scarce resources as land, capital, and labor interacting during critical seasons to determine the best farm plan” (Beneke, Raymond R. and Winterboer, Ronald., 1973).

“Linear Programming, a type of mathematical modeling, is a prescriptive model where the values of independent variables are under the decision maker’s control” (Ragsdale, 1998). LP falls under Mathematical Programming, which allows decision makers to determine the most efficient use of limited resources in order to optimize production.

The production possibilities could be plotted on a two dimensional graph. Graphical representations of resource allocation in the agricultural industry are not practical for evaluating economical production. Production agriculture requires producers to utilize numerous inputs in the production of the different crop enterprises. This is precisely why LP is the best tool for optimization. LP is most useful for optimizing large-scale operations where *n* products are going to be produced using *m* inputs. Thousands of possible input applications exist leaving producers with millions of production plans to evaluate. Hence, “the great advantage of programming is that it allows one to test a wide range of alternative adjustments and to analyze their consequences thoroughly with a small input of managerial time” (Beneke Raymond R., Ronald Winterboer., 1973).

However, LP is not without its limitations. These limitations include: the inability to predict prices, the lack of operator risk preference accounting for diminishing marginal returns, and poor handling of decreasing cost. These limitations should not be enough to keep operators from using the method. It simply requires them to be knowledgeable about their firm, and have all the necessary data available. In other words, firms need to determine all of the coefficients required for optimization in the model. For example, because the model doesn’t know the current commodity prices or forecasted prices, the operator must have that information available.

Ragsdale (1998) gives five steps for formulating an LP model. First of all, the manager must understand the problem, and be able to clearly define the problem so that formulation depicts the production method. Second, the manager must identify the decision variables. For example, how many acres of cotton to produce? Next he/she should state the objective function as a linear combination of the decision variables. A system of equations explains the mathematical relationship between the decision variables. Next the decision maker must state the constraints as linear combinations of the decision variables. These constraints identify the restrictions the producer faces preventing a solution utilizing more resources than are available. Finally, the upper and lower bounds of the decision variables must be identified. These are defined by adding in any equality or inequality constraints.

LP is accomplished by using a series of equations to solve the optimization problem. Usually this formulation begins with the objective function and then applies a series of constraints. The equality or inequality constraints define the feasible region of production for the firm. This feasible region, however, is not the optimal point. Rather it is the set of all possible solutions. Chiang (1984) gives the following system of equations as a representation of a longhand problem. Note the equations will have *n* variables and *m* constraints.

$$\begin{aligned} &Maximize && \prod = c_1x_1 + c_2x_2 + \cdots + c_nx_n \\ &Subject\ to && a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq r_1 \\ & && a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \leq r_2 \\ & && a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \leq r_m \\ & && and\ x_j \qquad \geq 0 \qquad (j = 1,2, \ldots n) \end{aligned}$$

where $\prod$ is symbolic for the object to be maximized. The *x* variables are the choice variables and the *c* variables are their coefficients. The *r* variables on the RHS represent the restrictions imposed on the program.

The task of determining the optimal plan in LP is accomplished using the simplex method. To use the simplex method, all of the constraints must be entered as equalities. This is not typical of most production factors. Therefore, the inequality constraints must be transformed into equalities. This is accomplished by creating slack variables. This transformation of inequalities to equalities yields a system of linear equations. If more variables exist than constraints, then the variables used to solve the system of equations are basic variables. If a solution is obtained using these basic variables, then that solution is a basic feasible solution, which falls in the feasible region. Evaluating the different resource combinations will yield all of the solutions in the feasible region, and the boundary of that region. The solutions on the boundary line, or the production possibilities curve, are referred to as the extreme points. With so many points, how is the finite optimal solution to be determined?

Again Chiang (1984) demonstrates the transformation using slack variables. Given the objective function

$$\begin{aligned} &Maximize \quad \prod = 40x_1 + 30x_2 \\ &Subject\ to \quad x_1 \leq 16 \\ &\qquad x_2 \leq 8 \\ &\qquad x_1 + x_2 \leq 24 \\ &and \quad x_1, x_2 \geq 0 \end{aligned}$$

Adding slack variables gives,

$$\begin{aligned} &Maximize \quad \prod = 40x_1 + 30x_2 + 0s_1 + 0s_2 + 0s_3 \\ &Subject\ to \quad x_1 + s_1 = 16 \\ &\qquad x_2 + s_2 = 8 \\ &\qquad x_1 + 2x_2 + s_3 = 24 \\ &and \quad x_1, x_2, s_1, s_2, s_3 \geq 0 \end{aligned}$$

where $\prod$ represent profit, x_n represents the decision variables, and s_n represents the slack variables. The slack variables help to maintain the non-negative requirement. Since their coefficients in the objective function are 0, they may be omitted altogether. Adding the slack variables helps to determine the basic feasible solutions and the extreme points.

"The simplex method operates by first identifying any basic feasible solution (or extreme point), then moving to an adjacent extreme point, if such a move improves the value of the objective function. When no adjacent extreme point has a better objective function value, the correct extreme point is optimal and simplex method terminates" (Ragsdale, 1998). In order to move from one extreme point to another, basic variables are interchanged with non-basic variables.

Linear programming will be used to analyze the transportation costs associated with moving poultry litter from surplus to deficit regions. The issues surrounding the use of poultry litter as fertilizer have been discussed as well as have the environmental regulations and policies. The data and methodology are discussed in Chapter III.

CHAPTER III

METHODOLOGY

This chapter includes a description of the data and the methodology used in this study. More specifically, four step-by-step methods were used: 1. The division of the counties into "removal" and "application" counties in terms of excessive litter production and their transfer to mainly major crop producing counties; 2. The nutrient replacement value calculation based on fertilizer cost analysis of broiler litter to commercial fertilizer; 3. A linear-programming model whose objective is to minimize the total expenditure on crop nutrients by substituting broiler litter for chemical fertilizer; and 4. A production function that estimates yield response of selected crops to poultry litter with the optimal application rate in order to obtain the demand for poultry litter.

3.1 Data Collection and Identification of "Removal" and "Application" Counties

Most of the data were collected from Georgia Agricultural Statistics Service reports (GASS, 2007). The data include acreages for each of the six selected crops as well as broiler production by county. Estimated broiler litter production for each county was calculated from the number of broilers reported for the county. The majority of the state counties produce insufficient broiler litter to meet the nitrogen, phosphorus, and potassium needs of the respective county. The major crop-producing counties are Mitchell, Burke, Bulloch, Colquitt, and Dooly (Figure 2.1). Since the highest crop- and litter-producing counties are not the same, the distances between the crop and litter-producing counties are among the major variables influencing the optimum litter transportation decision. The distance data on 159 by 159 matrixes was obtained through “Network analysis” of GIS software, ArcGIS 9.2, and the fertilizer material and price data from 2006 to 2008 was received from Agricultural Price Summary, USDA.

At the request of the Georgia Environmental Protection Division of the Department of Natural Resources, Environmental Quality Incentive Program (EQIP) members had investigated possible methods of identification of counties that may present higher risks of water quality impairment in Georgia, in 2006, on the basis of Georgia Statewide Pilot Poultry Litter Transfer Program. While the utilization of poultry litter as a fertilizer and soil amendment is recognized as the most effective utilization strategy, long-term use leads to a build-up of phosphorus in the soil due to imbalances between the nutrient content of litter and the nutrient needs of most crops. High soil test P levels can lead to increased risk of eutrophication in surface water (Radcliff, D.E., M.L. Cabrera., and W.C. Merka., 1996).

Calculation of Phosphorus Application and Uptake

The measures of P risk were based on the following four initial values for each county: 1. P generated in poultry litter. 2. P removed by crops in the county. 3. Acres of crops and pasture in the county, and 4. Total acres in the county. All the data on poultry and crop production for each county used to make the calculations were from the Center for Agribusiness and Economic Development’s 2002 Farm Gate Report. The values of P generated per poultry unit were determined based on Standards of the ASAE and provided by Dr. John Worley of the Department of Biological and Agricultural Engineering at the University of Georgia. These values were: Broilers- 0.1 lb P per year per space (Space means room for one bird in a house), and Hens- 0.4 lb P per year per space. The values for crop removal of P per unit of yield are those published by Lander, Moffitt, and Alt (1998) with the addition that P removal by grass and hay was considered to be the same as for the published values for alfalfa hay. Phosphorus removal for pasture was 11 lb P per acre (Lander, Moffitt, and Alt, 1998) with acres of pasture based on numbers of beef cows in each county times a constant. Yield values were for the crop year 2002 as reported in the 2002 Georgia Farm Gate Value Report. Although this was a dry year, comparison with other years revealed that yield differences between years were small.

3.2 Potential Value of Broiler Litter as Fertilizer in Georgia

Because of crop nitrogen/phosphorus nutrient ratio requirements, rotation considerations, and other management requirements, some crops are more suitable than others for nutrient application with litter. An example of a crop relatively well-suited for poultry litter applications is corn (Pelletier, 1999). Litter applications in spring before planting can provide nutrients at the time needed by growing plants. An example of a crop whose nutrient needs are less well-served by poultry litter is soybeans (Pelletier, 1999). Soybeans, together with peanuts and hay, do not require nitrogen applications, and a valuable nutrient source in the poultry litter would be underutilized.

Another important criterion in determining the suitability of a crop for poultry litter applications is the manner in which fertilizer is applied. Some crops require a very uniform fertilizer application. For crops such as wheat and barley, the application of poultry litter must be closely monitored to ensure that nutrient needs are not exceeded at any given time. Although wheat and barley are not best-suited crops for poultry litter, success using poultry litter for fertilizer can be achieved with monitored applications at the appropriate times (Pelletier, 1999).

Broiler Litter Nutrient Availability to Crops

Nutrient concentrations per ton of broiler litter given in table 2.3 will help to estimate the nutrient concentration of a “typical” ton of litter. The given nitrogen concentration is 64 pounds, phosphorus concentration is 54 pounds, and potassium concentration is 48 pounds per ton of broiler litter.

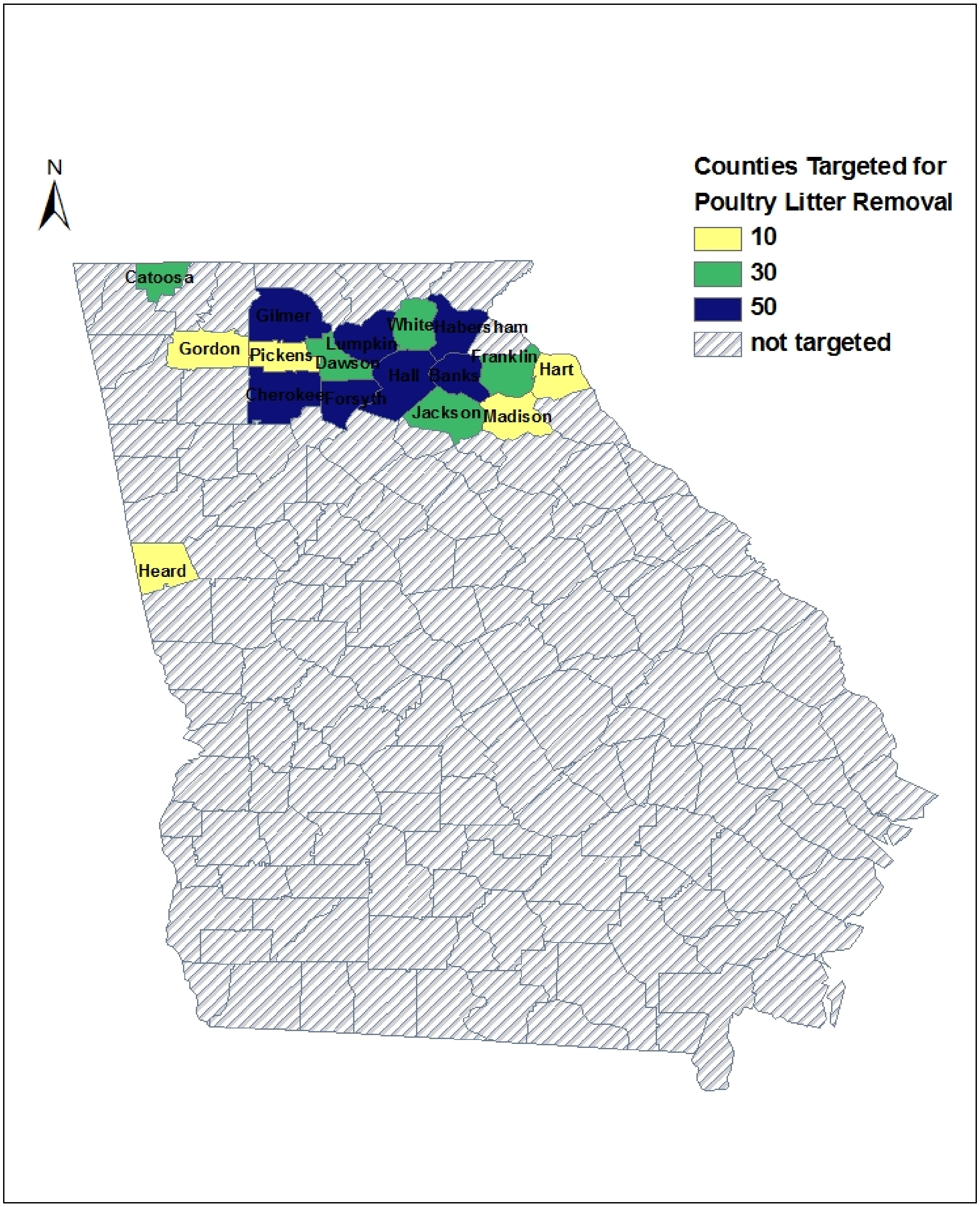

Figure 3.1 Poultry Litter Removal Counties

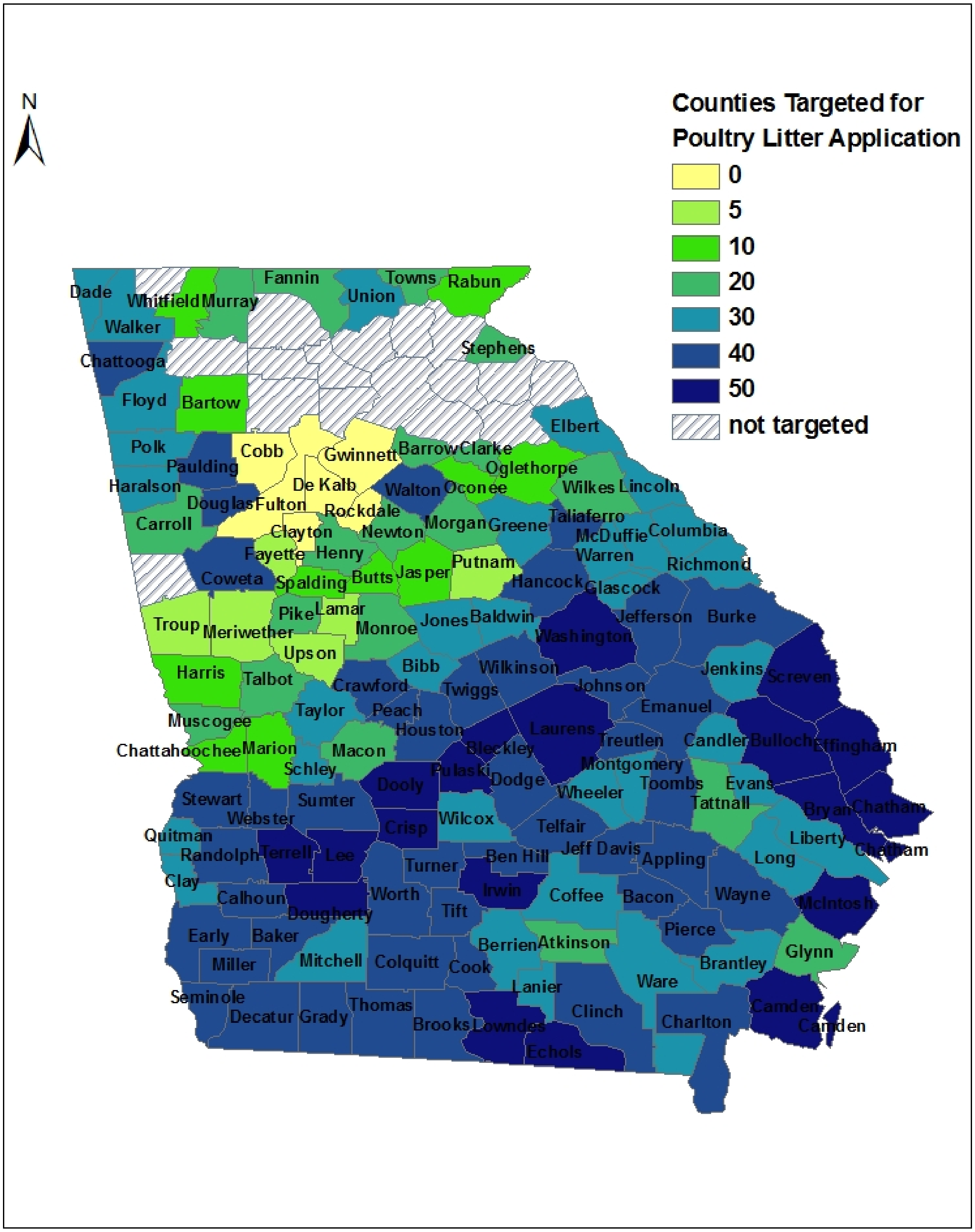

Figure 3.2 Poultry Litter Transfer for Application

Not all nitrogen in broiler litter removed from a production facility will be immediately available to the crops on which it is applied. Some nitrogen is lost through volatization ammonium (NH_4-N). A portion of organic nitrogen is not available to plants in the first year after application. In estimating nitrogen availability from poultry litter applications, the following assumptions are used:

1. Organic/inorganic nitrogen per ton (Mitchell, C.C., Donald, J.O., Payne, V.W.E., 1992)

    Organic N: 75 percent

    Inorganic N: 25 percent

2. Ammonium volatization after application (*Virginia Nutrient Management Standards and Criteria)*

    Spring application, no incorporation: 50 percent

3. Organic N availability

    Year 1: 50 percent

    Year 2: 12 percent

    Year 3: 5 percent

    Year 4: 2 percent

Therefore, the "typical" ton of broiler litter estimates the following nitrogen availability during the first year after application:

1. Organic N: 64 lbs x 75% organic x 50% Year 1 availability = 24 lbs/ton
2. Inorganic N: 64 lbs x 25% x 50% availability after volatization = 8 lbs/ton
3. Total Year 1 availability: 24 lbs/ton Organic N + 8 lbs/ton Inorganic N = 32 lbs/ton N available

Table 3.1 shows that after four years of annual applications, 41 pounds of nitrogen will be available to plants from each ton of litter applied. According to Mitchell *et al.* (1992), all phosphorus and potassium applied are considered available to the crop in year 1. Accordingly, it is assumed that each ton of broiler litter applied to crops provides the following crop-available nutrients during the first year after application: nitrogen 32 lbs/ton, phosphorus 54 lbs/ton, and potassium 48 lbs/ton.

Table 3.1 Crop Available Nitrogen from Annual Applications[1]

Pounds of N Available per Ton of Applied Litter					
Year					
Annual Applications	**1**	**2**	**3**	**4**	**5**
1st	32	6	2	1	-
2nd	-	32	6	2	1
3rd	-	-	32	6	2
4th	-	-	-	32	6
5th	-	-	-	-	32
Total	32	38	40	41	41

[1]N pounds rounded to nearest integer

Procedures for Estimating Crop Needs

Several factors determine the potential litter nutrient needs of crop enterprises suitable for poultry litter applications. The first factor includes the nutrient needs of each crop. The nutrient needs for the selected crops were calculated based on the data on crop yield and nutrient crop needs for each crop and county.

In addition, phosphorus uptake by crop was estimated. Agronomic recommendations indicate the nutrients that the plant needs to achieve optimum growth. Plant uptake, on the other hand, indicates the amount of nutrients that the plant removes from the soil. For “high” and “very high" soil test phosphorus levels, there is expected to be no agronomic response from phosphorus applications. In such cases, nutrient management planning does allow for application of phosphorus in an amount equal to expected plant uptake. Potential phosphorus applications by county and crop were thus calculated based on both agronomic needs and plant uptake, and the greater of the two estimates is used here as reflecting county phosphorus need. The plant uptake needs result in state phosphorus applications higher than those estimated for application based on agronomic needs.

Total Nutrient Needs

Based on the methodology described above, county nutrient needs were determined for each selected crop on a county basis. A weighted average of these results on a state basis is found in Table 3.2.

Table 3.2 Georgia Weighted Average Crop Nutrient Needs[1], 2007

Crop	**Nitrogen (N) (lbs/acre)**	**Phosphorus (P_2O_5) (lbs/acre)**	**Potassium (K_2O) (lbs/acre)**
Cotton	20.64 (41.19-9.69)[2]	8.19 (16.35-3.85)	10.16 (20.27-4.77)
Corn Grain	120.25 (175.5-9)	47.21 (68.9-3.53)	35.63 (52-2.67)
Corn Silage	75.42 (110.07-5.64)	27.90 (40.72-2.09)	75.42 (110.07-5.64)
Wheat	62.49 (93.75-18.75)	31.24 (46.88-9.88)	16.87 (25.31-5.06)
Peanuts	0	17.24 (21.45-1.65)	27.43 (34.13-2.63)
Soybean	0	27.32 (82-4.1)	49.31 (148-7.4)
Hay	0	41.02 (180-9)	118.58 (520-26)

[1]Crop nutrient need by county weighted by harvested acreage across state calculated from Georgia Agricultural Statistics Service (GASS)

[2]Range of nutrient need across counties

Table 3.3 summarizes estimates of total crop nutrient needs for 2007. The amount of poultry litter necessary to meet such nutrient needs on a phosphorus basis (assuming that no additional phosphorus is applied through commercial fertilizer applications) is also indicated. Litter needs are based on the weighted average poultry litter nutrient concentrations indicated in Table 2.3. Litter needs based on phosphorus and nitrogen needs by crop and county are shown in Appendix C.6. Shifting from nitrogen to a phosphorus basis for litter applications indicates that the amount of litter which can be applied is reduced by more than 50 percent.

Table 3.3 Georgia Crop Nutrient and Litter Needs, 2007

Crop	**Nitrogen (million lbs.)**	**Phosphorus (million lbs.)**	**Litter Need Based on:**	
			Nitrogen Basis ('000 tons)	**Phosphorus Basis ('000 tons)**
Cotton	21.73	8.62	339.50	159.67
Corn Grain	55.74	21.88	870.88	405.22
Corn Silage	34.96	12.93	546.21	239.48
Wheat	17.91	8.95	279.81	165.79
Peanuts	0	9.27	0	171.68
Soybean	0	7.50	0	139.00
Hay	0	32.37	0	599.50
Total	130.34	101.52	2036.40	1880.34

Economic Value of Broiler Litter versus Commercial Fertilizer

Determining the economic value of broiler litter relative to commercial fertilizer helps to estimate the potential use of broiler litter as fertilizer in Georgia. Number of studies, for instance, Bosch and Napit (1992), indicate that poultry litter could be a viable alternative to commercial fertilizer when applied on a nitrogen basis. In order to assess the economic feasibility of broiler litter as fertilizer, it is necessary to estimate the relative costs of fertilization with commercial fertilizer compared to the costs of using broiler litter as fertilizer.

Several key assumptions are used to make this comparison. The first assumption is based on estimated crop available nitrogen as described in Table 3.1. The estimated crop available nitrogen per ton of broiler litter is 32 pounds in the first year. If annual applications in equal quantities are made for 4 years, 41 pounds of nitrogen will be crop-available per ton due to carryover effects. However, in this study, the conservative first-year value of 32 pounds will be used. Another key assumption is that broiler litter will be applied on a phosphorus basis. Beginning in October of 2001, nutrient management plans for poultry growers will require that litter applications on their farms be made on a phosphorus basis.

Table 3.4 Georgia Average Chemical Fertilizer Nutrient Application Rates and Costs[1]

Crop	N Applied (lbs/acre)	P_2O_5 Applied (lbs/acre)	K_2O Applied (lbs/acre)	N Cost ($/acre)	P_2O_5 Cost ($/acre)	K_2O Cost ($/acre)	Total Cost ($/acre)
Cotton	20.64	8.19	10.16	20.23	7.53	7. 32	44.58
Corn Grain	120.25	47.21	35.63	117.85	43.43	25.65	196.43
Corn Silage	75.42	27.90	75.42	73.91	25.67	54.30	163.38
Wheat	62.49	31.24	16.87	61.24	28.74	12.15	111.63
Peanuts	0	17.24	27.43	0	15.86	19.75	45.11
Soybean	0	27.32	49.31	0	25.13	35.50	70.13
Hay	0	41.02	118.58	0	37.74	85.38	132.62

[1]Application rates are acreage-weighted averages of estimated county rates. Commercial nutrient costs for this analysis are $0.98/lb (N), $0.92/lb ($P_2O_5$), and $0.72/lb ($K_2O$). Total cost includes $9.50/acre application charge. Source: *Agricultural Price Summary,* USDA, 2008 (Nutrient Prices); *Doane's Ag. Report,* Vol. 69, No. 12-6, 3/24/06. (Fertilizer Application Costs).

Using these assumptions and secondary data sources, nutrient costs with chemical fertilizer and broiler litter as alternative nutrient sources for cotton, corn (grain and silage), wheat, peanuts, soybean, and hay were estimated. Table 3.4 summarizes the annual costs for commercial fertilizer for each crop enterprise based on weighted average Georgia crop nutrient needs presented in Table 3.2. These commercial fertilizer costs are based on 2008 average prices.

To estimate relative costs of broiler litter versus commercial fertilizer, the costs of buying, storing, assembling, and applying broiler litter must be estimated. The removal, assembly, storage, testing, loading, application, and brokerage cost estimates are based on the method developed by Bosch and Napit (1991). The figures were updated and adjusted with more recent equipment and labor costs based on 2008 *Agricultural Prices* and on information from EQIP program from Oklahoma 2006 (EQIP, 2006). It is assumed that litter is hauled 10 miles in a walking trailer to a storage facility. A front-end loader is used to fill a 14-ton fertilizer spreader. Loading and spreading takes 50 minutes per load.

Table 3.5 Total Broiler Litter Application Cost

	$/Ton
Removal	$3.56[1]
Assembly	$4.00[2]
Storage	$2.00[2]
Testing	$0.75[1]
Loading	$0.70[1]
Spreading	$3.70[1]
Brokerage	$1.00[1]
Total	**$15.71**

Source: [1]*Agricultural Price Summary,* USDA, 2006

[2]Kenneth Young *et al.* (2005)

The following assumptions are used to estimate broiler litter application cost: 1) 8,000 tons per year hauling capacity; 2) 1 full-time employee; 3) 25-ton walking bed trailer to haul litter; 4) 4,000-ton storage capacity for assembling litter haul; 5) $0.70 per ton loading cost; and 6) 14-ton spreader on truck.

These assumptions are used to calculate costs per ton of broiler litter (Table 3.5). Costs assume that litter is cleaned out of houses in exchange for free litter.

Transportation Costs

Most of the litter growers Georgia indicate that poultry litter can be transported in an 18-wheeler walking trailer with 25-ton capacity at a cost of ranging from $2 to $5 per ton-mile without a backhaul including the cost of loading litter at a centralized litter storage location. The cost without a backhaul is used here, but opportunities exist for economizing on transport costs with backhauls if bio-security issues could be resolved. The distance that poultry litter can be transported to satisfy phosphorus needs at a per-acre nutrient cost less than or equal to that of commercial fertilizer is found by equating the two costs and solving for mileage:

FC = (N_rec*PN) + (P_rec*PP) + (K_rec*KP) + FAPP

LC = PL_rec*((TC*BTD) + LAPP) + PN*(N_rec - (PLN*PL_rec)) + PK*(K_rec - (PLK*PL_rec)) + FAPP

Where (all costs on per-acre basis) FC is total cost of commercial fertilizer nutrients and application; LC is total cost of litter, application and chemical fertilizer supplements; N_rec, P_rec, K_rec are nutrient needs; PN, PP, and PK are unit commercial fertilizer prices; PL_rec is tons of poultry litter to satisfy phosphorus needs, PLN, PLP, and PLK are nutrient concentrations in poultry litter; FAPP is commercial fertilizer application cost, LAPP is all costs of litter application except transport, TC is the per-ton/mile litter transport cost; and BTD is the breakeven transport distance. Equating FC = LC and solving for BTD, gives us the breakeven distance of litter transportation for each selected crop.

3.3 Cost Minimization Model

A linear programming model was developed, which assumes the satisfaction of the crop nutrient needs of state. The objective of the model is to reduce the total costs of satisfying nutrient needs in the state without over applying phosphorus and nitrogen. The model allows for satisfying the nutrient needs of the region by applying either chemical fertilizer or litter, using the region's constraints on broiler litter production and crop acreages. The phosphorus-consistent rule for litter application was a binding constraint imposed on the six selected major crops grown in the state: cotton, corn, wheat, peanuts, soybean, and hay.

The objectives of the cost-minimizing model were to:

1. minimize the total expenditure on crop nutrients by substituting broiler litter for chemical fertilizer in Georgia,
2. analyze the economic tradeoff associated with that substitution,
3. provide an overview of the economic interdependencies inherent in broiler litter transportation for removal and application counties

The economic model for our analysis was:

$$\min Z = \sum_i \sum_c \sum_k C_{ikr} * X_{ick} \qquad (1)$$

Subject to:

$$\sum_i N_{NKti} * X_{ick} \geq R_{NKtck} \;\; and \;\; \sum_i N_{Pti} * X_{ick} = R_{Ptck} \qquad \forall\, t, c, k \qquad (2)$$

$$\sum_c \sum_k X_{PL,c,k,r} \leq PL_r \qquad \forall\, r,\; r{:}\, removal\ county \qquad (3)$$

$$\sum_c \sum_k F_{ck} = R_k \qquad (4)$$

Here, X_{ick} is fertilizer i (including poultry litter) applied to crop c in county k, C_{ikr} is total cost per ton of fertilizer i in county k ($C_{ikr}=P_i+A_i+T_i*D_{ikr}$: where, P_i is the price of fertilizer i, A_i is the application costs for both poultry litter and commercial fertilizer, T_i is the transport cost associated with transferring the poultry litter, and D_{ikr} is the distance from removal county r to application county a,); N_{ti} is the pounds per ton of nutrient t in fertilizer i (t=N-nitrogen, P-phosphorus, and K-potassium), R_{tck} is the crop c need for nutrient t in county k; $X_{PL,c,k,r}$ is the poultry litter applied to crop c in county k (both removal and application), PL_r is the total available poultry litter from both removal county r and local application county a. Equation (1) is the objective function and equations (2) – (4) are constraint equations.

The objective function, equation (1), minimizes the total cost of meeting nutrient requirements for six selected crops in the state which entails minimizing the costs of chemical fertilizer, broiler litter application, and transportation. Broiler litter hauling, loading, and spreading costs are built into the model. The first constraint, equation (2), requires that all nutrient needs of the region's crop be met from either broiler litter or chemical fertilizer. The second constraint, equation (3), indicates that the total litter used in removal and application counties cannot exceed the total amount of litter produced in the state. Equation (4) states that all of the crop land in the six crops in each county sum to the total crop land planted in the six crops in the region (R).

3.4 Production Function

This methodology was based on the study held by Mullen and Gascho (2001). To determine the application rate of broiler litter that maximizes profits for a producer, an expression for net returns as a function of litter application rates is derived for each crop. A producer's net returns to the production of crop j ($\prod_j$) are equal to the product of the price received for crop j (P_j) and total yield of crop j (Y_j), minus total costs incurred in the production of crop j (C_j). Net returns can be expressed acre basis by simply dividing $\prod_j$ by the number of acres planted crop j (A_j), as in equation (5):

$$\frac{\Pi_j}{A_j} = \pi_j = P_j y_j - \sum_i w_i x_{ij} \qquad (5)$$

Where: π_j = per acre net returns to crop j

y_j = yield per acre of crop j

w_i = wage paid to input i

x_{ij} = use of input i per acre of crop j

Net returns per acre can be maximized with respect to input use by expressing per acre yield as a function of input level such that $y_j = f(x_j)$. Maximization leads to the standard set of first order conditions:

$$\frac{\partial \pi_j}{x_{ij}} = P_j f_i - w_i = 0 \qquad \forall\, i \qquad (6)$$

And a matrix of second order derivates that is negative semi-definite.[2] To determine the profit maximizing level of input use per acre, the system of equations represented by (6) is solved simultaneously for the x_{ij}, leading to a set of input demand functions dependent on the price of the crop and the price of inputs, $x_{ij}^* = g(P_j, w_i)$. Within a given area, total demand of an input, X_i^*, may be calculated using equation (7):

$$X_i^* = \sum_j A_j\, x_{ij}^* \qquad (7)$$

Data from a 4-year experiment (1996-1999) conducted at the Coastal Plain Experiment Station in Tifton, Georgia, were used to estimate the yield response of each crop to broiler litter application. The experiment examined the response of each crop within a double-cropped,

[2] Here f_i refers to first derivative of production function $f(x_{ij})$ with respect to input i.

irrigated 3-year rotation to four litter application rates (0, 2, 4, and 6 tons per acre)[3]. Broiler litter (broiler manure and wood shavings) was mechanically broadcast before each crop in a randomized complete block design with 4 blocks. For the initial summer crops in 1996, the litter was broadcast and the fallowed soil was disk-tilled and planted conventionally. For the duration the 4-year experiment, winter crops were no-tilled and summer crops were strip-tilled with row sub-soiling into residues remaining from the previous crop, following broadcasting of the litter treatments. No deep tillage was performed during the experiment. No commercial fertilizer was applied. Irrigation was applied for full yield potential by a lateral-move sprinkler system. All crops were grown with best management practices, except for the variables of broiler litter rate imposed.

The biological response of selected row crops – cotton, corn, wheat, peanuts, soybean, and hay– were estimated as a quadratic function of broiler litter application rate, as in equation (8). The marginal influence of litter is represented by the coefficient β_j. All other factors affecting yield are reflected in the intercept, α_j.

$$y_j = \alpha_j + \beta_j R_j + \gamma_i R_j^2 \qquad (8)$$

for j = {cotton, wheat, and peanuts}

where, R_j = Ton of poultry litter per acre.

Equation (8) was estimated by ordinary least squares. Using the crop production functions from equation (8), the per acre demand for poultry litter for each crop can be derived, as in equation (9). Substituting in the estimated values of α, β, and γ, the price of the crop, and the cost of poultry litter leads to an estimate of the profit maximizing litter application rate, R_j*.

$$R_j^* = \left[\left(\frac{w_{litter}}{P_j}\right) - \beta_j\right] / (2 * \gamma_j) \qquad (9)$$

[3] The rotation used was cotton-fallow, peanut-canola, millet-wheat. Each crop was grown in each year of the experiment.

For the analysis, the P_j for the selected row crops were taken to be the marketing year average price received by Georgia farmers from 2007 (GASS, 2007). Table 3.6 presents the prices used in the analysis.

Table 3.6 Price Received by Farmers for Each Crop, 2007

Crop	Average Price, 2007
Cotton ($/lb. lint)	0.70
Corn ($/bu.)	3.44
Wheat ($/bu.)	4.32
Peanuts ($/lb.)	0.23
Soybean ($/bu.)	7.57
Hay ($/ton)	76

Source: www.georgiastats.uga.edu

From the row crop producer's perspective the cost of using poultry litter as a fertilizer may be broken into three categories: (1) the price of the litter itself, (2) the cost of transporting the litter from the broiler to row crop fields, and (3) the cost of spreading the litter on the fields. Estimates of the price of poultry litter are difficult to find in the literature. One recent estimate of the price of poultry litter is $10 per ton (GASS, 2007). The transportation and spreading costs were estimated by EQIP (2006) and obtained from *Agricultural Price Summary* (USDA, 2006) to be $3.50 per mile and $3.70 per ton, respectively. The total cost of poultry litter, W_{litter}, to the row crop producer is equal to the price of litter plus the transportation and the spreading costs.

CHAPTER IV

RESULTS AND IMPLICATIONS

This chapter reports the fertilizer cost analysis of broiler litter as a crop nutrient compared to commercial fertilizers with regard to nutrient replacement. It also demonstrates the breakeven transportation distances (BTDs) for all selected crops. The results of cost minimization model are also presented in this chapter. The overall model is discussed without any restrictions. Priority-based model takes into consideration that all surplus litter produced in "removal" counties should be transported. Sensitivity analysis and shadow prices discussion will end the second part. The production function results and analyses will close chapter IV.

4.1 Broiler Litter as a Crop Nutrient Source

Among the several solutions outlined for the broiler litter disposal in the state are as animal feed and as a source of crop nutrients. However, broiler litter is not widely accepted as an animal feed; this study focused on its use as a crop nutrient. The average macronutrient (N-P-K) composition in 1 ton of broiler litter is 64 pounds of N, 54 pounds of phosphorus and 48 pounds of potassium (Ritz and Merka, 2004). Current estimates of the value of the macronutrient content in broiler litter is $146.96 per ton, using 2008 market prices (USDA, NASS, 2008) for the macronutrients based on commercial fertilizer prices. Imperfect information about the benefits of reasonable long-term application of broiler litter, and the absence of well-functioning market have resulted in current selling prices of approximately $10 per ton "as is" basis when it leaves the broiler production facilities.

The chemical fertilizer cost used in this analysis was obtained from Agricultural Price Summary (USDA, NASS, 2008). According to the NASS (USDA) report, the prices of customapplied N-P-K in the South-East region of the US were $0.98, $0.92, and $0.72 per pound, respectively. Hauling and application costs were $0.70 per mile; and $9.50 per acre for commercial fertilizer and $15.71 per acre for broiler litter application. At current prices, using the recommended levels of chemical fertilizer will cost $183.20, $172.20, $144.00, $63.60, $94.40, and $38.00 per acre for corn, cotton, wheat, peanuts, soybean and hay, respectively. Given the assumed nutrient content in broiler litter and the prevailing costs of loading ($0.70/ton), hauling ($0.70/ton per mile), and spreading ($3.70/acre), using broiler litter at the recommended rate will satisfy the phosphorus requirement at a cost saving of up to $53.80 per acre over chemical fertilizer. This, the difference between the cost when fertilizer only option is used and fertilizer plus litter is used, suggests that litter can be transported economically within a 151-mile radius of a production facility.

This constraint on distance accommodates an economic transfer of litter from the concentrated litter-producing “removal” counties to the major-crop producing counties such as Dooly and Bulloch. The break-even distances for the economical utilization of litter in the production of corn, cotton and other selected crops in Georgia based on the stated assumptions are identified in table 4.1. Because of the carry-over effect of nitrogen from 1 to 4 years, litter can be transported further if it is applied continuously. For example, in cotton, litter can be economically transported 139 miles in the first year, but the break-even distance increases annually to 151 miles in the fourth year.

Table 4.1 Economics of Using Broiler Litter as a Substitute of Chemical Fertilizers for Selected Crops in Georgia (per acre basis)

Crop	Year of crop production	Cost when fertilizer only option is used	Cost if (fertilizer + litter is used ($)[1]			Savings from (fertilizer + litter) option ($)	Breakeven distance for litter transportation under (fertilizer + litter) option (miles)[2]
			N	K	Litter		
Corn	Year1	$183.20	$94.39	$3.23	$36.80	$33.07	131.10
	Year 2	$183.20	$90.04	$3.23	$36.80	$37.42	137.30
	Year 3	$183.20	$88.59	$3.23	$36.80	$38.87	139.40
	Year 4	$183.20	$87.87	$3.23	$36.80	$39.60	140.40
Cotton	Year1	$172.20	$39.44	$25.46	$46.00	$45.60	139.30
	Year 2	$172.20	$33.97	$25.46	$46.00	$51.06	147.10
	Year 3	$172.20	$32.14	$25.46	$46.00	$52.89	149.70
	Year 4	$172.20	$31.23	$25.46	$46.00	$53.80	151.00
Wheat	Year1	$144.00	$55.19	$3.23	$36.80	$33.07	131.10
	Year 2	$144.00	$50.84	$3.23	$36.80	$37.42	137.30
	Year 3	$144.00	$49.39	$3.23	$36.80	$38.87	139.40
	Year 4	$144.00	$48.67	$3.23	$36.80	$39.60	140.40
Peanuts	Year1	$63.60	$ -	$16.65	$27.60	$3.64	122.40
	Year 2	$63.60	$ -	$16.65	$27.60	$3.64	127.80
	Year 3	$63.60	$ -	$16.65	$27.60	$3.64	128.70
	Year 4	$63.60	$ -	$16.65	$27.60	$3.64	129.50
Soybean	Year1	$94.40	$ -	$32.03	$36.80	$9.86	131.10
	Year 2	$94.40	$ -	$32.03	$36.80	$9.86	137.30
	Year 3	$94.40	$ -	$32.03	$36.80	$9.86	139.40
	Year 4	$94.40	$ -	$32.03	$36.80	$9.86	140.40

[1]The Georgia Cooperative Extension Service recommended fertilizer rate is used for P based litter application

[2]The cost saving from litter is used to find the break-even distance.

At current price relationships, broiler litter can be a profitable source of nutrients in the state if transported up to 151 miles. This means that potentially, broiler litter can be used to satisfy crop nutrient needs. However, it is unknown whether the nutrient needs of the state can be satisfied given environmental constraints at minimum costs. A linear programming model which was developed with the purpose of minimizing the costs will address these concerns.

4.2 Cost-Minimization Model

All counties in Georgia were divided into removal and application counties on the basis of the annual statistics for crop acreages and litter production. Removal counties were those in which litter production exceeds the cumulative nutrient demands for the six selected major crops. Similarly, application counties were mainly those in which litter production cannot meet the crops' nutrient demands. Seventeen removal and 142 application counties were identified in Table 4.2.

Table 4.2 Surplus and Application Amount of Broiler Litter Based on the Nitrogen and Phosphorus Requirement of Corn, Cotton, Wheat, Peanuts, Soybean and Hay in Georgia

Litter Surplus Counties	**Amount of Surplus Litter (tons)**	
	N Based	**P Based**
Banks	50,997	66,802
Catoosa	8,845	12,641
Cherokee	7,859	14,220
Dawson	16,681	20,431
Forsyth	6,043	8,513
Franklin	83,740	102,453
Gilmer	55,678	65,850
Gordon	23,067	47,178
Habersham	68,169	78,939
Hall	74,349	85,858
Hart	11,172	43,036
Heard	11,624	14,319

Jackson	39,845	58,032
Lumpkin	1,894	8,510
Madison	41,517	70,998
Pickens	-1,314	13,045
White	10,880	20,654
Total Surplus Counties	*511,046*	*731,479*
Appling	-63,939	-11,208
Atkinson	-19,361	10,198
Bacon	-49,821	-13,477
Baker	-82,659	-15,770
Baldwin	-16,954	-4,861
Barrow	-10,274	3,657
Bartow	-13,995	15,532
Ben Hill	-46,487	-11,975
Berrien	-65,300	-16,246
Bibb	-14,295	-3,827
Bleckley	-36,428	-12,239
Brantley	-8,393	-2,582
Brooks	-71,386	-18,209
Bryan	-6,794	-1,989
Bulloch	-168,285	-48,853
Burke	-119,729	-36,700
Butts	-7,801	-2,725
Calhoun	-107,985	-27,592
Camden	-298	-104
Candler	-84,229	-28,463
Carroll	26,806	39,187
Charlton	-3,826	-1,028
Chatham	-944	-339
Chattahoochee	601	1,181

Chattooga	-16,459	-5,107
Clarke	-9,297	-2,487
Clay	-25,899	-7,143
Clayton	-298	-104
Clinch	-4,251	-928
Cobb	0	0
Coffee	-50,056	11,729
Colquitt	-29,497	32,334
Columbia	-13,993	-4,908
Cook	-40,051	-7,588
Coweta	-6,819	-2,524
Crawford	3,564	8,393
Crisp	-52,178	-14,250
Dade	262	3,803
Decatur	-114,281	-23,209
De Kalb	0	0
Dodge	-48,426	-16,273
Dooly	-76,689	-20,381
Dougherty	-24,726	-6,868
Douglas	-745	-126
Early	-105,851	-29,563
Echols	-3,547	-1,342
Effingham	-29,759	-9,409
Elbert	11,655	21,356
Emanuel	-52,503	-16,539
Evans	-17,198	-731
Fanning	4,545	5,630
Fayette	-368	-127
Floyd	-21,140	3,593
Fulton	-4,466	-1,580

Glascock	-30,487	-10,507
Glynn	0	0
Grady	-66,264	-15,258
Greene	-71,885	-20,934
Gwinnett	2,267	2,267
Hancock	-30,281	-10,675
Haralson	-1,070	9,841
Harris	-15,568	-5,590
Henry	-27,915	-10,015
Houston	-27,944	-6,071
Irwin	-110,649	-30,856
Jasper	-38,844	-13,507
Jeff Davis	-48,311	-9,364
Jefferson	-95,851	-32,403
Jenkins	-91,201	-29,950
Johnson	-31,971	-11,098
Jones	-7,827	-1,443
Lamar	-9,923	393
Lanier	-19,080	-5,557
Laurens	-73,430	-25,430
Lee	-72,324	-23,397
Liberty	-3,311	-1,148
Lincoln	-18,574	-6,515
Long	-4,324	954
Lowndes	-52,205	-16,982
Macon	-9,330	21,692
Marion	-6,738	4,380
McDuffie	-8,107	-2,885
McIntosh	0	0
Meriwether	-11,345	-4,035

Miller	-155,887	-43,874
Mitchell	-91,027	-5,482
Monroe	4,497	8,345
Montgomery	-16,594	-5,183
Morgan	-17,534	6,861
Murray	-22,567	11,885
Muscogee	-96	-34
Newton	-22,645	-7,697
Oconee	3,582	21,834
Oglethorpe	13,221	42,208
Paulding	3,392	6,136
Peach	-12,146	-4,359
Pierce	-90,036	-27,664
Pike	-5,282	536
Polk	-9,784	873
Pulaski	-49,794	-12,408
Putnam	-15,099	-5,293
Quitman	-3,000	-963
Rabun	943	2,138
Randolph	-97,342	-29,891
Richmond	-13,362	-4,660
Rockdale	-446	-156
Schley	1,415	5,672
Screven	-75,705	-22,934
Seminole	-99,241	-28,051
Spalding	-4,189	-1,595
Stephens	4,611	12,749
Stewart	-6,900	-1,194
Sumter	-84,818	-24,054
Talbot	-12,376	-4,383

Taliaferro	0	0
Tattnall	-12,138	31,007
Taylor	-4,262	4,986
Telfair	-27,670	-8,734
Terrell	-77,311	-25,099
Thomas	-94,519	-26,606
Tift	-84,473	-25,287
Toombs	-38,505	-11,669
Towns	-9,425	-3,169
Treutlen	-6,505	-2,159
Troup	-6,296	-2,287
Turner	-42,999	-9,542
Twiggs	-21,383	-7,415
Union	-4,115	-138
Upson	4,660	6,674
Walker	-34,585	240
Walton	-26,967	-6,670
Ware	-20,461	-3,690
Warren	-48,044	-16,692
Washington	-52,904	-18,226
Wayne	-43,046	-13,267
Webster	-14,605	-3,921
Wheeler	-34,071	-10,668
Whitfield	8,833	12,487
Wilcox	-29,775	1,412
Wilkes	-61,827	-11,727
Wilkinson	-10,547	-3,190
Worth	-98,566	-25,002
Total	*-4,448,454*	*-815,864*

Initially, there were 17 removal and 142 application counties. Because of the absence of selected crop acreages, 10 counties from application category were shortened making it 17 removal and 132 application counties. Litter availability of removal counties based on total litter produced, total litter used, total litter left, and percentage of total litter utilized by each county are identified in table 4.3.

Table 4.3 Total Amount of Broiler Litter Used Based on the Phosphorus Intake Rate in Removal Counties

County	Total litter production (tons)	Total litter used (tons)	Total litter left (tons)	Total use (percent)
Banks	78,251	1,793	76,458	2.29%
Catoosa	14,729	787	13,942	5.34%
Cherokee	13,617	769	12,848	5.65%
Dawson	19,037	815	18,222	4.28%
Forsyth	8,782	315	8,467	3.58%
Franklin	110,892	3,444	107,448	3.11%
Gilmer	77,413	1,444	75,968	1.87%
Gordon	59,748	7,078	52,670	11.85%
Habersham	82,087	3,037	79,050	3.70%
Hall	62,933	1,889	61,044	3.00%
Hart	63,207	5,520	57,686	8.73%
Heard	15,840	507	15,333	3.20%
Jackson	68,406	5,074	63,332	7.42%
Lumpkin	10,325	806	9,519	7.80%
Madison	89,901	3,669	86,232	4.08%
Pickens	21,068	1,148	19,920	5.45%
White	26,723	1,133	25,590	4.24%
Total Removal Counties	**822,959**	**39,229**	**783,730**	**4.77%**

However, the majority of the litter produced in the removal counties was not fully utilized. Counties with the lowest amounts of total litter utilization were Gilmer (1.87%), Banks (2.29%), Hall (3.00%), Franklin (3.11%), and Heard (3.20%). Counties with the relatively higher amounts of total litter utilization were Gordon (11.85%), Hart (8.73%), Lumpkin (7.80%), Jackson (7.42%), and Cherokee (5.65%). Low litter utilization in all removal counties is primarily due to a combination of high litter production and relatively small crop acreages within the same county.

Table 4.4 Total Amount of Excessive Broiler Litter Used Based on the Phosphorus Intake Rate in Application Counties

County	Total litter production (tons)	Total litter used (tons)	Total litter left (tons)	Total use (percent)
Atkinson	21,728	15,606	6,121	71.83%
Barrow	8,630	1,796	6,834	20.81%
Bartow	31,264	7,560	23,703	24.18%
Carroll	45,853	1,481	44,372	3.23%
Chattahoochee	1,493	46	1,447	3.10%
Clarke	1,090	552	538	50.64%
Coffee	44,170	43,476	694	98.43%
Crawford	10,071	1,768	8,303	17.55%
Dade	5,697	667	5,030	11.70%
Douglas	208	65	143	31.19%
Elbert	27,670	4,607	23,063	16.65%
Fannin	6,293	526	5,767	8.36%
Floyd	17,000	8,156	8,844	47.98%
Greene	6,841	3,241	3,600	47.38%
Haralson	15,663	964	14,699	6.16%
Jones	1,995	1,019	976	51.06%

Lamar	7,883	4,130	3,753	52.39%
Long	4,254	1,370	2,884	32.20%
Macon	37,591	29,218	8,373	77.73%
Marion	9,251	5,158	4,093	55.75%
Monroe	10,552	747	9,804	7.08%
Morgan	20,489	4,648	15,841	22.69%
Murray	32,236	5,879	26,357	18.24%
Oconee	32,093	2,870	29,223	8.94%
Oglethorpe	60,060	4,889	55,171	8.14%
Paulding	6,809	556	6,253	8.16%
Pike	3,776	1,304	2,471	34.55%
Polk	6,493	5,344	1,149	82.31%
Rabun	2,046	163	1,883	7.97%
Schley	9,434	2,905	6,530	30.79%
Stephens	17,133	692	16,442	4.04%
Tattnall	51,318	25,593	25,725	49.87%
Union	2,179	722	1,457	33.14%
Upson	7,854	1,144	6,709	14.57%
Walker	20,148	3,370	16,777	16.73%
Walton	4,531	4,167	365	91.95%
Whitfield	40,883	1,327	39,556	3.25%
Wilkes	15,343	4,220	11,123	27.51%
Total Excess Application Counties	**648,021**	**201,948**	**446,073**	**31.16%**

Similarly, the excess litter availability from application counties is shown in table 4.4. Counties with lowest amounts of litter utilization among excessive application counties were Chattahoochee (3.10%), Carroll (3.23%), Whitfield (3.25%), and Stephens (4.04%). And counties with the highest amounts of litter utilization were Coffee (98.43%), Walton (91.95%), Polk (82.31%), and Macon (77.73%). It is important to note that counties such as Oglethorpe, Tattnall, Carroll, Coffee, Whitfield, Macon, Murray, Oconee, and Bartow, total of 38 counties among "application" category, have high broiler litter production together with high crop acreage. All other application counties except these 38 either don't have any litter production or have insufficient litter available. From figure 4.1 we can see that there are 94 insufficient litter counties, mainly southern major crop-producing counties, which are the main focus for litter transfer in our analysis.

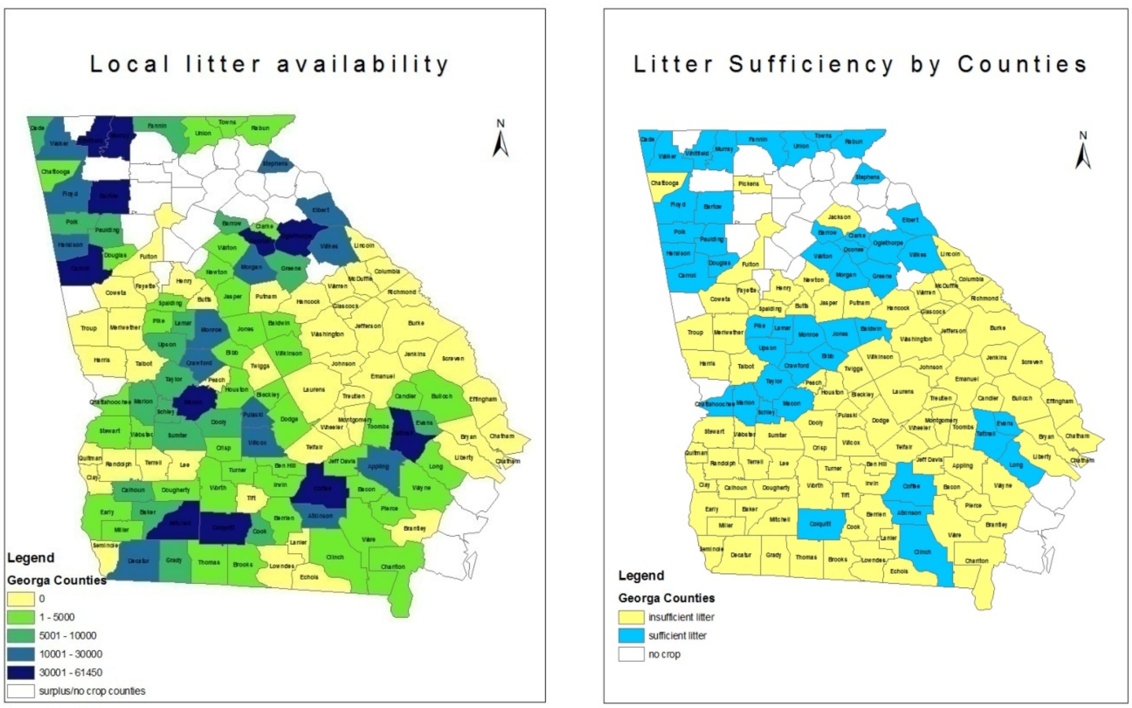

Figure 4.1 Local Litter Availability and Litter Sufficiency for "Application" Counties

As we mentioned above, low litter utilization was primarily due to a combination of high litter production and relatively small crop acreages within the same county. By virtue of the relative location of "removal" and "application" counties, distance and its influence on litter transportation and distribution costs becomes an additional explanatory variable accounting for the low rates of litter utilization.

The optimal solution for importing and exporting counties, quantities and distances is identified in table 4.5. For purposes of interpretation, the discussion is oriented around the three leading surplus counties. Madison is the highest exporting and second-largest litter producing county in the state. It utilizes 49% of the total litter it produces: 4% is applied to in-county crops and 45% is exported to other counties. Laurens, Jefferson, Lee, Washington, Candler, and Toombs are possible litter importing counties from Madison and indeed, Laurens County receives the majority of Madison County's exported litter, due to proximity and large crop acreages.

Hart is the second-largest exporting county in the state, in terms of total broiler litter transferred. Forty six percent of the litter was utilized in county and in exports (table 4.3 and 4.5). Of that 46%, 9% was used in county and 37% was exported (table 4.5). Litter exports from Hart to Bullock and Screven counties constituted 54% of total exports. The remaining 46% of total exports went to Burke, Emanuel, Wheeler, Telfair, and Richmond counties. Shipping distances from Hart County to Bullock and Screven counties are 174 and 159 miles, respectively.

Cherokee is the third largest county in terms of total broiler litter transfer in the state with the total litter transportation of 8,704 tons (table 4.5). Seventy percent of the litter produced is utilized as a source of plant nutrients, either in county or after export to counties such as Randolph and Terrell, two nearby high-crop-producing counties.

Generally, litter exports can be explained in terms of crop acreages and transportation cost or its distance proxy in the importing counties. If counties producing excess broiler litter are close to counties with a category of "application", they export litter to these counties.

Table 4.5 Amount of Broiler Litter Transferred from "Removal" Counties to "Application" Counties

Supply counties	Total litter transferred (tons)	Litter transferred (%)	Demand counties	Distance (miles)	Litter transferred (tons)
Cherokee	8,704	64	Miller	242	974
			Randolph	198	4,258
			Seminole	255	694
			Terrell	203	2,778
Forsyth	222	3	Henry	68.1	222
Gordon	723	1	Clay	242	723
Hart	23,006	37	Bullock	174	6,513
			Burke	117	3,611
			Emanuel	137	3,708
			Richmond	103	233
			Screven	159	5,833
			Telfair	178	1,149
			Wheeler	178	1,959
Heard	361	2	Glascock	109	361
Jackson	122	0.3	Butts	72.6	122
Madison	39,721	45	Bleckley	144	1,431
			Bryan	194	444
			Candler	159	2,616
			Dougherty	213	50
			Early	279	2,393
			Effingham	204	1,833
			Fayette	109	7
			Jefferson	105	5,082
			Johnson	115	2,194

			Lanier	256	181
			Laurens	130	6,549
			Lee	207	3,391
			Liberty	220	84
			Lowndes	259	833
			McDuffie	71.2	167
			Montgomery	161	1,860
			Peach	134	1,472
			Pierce	231	1,617
			Tift	211	150
			Toombs	166	2,399
			Treutlen	144	1,013
			Twiggs	122	363
			Warren	70.4	222
			Washington	96.5	3,333
			Wayne	218	37

Because the model was designed to minimize total cost, the optimal solution did not export all excessive litter from the "removal" counties if it was not cheaper to do so.

Priority-based model

The preceding analysis addressed the economics of transporting broiler litter from "removal" counties to "application" counties. The optimal cost-minimizing solution does not address the economic and social concerns associated with excess litter production in the "removal" counties in northern Georgia. Litter utilization rates of only 70% (Cherokee), 49% (Madison), 46% (Hart), and 14% (Gordon) translates into an optimal solution that leaves 31 % of the total excessive broiler litter in seven litter-exporting counties (Cherokee, Forsyth, Gordon, Hart, Heard, Jackson, and Madison). Therefore, an optimal solution is not necessarily a satisfactory solution for excessively surplus litter-producing “removal” counties.

A priority-based model was developed to transfer significant amounts of surplus broiler litter from the major broiler-producing counties. Its main objective is to transfer broiler litter either on a priority basis or on the basis of surplus amounts of litter left after in-county use. The model exports surplus litter iteratively; that is, it first exports surplus amounts of broiler litter from the most surplus litter producing county. Next, it exports litter from the second most surplus litter-producing county, and does so iteratively. Therefore, this model first exports all surplus broiler litter from Franklin County (because Franklin County is the highest litter-producing county), and other “removal” counties will only be exported after all surplus litter produced in Franklin County has been exported. This was accomplished by adding activities to account for underutilized litter in “removal” counties. Additionally, litter constraints for these counties were changed from inequalities to equalities, such that the underutilization activities were forced into the optimal solution to account for all litter not used in a specific county or exported from that county. Finally, by assigning appropriate penalties in the objective function to the underutilization activities, the model was forced to first utilize all Franklin County litter followed by Madison, then Habersham, and so on. The monetary values of the objective function were adjusted through accounting equations to get accurate solution values.

The results of the priority-based model are presented in table 4.6. The results show that all of the surplus litter from “removal” counties can be utilized with the priority model differing from the non-priority (full model). The optimization model without priority retained about 70% of excessive broiler litter in “removal” counties.

Table 4.6 Total Amount of Broiler Litter Exported form "Removal" Counties to "Application" Counties

Removal	Banks	Catoosa	Cherokee	Dawson	Forsyth	Franklin	Gilmer	Gordon	Habersham	Hall	Hart	Heard	Jackson	Lumpkin	Madison	Pickens	White
Application	78,121	14,683	13,609	18,407	8,690	110,262	77,080	56,726	80,346	62,248	61,483	15,611	65,739	9,992	89,010	20,753	26,479
Appling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baldwin	0	0	0	0	0	0	0	0	0	0	0	0	815	0	0	0	0
Ben Hill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Berrien	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bibb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,112	0	0
Bleckley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,018	0	0
Brantley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brooks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bryan	0	0	0	0	0	444	0	0	0	0	0	0	0	0	0	0	0
Bulloch	0	0	0	0	0	60,540	0	0	0	0	0	1,849	0	0	0	0	0
Burke	49,056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butts	0	0	0	0	0	0	0	0	0	0	0	0	404	0	0	0	0
Calhoun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candler	0	0	0	0	0	22,167	0	0	0	0	0	0	0	0	0	0	0
Charlton	0	0	0	0	0	0	0	556	0	0	0	0	0	0	0	0	0
Chatham	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chattooga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clay	0	13,213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clinch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colquitt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Columbia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	24,574	0	0	0	0	0	0	0	0
Coweta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crisp	0	0	0	0	0	0	14,317	23,958	0	0	0	0	0	0	0	3,022	0
Decatur	0	0	0	0	0	0	43,831	0	0	8,331	0	0	0	0	0	0	0
Dodge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dooly	0	0	0	0	0	0	9,880	0	0	0	36,874	0	4,170	0	33,397	0	0
Dougherty	0	0	0	0	0	0	0	11,001	0	0	0	0	0	0	0	0	0
Early	0	0	0	0	0	0	0	0	0	2,393	0	0	0	0	0	0	0
Echols	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Removal	Banks	Catoosa	Cherokee	Dawson	Forsyth	Franklin	Gilmer	Gordon	Habersham	Hall	Hart	Heard	Jackson	Lumpkin	Madison	Pickens	White
Application	78,121	14,683	13,609	18,407	8,690	110,262	77,080	56,726	80,346	62,248	61,483	15,611	65,739	9,992	89,010	20,753	26,479
Effingham	0	0	0	0	0	0	0	1,833	0	0	0	0	0	0	0	0	0
Emanuel	0	0	0	0	0	3,708	0	0	0	0	0	0	0	0	0	0	0
Evans	8,677	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fayette	0	0	0	0	0	0	0	0	0	0	0	69	0	0	0	0	0
Fulton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glascock	0	0	0	0	0	0	0	0	0	0	0	3,535	0	0	0	0	0
Grady	0	0	0	0	0	0	0	0	0	0	0	0	32,976	0	0	0	0
Hancock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0	0	0	0	0	667	0	0	0	0
Henry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,481	0
Houston	0	0	0	0	0	0	0	0	0	12,383	0	0	0	6,344	0	0	0
Irwin	0	0	0	0	0	0	0	0	0	199	0	0	0	0	0	0	0
Jasper	0	0	0	0	0	0	0	0	0	0	0	0	1,296	0	0	0	0
Jeff Davis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson	19,296	0	0	0	0	17,197	0	0	0	0	0	0	0	0	0	0	0
Jenkins	0	0	0	0	0	4,469	0	0	16,611	0	0	0	0	0	0	0	0
Johnson	0	0	0	0	0	0	0	0	0	0	0	0	7,960	0	0	0	0
Lanier	0	0	0	0	0	0	0	0	0	181	0	0	0	0	0	0	0
Laurens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25,006	0	0
Lee	0	0	0	0	0	0	0	0	0	3,391	0	0	0	0	0	0	0
Liberty	0	0	0	0	0	84	0	0	0	0	0	0	0	0	0	0	0
Lincoln	148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lowndes	0	0	0	0	0	0	833	0	0	0	0	0	0	0	0	0	0
McDuffie	944	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meriwether	0	0	0	0	0	0	296	0	0	0	0	0	0	0	0	0	0
Miller	0	0	0	0	0	0	974	0	0	0	0	0	0	0	0	0	0
Mitchell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montgomery	0	0	0	0	0	0	0	0	0	0	6,693	0	0	0	0	0	0
Newton	0	0	0	0	0	0	0	0	0	0	0	0	1,241	0	0	0	0
Peach	0	0	0	0	0	0	0	0	2,267	0	0	0	0	0	0	5,664	0
Pierce	0	0	0	0	0	1,617	0	0	0	0	0	0	0	0	0	0	0
Pulaski	0	0	0	0	0	0	0	0	0	35,371	0	0	0	0	0	0	0
Putnam	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	0	0
Quitman	0	0	0	0	0	0	251	0	0	0	0	0	0	0	0	0	0

Removal	Banks	Catoosa	Cherokee	Dawson	Forsyth	Franklin	Gilmer	Gordon	Habersham	Hall	Hart	Heard	Jackson	Lumpkin	Madison	Pickens	White
Application	78,121	14,683	13,609	18,407	8,690	110,262	77,080	56,726	80,346	62,248	61,483	15,611	65,739	9,992	89,010	20,753	26,479
Randolph	0	0	4,258	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Richmond	0	0	0	0	0	0	0	0	937	0	0	0	0	0	0	0	0
Screven	0	0	0	0	0	0	0	0	35,957	0	0	0	0	0	0	0	0
Seminole	0	0	694	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spalding	0	0	0	0	0	0	870	0	0	0	0	0	0	0	0	0	0
Stewart	0	0	0	0	0	0	5,826	0	0	0	0	0	0	0	0	0	0
Sumter	0	1,470	5,656	0	8,690	0	0	0	0	0	0	0	0	3,497	0	0	26,441
Talbot	0	0	222	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taylor	0	0	0	8,011	0	0	0	0	0	0	0	0	0	0	0	0	0
Telfair	0	0	0	0	0	0	0	0	0	0	11,074	0	0	0	0	0	0
Terrell	0	0	2,778	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thomas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tift	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0
Toombs	0	0	0	0	0	0	0	0	0	0	0	10,158	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37
Treutlen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,801	0	0
Troup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Twiggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,675	0	0
Ware	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Warren	0	0	0	0	0	0	0	0	0	0	0	0	1,731	0	0	0	0
Washington	0	0	0	0	0	0	0	0	0	0	0	0	12,939	0	0	0	0
Wayne	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0
Webster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,586	0
Wheeler	0	0	0	0	0	0	0	0	0	0	6,843	0	0	0	0	0	0
Wilcox	0	0	0	10,396	0	0	0	19,377	0	0	0	0	0	0	0	0	0
Wilkinson	0	0	0	0	0	0	0	0	0	0	0	0	1,494	0	0	0	0
Worth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Analysis based on the priority model suggests that all surplus broiler litter from “removal” counties can be utilized when the model provides for a penalty structure. Imposing a penalty has the effect of exporting litter only from, for instance, Franklin County until its surplus litter is completely exported. The optimal solution with the priority model resulted in an additional cost of about $ 3 million above the solution of the non-priority optimization model. A comment here is worthwhile. Priority imposition is very often a consequence of issue or environmental forces. In the case of “removal” counties, these non-economic factors would cost society an estimated $3 million to export the retained 70% of excessive broiler litter from “removal” counties.

The objective function with the priority model was to remove the highest amount of surplus litter from “removal” counties. Accomplishing that objective meant failing to export significant amounts of broiler litter from the other major broiler-producing counties.

The priority-based optimization model exported almost all excessive litter. However, this does not mean that the priority model provides an acceptable solution to the problem of excess broiler litter accumulation in northern Georgia.

Sensitivity Analysis and Shadow Prices

The effects of changes in fertilizer prices on total litter use and their resulting impacts on the total cost of meeting the nutrient needs of the “application” counties were evaluated. The amount of litter applied did not change until the price of chemical fertilizer reached 172% of the current price. The total costs of meeting the nutrient needs increased proportionately with chemical fertilizer prices. The explanation is grounded in the phosphorus based analysis for litter application, which requires that deficit nitrogen needs be met with chemical fertilizers. Thus, there exists a direct relationship between chemical fertilizer price increases and increases in the total cost of meeting the nutrient needs of "application" and "removal" counties. Litter utilization was insensitive to chemical fertilizer price declines of up to 22%.

Shadow prices from the optimal solutions in the model showed the pattern recorded in table 4.7: litter is more valuable in the intensive cropping counties and in those most distant from the "removal" counties. Coastal counties such as Chatham and Effingham, which are much further from broiler-producing "removal" counties, have a shadow value for broiler litter of $38.78 per ton. Lowndes and Seminole are also at a considerable distance and have shadow values of $36.26 and $35.70 per ton, respectively. Similarly, Miller and Dougherty are both distant, intensive crop-producing counties with $33.88 and $22.96 shadow prices, respectively. However, the crop-intensive counties of Burke and Richmond, with shadow values of only $16.38 and $14.42, respectively, are much closer to the "removal" counties.

Table 4.7 Shadow Price Values of the Broiler Litter in Each of "Application" County in the Optimal Solution

	County	Shadow Price[a]	Constraint R.H. side
1	Appling	0.00	14,427
2	Bacon	0.03	2,489
3	Baker	0.01	9,023
4	Baldwin	0.00	1,819
5	Ben Hill	0.01	4,088
6	Berrien	0.01	4,367
7	Bibb	0.06	1,389
8	Bleckley	20.16	992
9	Brantley	0.80	0
10	Brooks	0.02	3,531

11	Bryan	27.16	0
12	Bulloch	24.36	4,708
13	Burke	16.38	0
14	Butts	10.16	0
15	Calhoun	0.01	7,689
16	Candler	22.26	272
17	Charlton	0.11	549
18	Chatham	38.78	0
19	Chattooga	0.26	802
20	Clay	4.31	0
21	Clinch	0.08	425
22	Colquitt	0.00	61,450
23	Columbia	33.18	0
24	Cook	0.01	5,610
25	Coweta	0.26	0
26	Crisp	0.03	3,089
27	Decatur	0.01	10,374
28	Dodge	0.03	2,688
29	Dooly	0.02	5,885
30	Dougherty	22.96	597
31	Early	29.82	543
32	Echols	31.92	0
33	Effingham	38.78	0
34	Emanuel	27.58	0
35	Evans	0.02	6,615
36	Fayette	24.92	0
37	Fulton	0.10	0
38	Glascock	6.51	0
39	Grady	0.01	9,800
40	Hancock	36.68	0
41	Harris	10.26	0

42	Henry	9.53	0
43	Houston	0.03	3,609
44	Irwin	30.52	1,493
45	Jasper	0.09	639
46	Jeff Davis	0.02	4,941
47	Jefferson	14.70	0
48	Jenkins	20.44	0
49	Johnson	16.10	0
50	Lanier	35.84	0
51	Laurens	18.20	0
52	Lee	28.98	0
53	Liberty	30.80	0
54	Lincoln	7.99	0
55	Lowndes	36.26	0
56	McDuffie	9.97	0
57	Meriwether	13.64	0
58	Miller	33.88	981
59	Mitchell	0.00	32,969
60	Montgomery	22.54	0
61	Newton	0.83	303
62	Peach	18.76	0
63	Pierce	32.34	549
64	Pulaski	0.01	11,200
65	Putnam	9.38	0
66	Quitman	1.45	0
67	Randolph	27.72	0
68	Richmond	14.42	0
69	Screven	22.26	0
70	Seminole	35.70	0
71	Spalding	0.11	500
72	Stewart	0.08	1,253

73	Sumter	0.01	6,818
74	Talbot	17.64	0
75	Taylor	0.02	7,754
76	Telfair	24.92	0
77	Terrell	28.42	0
78	Thomas	0.01	4,181
79	Tift	29.54	0
80	Toombs	23.24	964
81	Towns	0.03	209
82	Treutlen	20.16	0
83	Troup	14.42	0
84	Turner	0.02	4,795
85	Twiggs	17.08	0
86	Ware	0.05	2,516
87	Warren	9.81	0
88	Washington	13.51	0
89	Wayne	30.52	613
90	Webster	0.08	551
91	Wheeler	24.92	0
92	Wilcox	0.00	16,812
93	Wilkinson	0.19	518
94	Worth	0.02	2,688

[a] Shadow price is the change in the objective function for having one less ton of broiler litter available in the county

Both the insensitivity to changes in commercial fertilizer price and the shadow price pattern associated with distance and crop intensity support the robustness of optimization model. These results can be useful guides in formulating environmental policy to address water quality issues.

4.3 Production Function

Net returns as a function of litter application rates was derived for each selected crop in order to find out the application rate of poultry litter that maximizes profits for a producer. Net returns per acre were then maximized with respect to input use by expressing per acre yield as a function of input levels.

The biological response of the selected raw crops – cotton, wheat, and peanuts – was estimated as a quadratic function of broiler litter application rate. Table 4.8 represents the estimated parameter values for each crop and figure 4.2 illustrates the yield response of each crop.

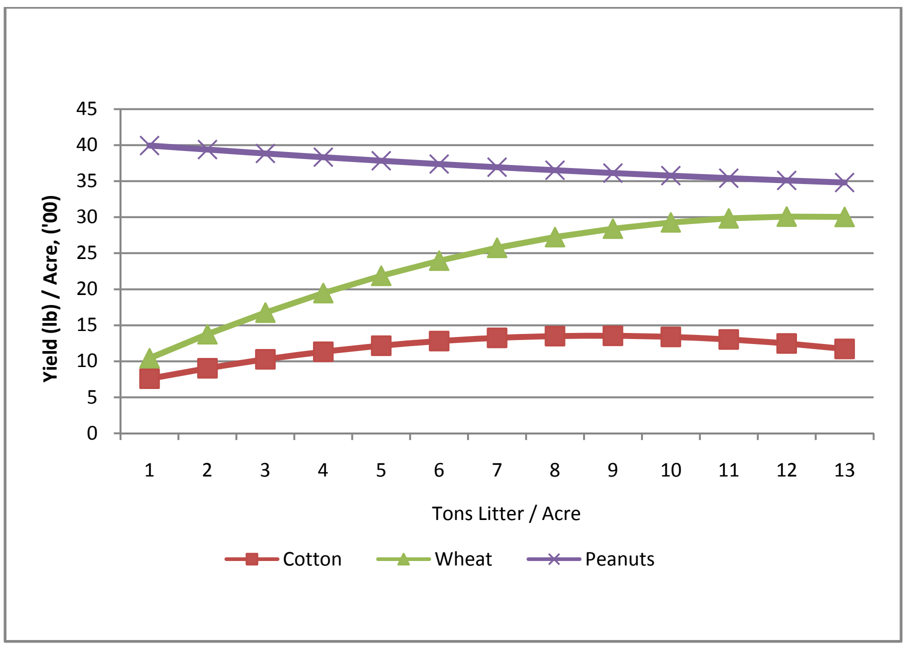

Figure 4.2 Crop Responses to Poultry Litter

Using the crop production function and the values from table 4.8, the per acre demand for broiler litter for each crop was derived. For the analysis, the price (P_j) for selected crops were taken to be the marketing year averaged price received by Georgia farmers for 2007 (GASS, 2007). Table 3.6 presents the crop prices used in the analysis.

Table 4.8 Estimated Parameter Values for Each Selected Crop

Crop	α	β	γ	R^2	F-stat
Cotton	593.7* (65.1)	349* (52.1)	-40* (8.3)	0.85	38
Wheat	678.8 (660)	756.7 (528)	-61.4 (84.1)	0.35	3.6
Peanuts	4052.7* (370.7)	-119.8 (296.6)	4.9 (47.2)	0.08	0.6
	*indicates p-value < 0.05; standard errors appear in parentheses; n = 16 for all crops				

Table 4.9 Estimated Poultry Litter Demand (Tons/Acre)

Crop	R*		w*
	w=$17.20	w=$14.40	R=2
Cotton	4.06	4.11	$132.49
Wheat	4.34	4.64	$39.36
Peanuts[a]	0	0	NA

[a]Peanuts demand is zero under any price because the estimated β_is above mentioned crops are negative – litter applications decrease these crops yield.

The cost of using poultry litter as fertilizer was formed of three parts: (1) the price of the litter itself - $10 (GASS, 2007), (2) the cost of transporting the litter from the broiler house to the row crop fields - $3.50 per mile (EQIP, 2006), also transportation cost of $0.7 was analyzed as an alternative scenario, and (3) the cost of spreading the litter on the fields - $3.70 per acre (USDA, 2006). The total costs of litter (Wlitter), therefore, were $17.20 and $14.40, respectively. The demand estimates are presented in table 4.9 and figure 4.3 plots the demand curves for each crop.

As both table 4.9 and figure 4.3 indicate, the amount of poultry litter demanded per acre by producers of each crop decreases as the total cost of the litter increases. However, under prevailing prices, the per acre demand for litter is well above agronomic recommendations, especially for cotton. Gascho *et al.* (2000) concluded, based on P application needs and concerns about NO_3-N movement in the soil, a rate of no greater than 2 tons per acre should be recommended when the application is repeated for each crop in the intensive, double-crop system. Under the both price scenarios, \$17.20 and \$14.40, the per acre demand for litter exceeds agronomic recommendations on both cotton and wheat except peanuts. To induce demand of 2 tons per acre for cotton and wheat, the total cost of poultry litter would have to reach the value of *w** reported in table 4.9.

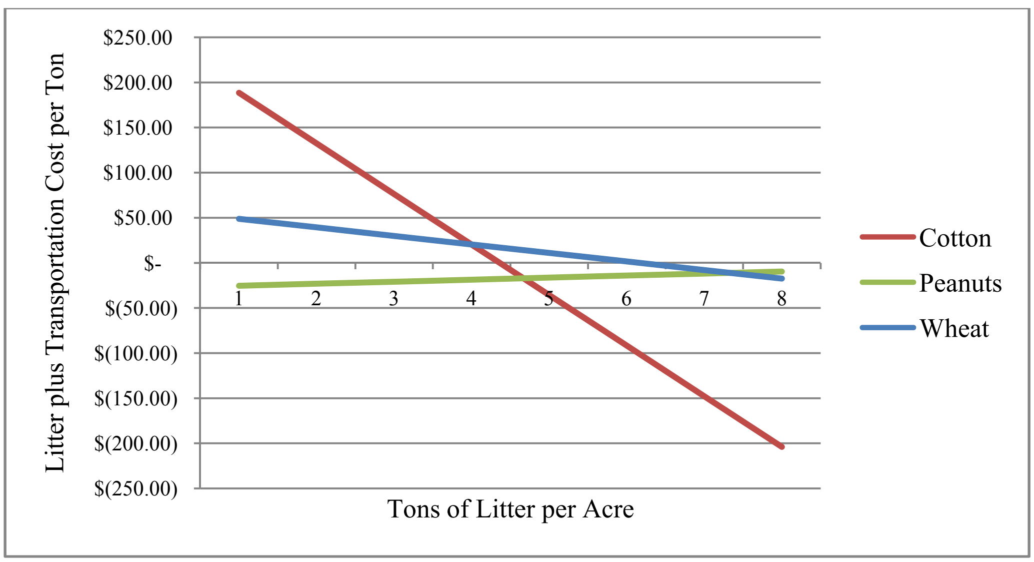

Figure 4.3 Broiler Litter Demand per Acre

At these application rates, the question remains: how would the demand for poultry litter in a given area compare to the amount of litter produced in that area? As a preliminary investigation into this question, broiler litter production within all application counties was estimated and compared to the litter demand estimates.

The amount of broiler litter generated within a given area may be expressed as a function of the number of broilers residing in that area. A broiler produces an estimated 3.22 lbs of litter during its 10 week life-cycle (Perkins *et al.,* 1964), of which approximately 2.49 lbs is manure (Gascho *et al.*, 2000). The total lbs of litter produced within a given area, then, is 3.22 times the number of broilers raised in the area.

In 2007, these application counties generated total of 920,368 tons of broiler litter (table 2.2) and their cotton and wheat acreages were 919,760 and 240,083, respectively (table 4.9). If all 919,760 acres of cotton are assumed to be planted to the intensive, double-cropped system described above, total demand for broiler litter within "application" counties would be 3,730,452 tons, when w_{litter} = $17.20; and 3,776,359 tons, when w_{litter} = $14.40. Similarly, if all 240,083 acres of wheat are assumed to be planted to the intensive, double-cropped system described above, total demand for broiler litter within "application" counties would be 1,043,737 tons, when w_{litter} = $17.20; and 1,114,660 tons, when w_{litter} = $14.40[4]. Demand on litter for both crops exceeded the local supply at each cost level considered. In fact, cost of broiler litter to the producer would have to reach $208.8 per ton for cotton in order to eliminate the excess demand within "application" counties. And this would lead wheat demand to become negative. Figure 4.3 illustrates these results.

Table 4.10 Litter Produced and Crop Acreage, 2007

County	Litter (tons)	Cotton (acre)	Wheat (acre)
Appling	14,427	21,500	2,000
Atkinson	21,728	4,948	1,772
Bacon	2,489	11,750	600
Baker	9,023	23,000	2,000

[4] Total demand within the given area is calculated using Equation (3) from 3.4 Production Functions, Chapter III.

Ben Hill	4,088	7,776	1,979
Berrien	4,367	19,587	788
Bleckley	992	11,035	3,989
Brantley	0	390	1,400
Brooks	3,531	0	0
Bryan	0	600	350
Bulloch	4,708	200	11,250
Burke	0	200	4,200
Calhoun	7,689	15,339	4,548
Camden	0	13,000	3,000
Candler	272	0	0
Charlton	549	6,575	100
Chatham	0	0	0
Clay	1,090	0	925
Clinch	0	75	2,843
Coffee	0	20,463	0
Colquitt	44,170	53,442	2,867
Cook	0	18,500	700
Crisp	10,071	30,136	3,625
Decatur	19,037	28,145	1,505
Dodge	0	130	7,600
Dooly	2,688	67,279	7,873
Dougherty	5,885	4,611	2,138
Early	208	35,617	5,792
Echols	543	1,600	600
Effingham	0	0	0
Emanuel	27,670	51	3,801
Evans	0	3,400	1,364
Glynn	0	19,670	4,705
Grady	59,748	0	0

Houston	0	88	0
Irwin	3,609	21,165	6,173
Jeff Davis	639	16,505	2,052
Jefferson	4,941	10,256	11,737
Jenkins	0	9,261	5,049
Johnson	0	684	3,319
Lanier	7,883	5,800	570
Laurens	0	5,174	12,589
Lee	0	12,574	10,067
Liberty	0	159	531
Long	0	0	0
Lowndes	4,254	8,340	0
Macon	10,325	10,196	8,864
Marion	0	144	1,920
McIntosh	89,901	26,730	2,144
Miller	0	0	0
Mitchell	981	43,049	5,975
Montgomery	10,552	2,238	1,503
Peach	6,809	30	3,500
Pierce	21,068	6,518	2,154
Pulaski	6,493	23,735	6,278
Quitman	0	226	691
Randolph	2,046	9,187	11,006
Schley	0	1,027	1,050
Screven	9,434	14,625	3,921
Seminole	0	26,287	3,881
Stewart	17,133	2,735	805
Sumter	1,253	22,094	11,732
Tattnall	0	8,165	5,431
Telfair	51,318	6,750	1,802

Terrell	7,754	28,000	7,000
Thomas	0	40,130	2,280
Tift	0	20,462	1,109
Toombs	4,181	3,452	916
Treutlen	964	1,628	737
Turner	0	20,518	4,338
Twiggs	0	5,422	630
Ware	20,148	1,818	427
Washington	2,516	534	7,500
Wayne	0	5,151	1,189
Webster	0	7,600	1,844
Wheeler	613	1,487	3,055
Wilcox	26,723	19,481	0
Wilkinson	16,812	724	0
Worth	15,343	50,592	0
Total	588,665	919,760	240,083

Source: GASS (2007)

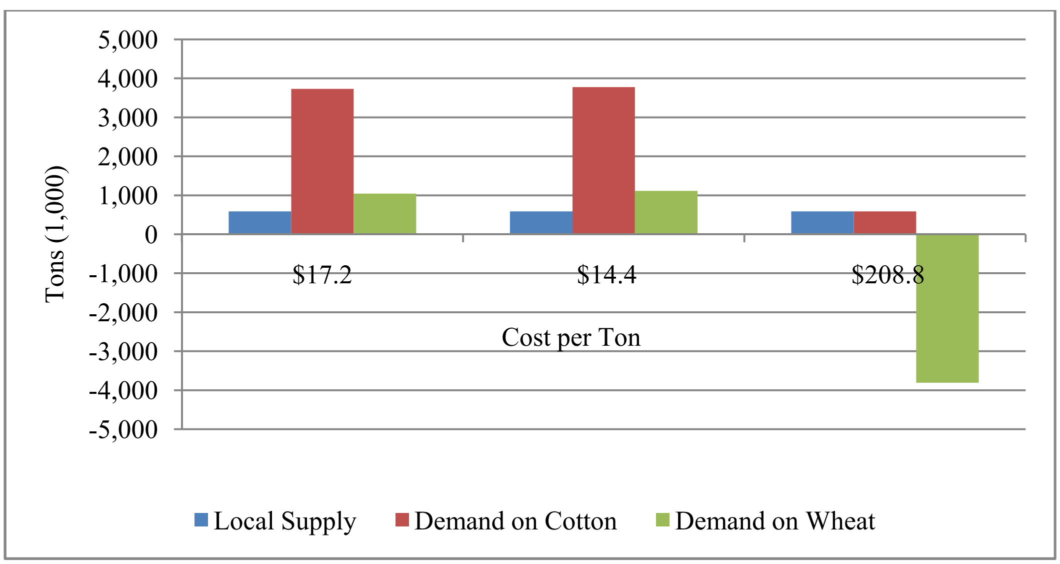

Figure 4.4 Tons of Broiler Litter Demanded within All Counties except Piedmont Region

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

Georgia ranks first in broiler production in the United States. In 2007, the production of more than 1.5 billion broilers in Georgia generated $4.72 billion in revenue. This accounted for approximately 50% of total farm receipts, making broiler production the state's number one agricultural enterprise. Georgia's heavy concentration of broiler-producing facilities attracts scrutiny from the US Department of Agriculture and US Environmental Protection Agency, which promote better manure-management practices in animal feeding operations in the interests of water quality.

Georgia's broiler industry generates an estimated 2.7 million tons of broiler litter annually. The absence of proper disposal facilities for the litter can cause air and water quality problems. Capturing economies of size to minimize processing and feed costs has greatly increased the concentration of broiler production in the northern Piedmont area: Franklin, Madison, Habersham, Banks and Gilmer. The transfer of litter from counties with an excess to areas where litter can be as a source of crop nutrients in an environmentally responsible way minimizes water and air quality deterioration in the region. This study identifies a strategy not only for Georgia, but also for other states with concentrated broiler production, to achieve optimum distribution of broiler litter that minimizes crop nutrient costs and promotes air and water quality.

Phosphorus was a primary element of concern in assessing surface water quality since it is generally considered a limiting nutrient for eutrophication in fresh water. Broiler litter contains high levels of water-soluble phosphorus, making it susceptible to runoff. In the past, researchers have considered nitrogen management to be a major agricultural issue. Phosphorus, however, has emerged as a serious concern in areas where animal operations predominate and there is major land application of manure.

Estimated broiler litter production for each county was calculated from the number of broilers reported for the county by Georgia Agricultural Statistics Service. The majority of the counties produce insufficient broiler litter to meet the nitrogen, phosphorus, and potassium needs of the respective county. Since the highest crop and litter producing counties are not the same, the distances between crop and litter producing counties are among the major variables influencing the optimal litter transportation decision.

All counties of Georgia were divided into “removal” and “application” counties on the basis of the annual statistics for crop acreages and litter production. “Removal” counties were those in which litter production exceeds the cumulative nutrient demands for the selected major crops. Similarly, “application” counties were those in which litter production cannot meet the crops’ nutrient demands.

The phosphorus based analysis was applied using the criterion that a farmer pays the minimum cost to meet the total nutrient needs of the six selected crops grown in Georgia when phosphorus is the binding constraint. The phosphorus based analysis is defined as the application of litter based on the rate of phosphorus recommended for a crop in the state by the Cooperative Extension Service. A transportation model was developed to find the optimal litter transfer to meet the crop nutrient demand in the state. The optimal solution thus obtained provides the minimum cost to meet the nutrient needs in the state. Calculations were then expanded to determine the additional cost required to prioritize the litter removal from the most problematic counties in the state. The changes in the total litter used and in the cost were calculated for parametrically varying prices of chemical fertilizer. Shadow prices were examined to substantiate the model results.

5.2 Conclusions

This study suggests that litter can be economically exported from the heavy broiler-producing counties so as to minimize environmental problems in those counties. However, the findings suggest that it will not be possible to completely overcome the surplus litter production problem in northern Georgia. The surplus litter production problem in the most concentrated broiler-producing counties can be resolved at an additional cost of $3 million.

Study findings suggest that total nutrient requirement cost as well as the excess litter problem can be minimized if litter is transported from the heavy broiler-producing counties to other counties, especially, to major crop-producing counties in Georgia based on the phosphorus consistent analysis. A key assumption is that litter can be exported from one county to others like any other commodity. The validity of this assumption depends upon the acceptance of litter by crop producers.

This study did not consider all crop types thus, all crop acreages in Georgia as potential recipients of broiler litter for use as crop nutrients. Looking at agriculture statewide does suggest that it might be possible to resolve the litter problem completely. This would require smoothly operating market mechanisms for all facets of litter distribution, strict compliance with regulations, and adherence to responsible litter utilization practices by users. The break-even distance calculated in this study may not allow for enough economic incentive to set up a system of exports from surplus litter-producing counties to crop-producing counties without subsidies. Thus, the short-term solution to northern Georgia's problem of excessive litter production as suggested by the transportation model may not prove to be an optimal long-term solution for the state. Extending the study into adjacent areas of Alabama and Tennessee might be desirable.

Model findings are helpful in establishing parameters for policy tools such as a zonal tax, a zonal permit, or a zonal quota for promoting environmental management of broiler litter consistent with a sustainable broiler industry and protection of Georgia's water resources from phosphorus and nitrogen pollution (Innes, 2000; Goetz and Zilberman, 2000).

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APPENDICES

Appendix A. State Rule 391-3-6, Animal (Non-Swine) Feeding Operations (2003)

Animal (Non-Swine) Feeding Operations Program.

In June, 2001, the Department of Natural Resources Board approved the Georgia Environmental Protection Division's Animal (Non-Swine) Feeding Operators Rule 391-3-6. This rule requires poultry producers with liquid manure handling systems or continuous overflow watering systems to be permitted. The permits required under this rule are the Land Application System (LAS) and the National Pollutant Discharge Elimination System (NPDES) permits. To obtain these permits, producers must complete a comprehensive nutrient management plan and certified operator training.

*Poultry Operations Requiring LAS permitting***.**

The LAS permit is required for poultry operators in the following categories:

- 9,000 laying hens or broilers with liquid manure handling systems.
- 30,000 laying hens or broilers if the facility has continuous overflow watering system.
- 16,000 turkeys.
- 1,500 ducks.

Poultry operations requiring NPDES permitting.

The NPDES permit is required for poultry operators in the following categories:

- 30,000 laying hens or broilers with liquid manure handling systems.
- 100,000 laying hens or broilers with continuous overflow watering systems.
- 55,000 turkeys.
- 5,000 ducks.

With the passage of EPD's Animal (Non-Swine) Feeding Operations rule, the Georgia Department of Agriculture adopted their *Animal Feeding Operators Training and Certification Rule 40-16-5* in June of 2001. The rule provides for certification training required to meet the Georgia Environmental Protection Division's AFO/CAFO permitting rule. Training requires 1½ days of classroom instruction followed by a written examination. A minimum score of 70 percent on the exam is necessary for certification. In addition, the rule requires 4 hours of continuing education every 2 years.

By definition, Georgia's *Animal (Non-Swine) Feeding Operations Rule* exempts dry manure poultry operations from the mandatory program. This exemption, however, will change for some dry manure poultry operators in the near future.

EPA's New CAFO Regulations.

In 2001, Georgia's EPD did not include dry manure poultry operations in their AFO rule. This was partly a result of the implementation of the voluntary program and partly due to the fact that the U.S. Environmental Protection Agency (EPA) was expected to release a new version of their CAFO rule in 2002 that would address dry manure operations. In December of 2002, EPA unveiled to the states their "new" CAFO rule, which simplified and clarified the existing rule. This new rule includes some dry manure poultry operations and will require some amendments to the current Georgia rules. States must adopt rules that are at least equal to the federal rules. States do, however, have the option of adopting rules that are more stringent than the federal rules if necessary for protection of the environment. Georgia will be considering amendments of its AFO/CAFO rules in 2003.

New Requirements for Poultry. Several of the components of EPA's new CAFO rules have implications for poultry producers.

- Large poultry operations will be required to have NPDES permits regardless of the type of manure handled. Large poultry operations are defined as operations with:
    - 125,000 or more broilers
    - 82,000 or more laying hens
    - 55,000 or more turkeys
- NMPs will be required to include phosphorous risk assessments.
- Setbacks of 100 feet from surface water and wells required for application of manures unless a 35-foot vegetative buffer is used.
- Large CAFOs will be required to keep records of manure transfers.
- Large CAFOs will be required to report annually to the permitting authority.

What is not required. EPA dropped a number of proposed requirements from their final rule. Some of the more significant requirements dropped are:

- No mandatory national co-permitting requirements.
- No requirement that NMPs have to be prepared by a certified planner.
- No NMP certification of manure recipients by sellers of poultry litter.
- No requirements on when manure may be applied to frozen or saturated land.
- No mandatory national ground water testing requirements.

Georgia's EPD must now consider the new EPA CAFO regulations and decide on what action needs to be taken in Georgia to comply with the new regulations. The state can either decide to go with the new regulations as finalized by EPA, or Georgia can decide to enact more stringent rules. Much of this decision may well depend on how effective and successful the voluntary program is perceived to be. It is imperative that Georgia poultry producers continue to develop and implement NMPs. The voluntary NMP program will serve as a solid basis of permitting for those individuals requiring the NPDES or LAS permits and, in addition, will provide continued assurance of environmentally sound programs for those poultry producers not subject to a state rule program.

Should you need assistance in developing an NMP or if you need more information on Georgia's poultry nutrient management plans, contact your local Cooperative Extension office or the departments of Poultry Science and Biological and Agricultural Engineering, the University of Georgia. Information on developing poultry NMPs can be found on the Department of Poultry Science web page www.department.caes.uga.edu/poultry/

Information on regulated CNMPs is also available on the AWARE web page:

www.engr.uga.edu/service/aware

Appendix B. Georgia EQIP “Removal” and “Application” Counties

Removal Counties	**Application Counties**						
	50 pts	**40 pts**	**30 pts**	**20 pts**	**10 pts**	**5 pts**	**0 pts**
Banks	Bleckley	Appling	Baldwin	Atkinson	Bartow	Fayette	Clayton
Catoosa	Bryan	Bacon	Berrien	Barrow	Butts	Lamar	Cobb
Cherokee	Bulloch	Baker	Bibb	Carroll	Chattahoochee	Meriwether	DeKalb
Dawson	Camden	Ben Hill	Brantley	Clarke	Harris	Putnam	Fulton
Forsyth	Chatham	Brooks	Candler	Fannin	Jasper	Troup	Gwinnett
Franklin	Crisp	Burke	Clay	Glynn	Marion	Upson	Rockdale
Gilmer	Dooly	Calhoun	Coffee	Henry	Oconee		
Gordon	Dougherty	Charlton	Columbia	Macon	Oglethorpe		
Habersham	Echols	Chattooga	Dade	Monroe	Rabun		
Hall	Effingham	Clinch	Elbert	Morgan	Spalding		
Hart	Irwin	Colquitt	Evans	Murray	Whitfield		
Heard	Laurens	Cook	Floyd	Muscogee			
Jackson	Lee	Coweta	Glascock	Newton			
Lumpkin	Lowndes	Crawford	Greene	Pike			
Madison	McIntosh	Decatur	Haralson	Stephens			
Pickens	Pulaski	Dodge	Jenkins	Talbot			
White	Screven	Douglas	Jones	Tattnall			
	Terrell	Early	Lanier	Towns			
	Washington	Emanuel	Liberty	Wilkes			
		Grady	Lincoln				
		Hancock	Long				
		Houston	McDuffie				
		Jeff Davis	Mitchell				
		Jefferson	Montgomery				
		Johnson	Polk				
		Miller	Quitman				
		Paulding	Richmond				
		Peach	Schley				
		Pierce	Taylor				
		Randolph	Union				
		Seminole	Walker				
		Stewart	Ware				
		Sumter	Warren				
		Taliaferro	Wheeler				
		Telfair	Wilcox				
	40 pts	Thomas					
	Walton	Tift					
	Wayne	Toombs					
	Webster	Treutlen					
	Wilkinson	Turner					
	Worth	Twiggs					

Appendix C. Application, Composition, and Record Keeping of Poultry Litter and Fertilizer

Table C.1 Mineral Analysis of Poultry Litter on As-Received Basis.

Manure Type	Ca	Mg	S	Fe	Mn	Zn	Cu	B	Al	Na
	lb/ton			ppm						
Litter										
Broiler cake	36	81	91	1459	340	272	366	35	2403	5764
Broiler cleanout	43	9	15	1610	334	265	319	33	2632	5498
Broiler stockpiled	54	10	12	1437	362	286	313	33	2236	5739
Breeder manure	120	11	8	1979	321	286	121	22	2897	4097
Pullet cleanout	37	67	59	2158	294	246	142	19	3393	3908
Layer manure										
Highrise cleanout[1]	86	6	9	5	2	0.5	0.4	Trace	- -	- -
Lagoon sludge[2]	71	7	12	4	2	2	0.8	0.1	- -	- -
Lagoon effluent[3]	35	7	8	5	3	0.4	0.4	Trace	- -	- -

[1]Annual manure accumulation in lbs/ton.
[2]lbs/1,000 gallons.
[3]lbs/acre-inch. Acre-inch is equivalent to 3630 cubic feet or 27,154 gallons.
Source: The University of Georgia Agricultural and Environmental Services Laboratory.

Table C.2 Typical First-Year Nitrogen Availability Coefficients for Different Poultry Manures.

Manure Type	Soil			
	Injection[1]	Soil Incorporation[2]	Broadcast[3]	Irrigation[4]
	N availability coefficient			
All poultry litters[5]	--	0.7	0.5	--
Layer				
Highrise cleanout	--	0.6	0.4	--
Lagoon sludge	0.6	0.6	0.4	0.4
Liquid effluent	0.8	0.7	0.4	0.3

[1] Manure injected directly into soil and covered immediately.
[2] Surface-spread manure plowed or disced into soil within two days.
[3] Surface-spread manure uncovered for one month or longer.
[4] Sprinkler-irrigated liquid uncovered for one month or longer.
[5] Includes in-house and stockpiled litters.

Table C.3 Yearly Application Rates for Broiler Litter Based on Nitrogen Application.

Crop	Maximum Application Rates		Time of Applications
	Single Application	Yearly Total	
	tons/acre		
Forages			
Bahia, Bermuda & dallis grass pasture	4	6	Spring-Summer
Fescue & orchard grass pasture	4	5	Fall & Spring
Bermuda & Bahia hay	4/cutting	cutting dependent	Spring-Summer
Cool season annual grass	4	6	Fall & Spring
Cool season annual grass with legume	3[2]	3	Fall
Warm season annual grass	4[2]	5	Spring-Summer
Row Crops[3]			
Corn, grain	4[2]	6.5	Fall-Spring
Corn, silage	4[2]	8	Fall-Spring
Cotton	3[2]	3	Fall-Spring
Grain sorghum & sweet sorghum	4[2]	4	Fall-Spring
Sorghum silage	4[2]	8	Fall-Spring

[1]Buffer zone is band of vegetation (grass, trees or wetland) between spreading area and intermittent or permanent surface water.
[2]Decrease the total application rate by 25 percent if incorporated immediately after application.
[3]Application rates should not be applied on crop land with greater than 8 percent slope.

Table C.4 Crop Fertilization Guidelines

Crop	lb N/RYE[1]	lb P_2O_5/RYE[1]
Corn (grain)	135 lb/150 bu	53 lb/150 bu
Corn (silage)	100/4.5 T	37/4.5 T
Cotton (seed & lint)	63/2600 lb	25/2600 lb
Sorghum (grain)	50/60 bu	25/60 bu
Wheat (grain)	50/40 bu	25/40 bu
Rye (grain)	35/30 bu	10/30 bu
Barley (grain)	35/40 bu	15/40 bu
Oats	50/80 bu	20/80 bu
Bermudagrass (hay[2],[3])	400/8 T	92/8 T
Tall fescue (hay[2],[3])	135/3.5 T	65/3.5 T
Orchardgrass (hay[2],[3])	300/6 T	100/6 T
Sorghum-Sudangrass (hay[2],[3])	319/8 T	122/8 T

[1]RYE = Realistic Yield Expectation
[2]Annual maintenance guideline
[3]Reduce N rate by 25 percent when grazing
Reference Sources: The Fertilizer Institute, The Potash and Phosphate Institute, North Carolina CES Circular AG 439-16

C.4 Crop Nitrogen Requirement Worksheet

	Example	**Your Farm**
1. Crop to be grown	Fescue hay	____________
2. Crop yield expectations from field records or NRCS standards	3.5 tons	____________
3. Nitrogen guidelines per unit of yield (Table C.4)	38 lb/ton	____________
4. Crop nitrogen requirement (2 x 3)	135 lb/acre	____________
5. Starter fertilizer nitrogen or previous legume nitrogen	0 lb/acre	____________
6. Commercial fertilizer nitrogen added	0 lb/acre	____________
7. Crop nitrogen need from poultry manure (4 - [5 + 6])	135 lb/acre	____________
8. Poultry manure plant available nitrogen		
a. Nitrogen composition of poultry manure from farm		
average or state average (Table 2.1.3)	64 lb/ton	____________
b. Nitrogen availability coefficient (Table C.2)	0.7	____________
c. Plant-available nitrogen (a x b)	44.8 lb/ton	____________
9. Poultry manure application rate (7 ÷ 8 c)	3.0 ton/acre	____________
10. Acres of crop to be grown	50 acres	____________
11. Total poultry manure required (9 x 10)	150 tons	____________

C.5 Crop Phosphorus Requirement Worksheet

	Example	Your Farm
1. Crop to be grown	Fescue hay	____________
2. Crop yield expectations from field records or NRCS standards	3.5 tons	____________
3. Phosphorus guidelines per unit of yield (Table C.4)	18 lb/ton	____________
4. Crop phosphorus requirement (2 x 3)	65 lb/acre	____________
5. Commercial fertilizer nitrogen added	0 lb/acre	____________
6. Crop phosphorus need from poultry manure (4 - [5 + 6])	65 lb/acre	____________
8. Poultry manure plant available phosphorus		
a. Phosphorus composition of poultry manure from farm		
average or state average (Table 2.1.3)	54 lb/ton	____________
b. Phosphorus availability coefficient (80%)	0.8	____________
c. Plant-available phosphorus (a x b)	43.2 lb/ton	____________
9. Poultry manure application rate (7 ÷ 8 c)	1.5 ton/acre	____________
10. Acres of crop to be grown	50 acres	____________
11. Total poultry manure required (9 x 10)	75 tons	____________

C.6 Litter Needs on Nitrogen and Phosphorus Basis

County/crop	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Appling	12375	10006	27930	5246	957	56513	5038	4118	4552	1186	496	15390
Atkinson	4453	3913	18969	130	3154	30619	1813	1610	3091	29	1635	8179
Bacon	8775	5491	16113	2098	547	33025	3573	2260	2626	475	284	9216
Baker	20025	14581	42809	1007	1116	79539	8153	6000	6976	228	579	21936
Baldwin	1013	0	0	0	889	1901	412	0	0	0	461	873
Banks	226	0	0	252	0	478	92	0	0	57	0	149
Barrow	0	4	0	0	0	4	0	2	0	0	0	2
Bartow	4248	555	0	3643	384	8830	1730	229	0	824	199	2981
Ben Hill	10487	4213	15341	422	2162	32624	4269	1734	2500	95	1121	9720
Berrien	15171	12259	30057	2908	442	60837	6177	5045	4898	658	229	17007
Bibb	383	0	0	1007	1131	2520	156	0	0	228	586	970
Bleckley	2356	8141	4045	4079	4512	23134	959	3350	659	923	2340	8231
Brantley	964	0	2140	81	0	3185	393	0	349	18	0	760
Brooks	5575	21708	33607	3394	1116	65400	2270	8933	5477	768	579	18026
Bryan	1768	189	1484	2149	251	5841	720	78	242	486	130	1656
Bulloch	15246	18964	36876	25874	6389	103349	6207	7804	6009	5852	3313	29185
Burke	21847	15557	35648	13596	5580	92229	8895	6402	5809	3075	2894	27075
Butts	209	0	0	661	384	1254	85	0	0	149	199	433
Calhoun	13986	10058	40867	297	4862	70070	5694	4139	6660	67	2521	19081
Camden	0	0	0	0	0	0	0	0	0	0	0	0
Candler	6931	7545	6188	10071	6836	37571	2822	3105	1008	2278	3545	12757
Carroll	0	0	0	0	0	0	0	0	0	0	0	0
Catoosa	92	0	0	0	140	232	38	0	0	0	72	110
Charlton	804	0	0	0	0	804	327	0	0	0	0	327

County/crop	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Chatham	141	0	0	0	0	141	57	0	0	0	0	57
Chattahoochee	0	0	0	0	0	0	0	0	0	0	0	0
Chattooga	1800	136	0	2256	212	4404	733	56	0	510	110	1409
Cherokee	23	0	0	0	0	23	9	0	0	0	0	9
Clarke	633	0	0	588	78	1298	258	0	0	133	41	431
Clay	477	5287	12554	0	439	18757	194	2176	2046	0	227	4643
Clayton	0	0	0	0	0	0	0	0	0	0	0	0
Clinch	316	74	1582	84	0	2057	129	31	258	19	0	436
Cobb	0	0	0	0	0	0	0	0	0	0	0	0
Coffee	12158	12040	43582	1433	1282	70495	4950	4955	7102	324	665	17996
Colquitt	8888	26793	32246	992	952	69871	3618	11026	5255	224	494	20617
Columbia	0	0	0	0	64	64	0	0	0	0	33	33
Cook	5525	9952	19250	1469	419	36614	2249	4095	3137	332	217	10031
Coweta	639	0	0	0	597	1236	260	0	0	0	310	570
Crawford	215	414	263	310	268	1469	88	170	43	70	139	510
Crisp	3951	16594	18333	1987	1526	42390	1609	6829	2988	449	791	12665
Dade	338	0	0	315	68	721	137	0	0	71	35	244
Dawson	2411	0	0	0	0	2411	981	0	0	0	0	981
Decatur	23504	18119	68555	1836	3237	115251	9569	7456	11172	415	1678	30291
DeKalb	0	0	0	0	0	0	0	0	0	0	0	0
Dodge	5525	6707	6836	3525	5301	27894	2249	2760	1114	797	2749	9669
Dooly	3895	34897	28596	4490	5339	77216	1586	14361	4660	1016	2768	24390
Dougherty	5985	2476	10860	1893	2008	23221	2437	1019	1770	428	1041	6694
Douglas	0	0	0	0	0	0	0	0	0	0	0	0
Early	9329	28136	53432	1012	4502	96410	3798	11579	8707	229	2334	26647
Echols	1761	0	0	0	0	1761	717	0	0	0	0	717

	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
County/crop	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Effingham	6599	1460	5098	5036	614	18807	2687	601	831	1139	318	5576
Elbert	804	785	0	839	781	3209	327	323	0	190	405	1245
Emanuel	4217	7724	14131	2828	2612	31512	1717	3179	2303	640	1354	9192
Evans	5273	2454	3094	4985	1674	17481	2147	1010	504	1128	868	5657
Fannin	804	0	0	63	78	945	327	0	0	14	41	382
Fayette	241	0	1	126	0	368	98	0	0	28	0	127
Floyd	5445	1076	0	2952	273	9747	2217	443	0	668	142	3469
Forsyth	251	0	0	0	0	251	102	0	0	0	0	102
Franklin	633	0	0	2098	0	2731	258	0	0	475	0	732
Fulton	281	0	0	0	6	287	115	0	0	0	3	118
Gilmer	1494	0	0	0	0	1494	608	0	0	0	0	608
Glascock	964	216	1758	1343	1563	5844	393	89	286	304	810	1882
Glynn	0	0	0	0	0	0	0	0	0	0	0	0
Gordon	11738	0	0	7931	1326	20995	4779	0	0	1794	688	7260
Grady	25086	12410	18687	3724	1157	61063	10213	5107	3045	842	600	19808
Greene	0	0	0	105	223	328	0	0	0	24	116	139
Gwinnett	0	0	0	0	0	0	0	0	0	0	0	0
Habersham	675	0	0	0	2734	3409	275	0	0	0	1418	1693
Hall	663	0	0	0	907	1570	270	0	0	0	470	740
Hancock	100	0	0	0	419	519	41	0	0	0	217	258
Haralson	259	0	0	403	0	662	106	0	0	91	0	197
Harris	668	0	0	0	614	1282	272	0	0	0	318	590
Hart	1311	368	0	2308	2188	6174	534	151	0	522	1134	2341
Heard	563	0	0	0	82	645	229	0	0	0	43	272
Henry	100	0	0	806	2009	2915	41	0	0	182	1042	1265
Houston	5112	5374	5204	5374	4756	25820	2081	2212	848	1215	2466	8823

	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
County/crop	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Irwin	28677	12782	51294	869	2234	95856	11675	5260	8359	196	1159	26650
Jackson	90	0	0	315	2441	2847	37	0	0	71	1266	1374
Jasper	1688	0	0	0	1367	3055	687	0	0	0	709	1396
Jeff Davis	3013	9376	14911	1091	577	28968	1227	3858	2430	247	299	8061
Jefferson	23485	7306	25914	8331	17464	82501	9561	3007	4223	1884	9056	27731
Jenkins	3988	5829	11509	5788	1856	28969	1624	2399	1876	1309	962	8169
Johnson	2089	619	7969	0	7366	18043	851	255	1299	0	3819	6223
Jones	0	0	0	0	0	0	0	0	0	0	0	0
Lamar	1025	927	0	755	4799	7506	417	381	0	171	2488	3458
Lanier	1876	3468	7322	856	201	13723	764	1427	1193	194	104	3682
Laurens	6728	2709	4914	15136	11705	41191	2739	1115	801	3423	6069	14147
Lee	29064	10997	23488	4197	3916	71662	11833	4525	3828	949	2031	23166
Liberty	530	47	0	355	0	932	216	19	0	80	0	315
Lincoln	241	0	0	0	0	241	98	0	0	0	0	98
Long	1575	69	258	1693	0	3595	641	29	42	383	0	1095
Lowndes	9040	4922	9688	5246	2093	30988	3681	2025	1579	1186	1085	9556
Lumpkin	1175	0	0	0	0	1175	478	0	0	0	0	478
Macon	8638	6116	7730	7245	6772	36501	3517	2517	1260	1638	3511	12443
Madison	145	15	0	1091	1423	2674	59	6	0	247	738	1050
Marion	817	95	2315	3198	1021	7446	333	39	377	723	530	2002
McDuffie	884	0	0	881	628	2393	360	0	0	199	326	885
McIntosh	0	0	0	0	0	0	0	0	0	0	0	0
Meriwether	0	0	0	315	614	929	0	0	0	71	318	389
Miller	17294	23744	68799	111	2276	112225	7041	9771	11212	25	1180	29229
Mitchell	27390	31067	54546	0	3110	116113	11151	12785	8889	0	1613	34438
Monroe	0	0	0	0	519	519	0	0	0	0	269	269

	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
County/crop	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Montgomery	2305	1791	1904	5578	1068	12647	939	737	310	1262	554	3801
Morgan	213	421	0	0	1674	2308	87	173	0	0	868	1128
Murray	4181	0	0	3978	949	9108	1702	0	0	900	492	3094
Muscogee	0	0	0	0	0	0	0	0	0	0	0	0
Newton	264	0	0	1469	1360	3093	107	0	0	332	705	1145
Oconee	844	183	0	781	1883	3690	344	75	0	177	977	1572
Oglethorpe	1350	0	0	0	684	2034	550	0	0	0	354	904
Paulding	321	0	0	0	0	321	131	0	0	0	0	131
Peach	1004	1978	844	2854	2609	9289	409	814	138	645	1353	3359
Pickens	1248	0	0	0	0	1248	508	0	0	0	0	508
Pierce	12452	3680	19132	9582	1989	46835	5069	1515	3118	2167	1032	12900
Pike	113	0	0	428	1132	1673	46	0	0	97	587	730
Polk	1973	660	0	3095	906	6634	803	271	0	700	470	2245
Pulaski	2350	16281	15638	3707	3710	41688	957	6700	2548	838	1924	12968
Putnam	76	0	0	0	22	99	31	0	0	0	12	43
Quitman	16	101	1336	0	922	2375	7	42	218	0	478	744
Rabun	301	0	0	0	21	322	123	0	0	0	11	134
Randolph	12045	9259	30495	11236	9840	72875	4904	3810	4969	2541	5102	21327
Richmond	1004	92	0	1167	384	2648	409	38	0	264	199	910
Rockdale	0	0	0	0	0	0	0	0	0	0	0	0
Schley	482	438	1051	389	837	3198	196	180	171	88	434	1070
Screven	15923	10560	16113	18884	1367	62848	6483	4346	2626	4271	709	18434
Seminole	13212	18922	47903	851	2746	83634	5379	7787	7806	192	1424	22589
Spalding	0	0	0	0	2734	2734	0	0	0	0	1418	1418
Stephens	22	0	0	0	0	22	9	0	0	0	0	9
Stewart	793	1464	2947	624	515	6343	323	603	480	141	267	1814

	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
County/crop	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Sumter	34385	16371	20319	13123	7438	91636	13999	6737	3311	2968	3857	30872
Talbot	251	0	0	0	220	471	102	0	0	0	114	216
Taliaferro	0	0	0	0	0	0	0	0	0	0	0	0
Tattnall	11840	3950	5483	18269	2382	41923	4820	1625	893	4132	1235	12706
Taylor	502	1487	1510	1846	1176	6522	204	612	246	418	610	2090
Telfair	2509	2921	5623	5209	2514	18776	1021	1202	916	1178	1304	5621
Terrell	19808	13587	23203	8057	8371	73025	8065	5591	3781	1822	4340	23599
Thomas	27964	15629	35570	3210	4353	86727	11385	6432	5797	726	2257	26597
Tift	3698	10956	29025	306	1799	45783	1506	4508	4730	69	933	11746
Toombs	7581	2297	3775	9405	682	23740	3087	945	615	2127	353	7128
Towns	110	0	0	0	0	110	45	0	0	0	0	45
Treutlen	685	1412	1024	1341	674	5135	279	581	167	303	350	1680
Troup	217	0	0	0	424	641	88	0	0	0	220	308
Turner	5322	11479	19519	1165	2335	39820	2167	4724	3181	263	1211	11546
Twiggs	464	2371	1065	340	0	4240	189	976	174	77	0	1415
Union	2009	0	0	0	0	2009	818	0	0	0	0	818
Upson	25	68	0	0	52	145	10	28	0	0	27	65
Walker	2813	0	0	3777	921	7510	1145	0	0	854	477	2477
Walton	954	112	0	1825	2232	5124	389	46	0	413	1157	2005
Ware	4122	684	10989	837	273	16906	1678	281	1791	189	142	4082
Warren	475	108	527	1007	391	2508	193	45	86	228	203	754
Washington	6991	625	6821	8292	9342	32071	2846	257	1112	1875	4844	10934
Wayne	6697	3062	8942	3333	673	22707	2727	1260	1457	754	349	6547
Webster	1129	2788	6381	709	1261	12267	459	1148	1040	160	654	3461
Wheeler	1710	650	3485	11126	3767	20737	696	268	568	2516	1953	6001
White	804	0	0	0	25	829	327	0	0	0	13	340

	Litter Needs on N Basis, in tons						Litter Needs on P Basis, in tons					
County/crop	corn	cotton	peanuts	soybean	wheat	Total litter N Basis	corn	cotton	peanuts	soybean	wheat	Total litter P Basis
Whitfield	1326	0	0	1679	126	3130	540	0	0	380	65	985
Wilcox	2387	12994	13219	1416	4785	34801	972	5347	2154	320	2481	11275
Wilkes	15	20	0	0	349	384	6	8	0	0	181	195
Wilkinson	80	246	151	1193	445	2116	33	101	25	270	231	659
Worth	9650	23581	54918	1888	3887	93925	3929	9704	8950	427	2016	25025
STATE TOTAL	706199	639993	1335701	361472	261791	3305156	287517	263371	217670	81751	135744	986053

C.7 Primary and Secondary Nutrient Composition of Some Selected Fertilizer Materials

Fertilizer Materials	Percent Water Solubility	Nutrient composition					
		N	P_2O_5	K_2O	Ca	Mg	S
Nitrogen	N	%					
Ammonia, anhydrous	100	82	-	-	-	-	-
Ammonia, aqua	100	16-25	-	-	-	-	-
Ammonium nitrate	100	33.5	-	-	-	-	-
Ammonium nitrate-limestone	100	20.5	-	-	7.3	4.4	-
Ammonium sulfate	100	21	-	-	-	-	23.7
Ammonium sulfate-nitrate	100	26	-	-	-	-	15.1
Calcium cyanamide	100	21	-	-	38.5	-	-
Calcium nitrate	100	15	-	-	19.4	1.5	-
Nitrogen solutions	100	21-49	-	-	-	-	-
Sodium nitrate	100	16	-	-	-	-	-
Sulfur-coated urea	Variable	35	-	-	-	-	21
Urea	100	46	-	-	-	-	-
Ureaform	Variable	38	-	-	-	-	-
Phosphate	P	%					
Ammoniated super-phosphate	35	3-6	18-20	-	17.2	-	12
Ammoniated phosphate nitrate	100	27	15	-	-	-	-
Ammonium phosphate sulfate	90+	13-16	20-39	-	-	-	15.4
Ammonium polyphosphate	100	10-15	34-62	-	-	-	-
Bone meal	-	2-4.5	22-28	-	20-25	-	-
Diammonium polyphosphate	95+	16-21	48-53	-	-	-	-
Monoammonium phosphate	90+	11	48	-	1.1	-	2.2
Nitric phosphates	40	14-22	10-22	-	8-10	-	1-3.6
Phosphoric acid	100	-	52-60	-	-	-	-
Rock phosphate	<1	-	30-36*	-	-	-	-
Superphosphate, normal	85	-	18-20	-	20.4	-	11.9
Superphosphate, concentrated	87	-	42-50	-	13.6	-	1.4
Superphosphoric acid	100	-	69-75	-	-	-	-
Potash	K	%					
Nitrate of soda-potash	100	15	-	14	-	-	-
Potassium chloride (muriate)	100	-	-	60-62	-	-	-
Potassium magnesium sulfate	100	-	-	22	-	11.2	22.7
Potassium nitrate	100	13	-	44	-	-	-
Potassium sulfate	100	-	-	50	-	1.2	17.6

**Relatively unavailable to plants in most soils*

Source: *Fertilizer Handbook,* The Fertilizer Institute

C.8 Fertilizer Material Prices for 2006-2008

Fertilizer Material Prices	2006	2007	2008
Nitrogen			
Ammonia, anhydrous	$ 521	$ 523	$ 803
Ammonium nitrate	$ 390	$ 425	$ 543
Ammonium sulfate	$ 266	$ 288	$ 391
Nitrogen solutions	$ 249	$ 286	$ 392
Urea	$ 362	$ 453	$ 552
Phosphate			
Diammonium polyphosphate	$ 354	$ 481	$ 879
Superphosphate, concentrated	$ 331	$ 433	$ 807
Potash			
Potassium chloride (muriate)	$ 294	$ 309	$ 524
Potassium magnesium sulfate			$ 449[1]

Source: USDA, NASS 2006-2008

[1] US 1 Farm Service Lyons, GA