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Economics of Poultry Litter Utilization and Optimal Environmental Policy for Phosphorus Disposal in Georgia[1]

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Abstract:

Poultry litter can be used as plant nutrients or cattle feed. Both of these alternatives may increase phosphorus concentration in the nearby watershed. Use of phosphorus consistent litter application rule in nutrient management combined with permit system has potential to curtail the over production of litter and prevent the possible contamination of water.

Economics of Poultry Litter Utilization and Optimal Environmental Policy for Phosphorus Disposal in Georgia

The poultry industry generates about 12 billion dollars in revenue (with 29,910,000 total chickens) to the state of Georgia and ranks as the number one agricultural industry in the state (NASS). Based on the total value generated from the poultry industry, Georgia ranks as the number one poultry producer in the United States. The poultry industry is responsible for 50 percent of the total GDP generated from agricultural enterprises in Georgia. More than half of the counties in Georgia produce poultry products worth more than one million dollars (figure 1). With this large amount of poultry production comes problems in disposing of the byproducts; litter and dead chickens. The Georgia poultry industry produces about 1.83 million tons of litter every year (table 1). The main problem associated with these byproducts is the lack of proper ways to dispose this huge amount of litter. In this paper, we will analyze the possible alternatives for poultry litter disposal and examine the economic and environmental benefits associated with them. The poultry industry in Georgia includes the production of broiler, layers, pullets, and turkeys. Of these, broiler production is the largest in terms of animal numbers, revenue generated, and the amount of litter produced. Thus we will focus our analysis on the disposal of broiler litter.

The broiler industry generates 39 percent of total GDP in the state of Georgia. The top five counties in the state, based on the sale of broilers, are Franklin, Banks, Madison, Gordon, and

Habersham. Approximately 46 percent of the total broiler production is concentrated in an eight county area of the central Piedmont region of Georgia. 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 area. There is also a positive benefit associated with poultry litter as there exists a profitable opportunity for the processing and marketing of this by-product.

Poultry litter is rich in the major plant nutrients, nitrogen, phosphorus, and potash. 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 two ways, it provides the needed plant nutrients and has 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 analysis, we will compare the costs and revenue of applying poultry litter versus chemical fertilizers in the production of the major row crop grown in Georgia (cotton).

Other alternative uses of poultry litters include its use as a livestock feed, as a fuel source and as a plant bedding material. We examine the costs associated with processing poultry litter for selected alternative uses in an effort to determine the most profitable use of poultry litter. We also calculate the alternative use of poultry litter which provides the maximum revenue to the poultry farmers with the minimum environment pollution.

In this study, we examine environmentally benign methods for disposal of poultry litter in cattle feed and as a source of nutrients in crop production. We then suggest few policy instruments to aid in controlling poultry litter disposal for amounts beyond what is required for crop production and cattle feed in the state.

Poultry Litter as Fertilizer

The alternative use of poultry litter requiring the least value-added processing 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 potash (N-P-K) in broiler litter was estimated to be 3-3-2 (Wood). The average amounts of the major nutrients (N-P-K) present in the different classes of poultry litter are shown in table 1. Significant amounts of secondary plant nutrients are also found in broiler litter. Any kind of poultry litter can be used as 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 after two years 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 detrimental to surface and ground water quality. However, if litter is applied according to the phosphorus requirements of the crop, both problems can be ameliorated. 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. A phosphorus-consistent policy has been implemented in Texas where the threshold phosphorus concentration in the soil is set at 200 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.

Due to the low nutrient content of litter, and thus high volumes required, 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, poultry production occurs in almost every county in the state, although a higher concentration occurs in the northern part of the state. Carpenter 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 may make composting unprofitable for broiler producers. This view is supported by Vervoort and Keeler 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 can poultry litter be transported to apply as sources of plant nutrients based on the phosphorus need of a crop. Bosch and Napit 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.* used the rule of thumb and estimated the amount of litter produced by broilers to be 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 5.9 billion pounds of broilers produced in Georgia during 1997, this would equal 3.07 billion pounds of litter.

Currently, poultry litter is applied to about half of the crop production area in north Georgia (Givan). The total crop land acreage in Georgia was 5,367,637 in 1997. Pasture and range land account for 7.7 percent of the total land acreage in the state (table 2). Both pasture and crop land are currently receiving applications of poultry litter. According to Givan 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 house, 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.* analyzed samples of poultry litter with 20 percent moisture content obtained from 147 broiler houses over 11 years and found the percentage of nitrogen (N), phosphorus (P_2O_5) and potash (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 or 60:60:40

pounds of N-P_2O_5 -K_2O 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 0.9 percent while the organic nitrogen is about 2.2 percent (Mitchell, Donald, and Payne). We also assume that organic nitrogen from litter is available only 50 percent 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 potash are available only 75 percent of the original application amount. These assumptions are consistent with the previous studies (Mitchell, Donald, and Payne; Hammond, Segars, and Goul).

Due to the concern over phosphorus run-off and eutrophication, litter should be applied to crops based on the phosphorus content of the litter and soil, and the phosphorous 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 is a major row crop in Georgia. It accounts for 8 percent of total GDP generated by agricultural enterprises in the state. Continuous application of chemical fertilizer and conventional tillage has reduced the productivity in cotton in Georgia (Trimble; Paudel). Poultry litter application helps to enhance soil productivity as it is a source of organic matter in 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 cotton, and because of a three-year assumption for complete nutrient recovery, cotton enterprise budgets were prepared for a three year application cycle. In addition to utilization of litter, it is suggested that no-till practices be used to reduce phosphorous runoff. We analyze net returns and break-even transportation distances under two scenarios - application of poultry litter consistent with phosphorus levels with no-till and application of chemical fertilizer with no-till in cotton.

A specific assumption used in preparing the enterprise budgets is that poultry litter is applied on an average size cotton farm in Georgia. It is assumed that these farms have all necessary farm machinery and equipment. Litter transportation cost in the Georgia Piedmont area is $0.10 per ton per mile (Kriesel, McIntosh, and Miller) . The cost of litter is $10 per ton (GASS). The University of Georgia Cooperative Extension Service recommends that nitrogen, phosphorus, and potash 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 organic matter, soil productivity should increase if poultry litter is applied continuously at a responsible rate. Paudel 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 Piedmont region is, at present, at one percent, continuous application of poultry litter has the potential to increase yield up to 12 percent above current levels. However, Paudel 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. Increases in organic matter help to improve soil tilth and decrease the soil erosion by increasing soil infiltration.

If poultry litter were applied to all cotton acreage in GA, 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 region (in the north) 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 production 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 for poultry waste disposal problems in the region. Table 3 shows the ten counties with the highest acreage of crop production, number of beef cattle, and the number of broilers. Total poultry litter use based on the phosphorus requirements of these three crops (both irrigated and dryland) are presented in table 4. Table 4 also shows the total acreage (irrigated and dryland), recommended amount of major plant nutrients, and phosphorus consistent poultry litter application rates for cotton, corn, and wheat. The nutrient needs not met by poultry litter are assumed to be supplied through application of chemical fertilizers.

Break-even transportation distances are calculated for cotton for illustration purposes. The summary of three years net returns, total costs and breakeven transportation distances are shown in table 5. A specific enterprise budget prepared for the first year of poultry litter application to no-till cotton is shown in appendix A.

The total potential amount of litter utilized in the production of cotton, corn, and wheat (using phosphorus consistent application rates) are shown in table 3. 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 the potential use in row crop production, poultry litter is currently applied to 7.5 percent of pasture and range land in the state.

Poultry Litter as an Animal Feed

A second alternative market for broiler litter is as cattle feed. Poultry litter is a good source of protein, energy, and minerals. Processing of broiler litter for cattle feed can be done by ensiling it with corn or sorghum, heat treatment to form pellets or simply stacking litter for at least 20 days before mixing with other feed ingredients. According to Ruffin and McCaskey, poultry litter is worth four times more if used as cattle feed than if used for plant nutrients. We analyze the economic feasibility of processing broiler litter for cattle feed, especially for the production of stocker cattle.

The beef cattle industry generated $238 million in the state of Georgia in 1997. The share of feed cost in cattle production is, on average, 22 percent of the total expenses. Broiler litter can be used directly or in combination with grains in animal rations. Since the broiler industries and cattle farms are located mostly in the nearby states (Figure 2), the use of litter as a feed ingredient seems one of the best alternative disposal method with a minimum transportation cost. Further, pasture land used for raising beef cattle can also receive applications of poultry litter as a nutrient source for winter annuals (although such practice is not encouraged if the feed ration already contains of poultry litter). Use of broiler litter as cattle feed may reduce the total cost of cattle feed and provide an alternative sink for broiler litter disposal. The average nutrient content of broiler litter varies, as there are no regulations on the amount of bedding material used and the number of batches of birds housed between clean-out. The average nutrient content of the broiler litter as obtained from 106 samples of dry broiler litter are shown in table 6 (Ruffin and McCaskey).

At present, the feeding of broiler litter is regulated by the Board of Agricultural and Industries by regulations that went into effect on January 1, 1977. According to the regulations, broiler litter should not be fed to dairy cows, nor should it be fed to stockers less than 15 days before slaughter. Because of the high amounts of uric acid in broiler litter, it should not be fed to calves below 400 pounds.

Gerken examined the use of broiler litter for cattle feed in Virginia. He found that the amount of poultry litter being fed to livestock ranged from 20 to 40 percent of the diet on a dry matter basis. Litter could provide all necessary nutrients needed for cattle production. In addition, Gerken found that the use of poultry litter in cattle diets can reduce overall feed costs and thus increase profits from cattle enterprises.

Ruffin and McCaskey noted that poultry litter exhibited variability in nutrient content due to the content of other materials mixed with litter. Suitable litter for feeding should have 12 to 25 percent moisture, at least 18 percent but not more than 25 percent crude protein and less than 28 percent ash. Beef cattle should be fed poultry litter after reaching 450 pounds and continue to be fed litter until 2 weeks before slaughter. The ration could contain 50 to 80 percent litter. If vitamins and anti-bloat ingredients are added, diets containing litter were found to be more economical than conventional diets, and Ruffin and McCaskey showed that litter as a feed ingredient is indeed worth more than four times that of litter as fertilizer. Litter was also found to be less costly substitute for grains normally incorporated in conventional feed rations.

Hardy and Freeman determined the market potential for range cubes formed from broiler litter. Their study showed that the average retail price for range cubes was around $186 per ton. Wholesale prices charged by suppliers were found to be approximately $158 tons per ton. They conclude that there exists a viable market for poultry litter as cattle feed. The prevailing market price of different kinds of cattle feeds containing broiler litter as part of the ration in North Georgia is presented in table 8.

In this study, we assumed that only 35 percent of total poultry litter produced in Georgia could be used as cattle feed. This assumption is necessary as only reasonably good quality litter is suitable for use as a feed ingredient. This assumption is also consistent with Ruffin and McCaskey. At this percentage, a total of 517,475 tons of Georgia broiler litter would be suitable for use in cattle feed. The proportion of broiler litter and grain in the ration depends on types of cattle (for example, brood cows versus stocker steers). A reasonable ration for stockers would consists of litter and corn in 50:50 mix. Other necessary feed additives such as an anti-bloat agent and vitamin A should be added to increase the digestibility and supply needed nutrients.

A feed ration made with the mixture of cracked corn and broiler litter should be fed daily at the rate equivalent to three percent of total body weight of the stocker cattle. Generally, vitamin A is added at 15,000 International Units per pound of feed. Rumensin or Borvatec[1] should be added to the ration at a rate of 150 mg per day for animals weighing less than 700 pounds and 200 mg per day for animals weighing more than 700 pounds. The Alabama Cooperative Extension Service (Walter and Marshall) report that, on average, 45.15 tons of feed containing poultry litter and cracked corn in a 50:50 proportion is sufficient to feed 65 stockers

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[1]Borvatec is an anti-bloating compound added in ration.

for an increase of 384 pounds weight per animal. Generally, stockers are purchased with the starting weight of approximately 400 pounds and sold when they reach 784 pounds. This means that for a heard of 65 stockers 22.6 tons of broiler litter would be necessary (along with other feed supplements) to achieve a total gain of 26,880 pounds weight. Stockers raised this way are also fed with winter annuals in addition to a broiler litter and grain mixed ration. However, if one wants to raise stockers entirely on grain and broiler litter then it is necessary to feed 88.73 tons of ration mixed in a proportion of 50:50 litter and grain for the same number of cattle.

The total number of stockers in Georgia equaled to 613,950 in 1997, which could have consumed 212,993 tons of broiler litter. The economic value of broiler litter fed to the livestock equals $4.26 million even without considering environmental benefit associated with it.

Among several alternatives for raising stockers in Georgia, three major alternatives for raising cattle are i) winter grazing with grain supplements, ii) winter grazing with poultry litter, and iii) dry lot feeding of a ration including poultry litter. Here we compare the cost of raising 65 head of stockers utilizing winter annual grasses with the same numbers of stockers utilizing winter annual grasses with broiler litter and grain. The enterprise budgets for these activities are shown in the appendices B-I and B-II.

Assumptions used in preparing the enterprise budgets for winter annual fed cattle are that farmers purchase stockers when they are 450 pounds then raise them for 200 days selling the stockers at approximately 784 pounds. We assume a 1.5 percent death loss. Stockers are stocked at a rate of 1.11 head/acre of pasture land. Cattle farmers are assumed to have all the necessary equipment and to properly depreciate the equipment when calculating the costs.

In case of poultry litter fed option, stockers are purchased when they are 450 pounds of weight and raised for 200 days selling the stockers when they get approximately 853 pounds. The weight gain per day per animal is 2.1 pounds. We considered 2 percent shrink in the final weight. Cattle are fed approximately 7.5 pounds of poultry litter and grain mixed ration per day.

With the prevailing price of $25 per ton of broiler litter suitable for cattle feed and, a farmer can achieve a 112 percent higher net return when the ration contains poultry litter than when ration consists of the traditional combination of winter annuals and grains. The budgets indicate that stockers fed with broiler litter generated a 10 percent higher return for each dollar invested while cattle raised with poultry litter generated 22 percent higher return for each dollar invested in the 65 animal herd.

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 7 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 and Sheridan; Bouwer).

Phosphorus is subject to runoff into surface waters 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).

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 *et al.*). In addition, since composting lowers the nutrient content of the litter it also decreases its commercial value (Vervoort and Keeler).

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).

Govindasamy *et al.* 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). 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). The down-side of adding alum in the production process is to increase 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 on no-till. Therefore, phosphorus runoff could be minimized if no-till management practices are followed and if litter is applied to clay soils (Cox). At present only 15 percent of total land in cotton cultivation is under no-till management practice (CTIC).

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.

We examine the impact of imposing a standards based tax and permit system for controlling the total amount of poultry litter produced in Georgia. If a standards based tax is imposed at the farm level, such policies tend to be infeasible in controlling nonpoint pollution (Moxey and White). To control nonpoint 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 and Easter).

The aggregate value of per year poultry litter production can be illustrated using a profit function. Suppose $p = [p_1 \quad p_2]$ is a vector of prices associated with use $l = [l_1 \quad l_2]$ of poultry litter. $c(l)$ is the direct cost associated with poultry litter disposal such as the cost of hauling, spreading, and transportation if it is used as plant nutrient source or cost of mixing with grains (corn or soybeans) if used for cattle feed. Suppose l_1 represents the amount of litter used for crop nutrient (based on optimum phosphorus rule), l_2 represents the total amount of litter used for the animal feeding. This results the remaining amount of litter is $(L - l_1 - l_2)$ which should be taxed to limit the unnecessary production.

The economic model for the standard based charge system can be established as follows:

$$\Pi = p\,l' - c(l_1) - c(l_2) - t\,(L - l_1 - l_2) \qquad (1)$$

Subject to,

$$l_1 + l_2 \leq L$$

$$p, l, L, t \geq 0$$

where $l_1 + l_2 = L$ is an environmentally safe level of poultry litter production. In this model, we make the simplifying assumption that poultry litter is the only source of phosphorus pollution in the nearby surface and ground water.

Since price vectors p_1 and p_2 are known to farmers at the time of poultry litter production, the role of a unit tax should be such that farmers get penalized highly if poultry litter production exceeds the total amount calculated as needed for fertilizer and cattle feed. If a poultry farmer produces litter above $l_1 + l_2$, his profits are reduced by the amount $p_i – c'(l_i)$ - t per unit of production where the subscript i depends upon the purpose for which the litter is to be sold. The total reduction in profit depends upon the portion of litter produced above the standard calculated by aggregating the amounts needed for plant nutrients and cattle feed. The optimal amount of tax (t) depends on the cost of cleaning nitrogen and phosphorus in the nearby water source as these are not currently treated in all water treatment plant. Since poultry litter pollution of water is nonpoint in nature, it is hard to determine the correct level of tax and find the efficient level of production. The general procedure is to use the concept of watershed management and charge producers according to the cost required to clean the contaminated water to bring phosphorus concentration to safe levels. Here, a stream inflow concept is appropriate. However, with increasing poultry litter production and the resulting groundwater and surface water pollution problems, the proper amount of tax needs to consider both the instream and recreational benefits. At least, the tax for producing one more unit of poultry litter should be satisfy $[p_2-c'(l_2)] < [p_1-c'(l_1)] < t$.

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 nonpoint or point sources of pollution. Permits also promote technical change (promote compliance through changing production systems or patterns) and are easy to implement as one does not have to use a trial and error method as in the tax system.

Permits would 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 raises revenue for the government, it is also a politically attractive tool for operation in regulating poultry litter production.

Assigning Permits

Limited numbers of poultry producers can potentially affect the water quality for many consumers in the state of Georgia. Because the action of poultry litter producers potentially pollute recreation and drinking water for many people in the surrounding area, we deal this problem as a multilateral externality. Further, water pollution resulting from poultry litter is equally experienced by all consumers in the poultry production and litter application area so we formulate our model as if we are dealing with the public goods. We also assume that the regulator has very little information about the nature of the derived profit function of the poultry producers and cannot tell which particular firms is more likely to handle the burden of reducing the litter production.

Suppose that poultry producer i's derived profit function is denoted by $\pi_i (l_i)$ where l_i is the amount of litter produced. If there is no litter production, profit will be zero which is obvious as poultry bird and poultry litter are joint products and one cannot be produced without others. Suppose also that the consumer j have quasilinear utility function that is denoted by $\varphi_j (l_j)$ and $\varphi_j'(l_j) < 0$. For the purpose of analysis, we also assume that both derived profit function and utility function are twice differential. More specifically, $\pi_i''(l) < 0$ for all i and $\varphi_j''(l) < 0$. Since we assumed that poultry litter related pollution is nondepletable multilateral exteranlity, the level of externality experienced by each consumer is $\sum_i l_i$. Therefore, if the allocation is to be pareto optimal then the level of litter produced should maximize the sum of consumer's utility and producer's profit. This can be written as:

$$\underset{(l_1,l_2,l_3......l_i)}{Max} \sum_{j=1}^{J} \varphi_j(\sum_i l_i) + \sum_{i=1}^{i} \pi_i(l_i). \qquad (2) \qquad (3)$$

$$FOC: \quad \sum_{j=1}^{J} \varphi_j^{/}(\sum_i l_i^{o}) \leq -\sum_{i=1}^{i} \pi_i^{/}(l_i^{o}).$$

Equation 3

provides both necessary and sufficient conditions for each firm i's optimal level of litter production denoted by l^o. Market based solution to control poultry litter can be created only if we can create a personalized market. However, in our situation we can manage this problem using tradeable externility permits since regulator knows exactly how much amount of litter is produced in a given location at a given year.

To allocate the appropriate level of permit using a partial market based approach, we suggest that first quota amount be established on the total level of poultry litter produced. Based on our results in previous sections, permits are then distributed to allow a firm to produce one more unit of litter production. Initial distribution of permit can be based on either the number of poultry bird housed for the specific purpose or the total amounts of phosphorus in the litter. If l^o is the optimal amount of litter production then $l^o = \sum l_i^o$ are given to the firms, with firm i receiving l_i of them. Suppose p_l^* is the equilibrium price of these permits, then each firm i's demand for permits l_i solves

$$\underset{l_i \geq 0}{Max}(\pi_i(l_i) + p_l^*(\bar{l}_j - h_j)) \quad . \tag{4}$$

The first order necessary and sufficient condition is

$$\pi_i^{/}(l_i) = p_l^* \quad . \tag{5}$$

The market clearing permits situation also guarantees that $\sum_i l_i = l_0$. The competitive equilibrium for permits than has price

$$p_l^* = -\sum_i \varphi_i^{/}(l^o) \tag{6}$$

and each firm i uses l_i^o permits and so results an optimal allocation. The permit can be assigned in each of the sub-basins in the watershed based on the difference between existing phosphorus level and the safe level of phosphorus for human consumption and recreation.

The problem exists on how to calculate the utility function of consumers. We can use marginal cost needed to clean up the phosphorus disposal as a surrogate for the reduction in the utility function. The marginal cost function for cleaning up extra phosphorus can be obtained from cost function used by industry for this purpose. The profit associated with producing litter by farmers can be obtained directly by asking farmers or one can also get the same value from the census of agriculture as there is strong correlationship between between the amounts of litter and chicken produced.

Based on the cost of phosphorus cleaning, one can assign the price for each permit distributed. The number of total permits issued should directly reference the total amount of litter that can safely be used in the form of cattle feed or as crop nutrients based on the phosphorus consistent rule. To obtain the efficiency from these permits, they should be traded among subzone in the same watershed and modified every fixed time period (most common are 3-5 years) based on the phosphorus pollution level in the watershed. Unlike air pollution which may face a thin market for trading, there are many poultry producers in the region who should actively trade permit among themselves once regulation gets started.

One of the best alternatives to reduce total phosphorus in poultry litter is to store it in a poultry littler stack house until it is ready to apply as plant nutrient. The Agricultural Stabilization and Conservation Service has been helpful in guiding poultry waste disposal methods and has provided cost sharing up to 75 percent of certain costs (Hammond). The ultimate solution may be to utilize all of these options in addition to permits in order enhance the water quality in the state. Most of the poultry operations in Georgia are large in size and need permits from the government for the land application (Hammond). Small operations may not need permits for land application but policies should be executed such that poultry farmers are not allowed to pollute nearby water sources and litter application should be restricted near water, especially within 100 feet of streams, ponds, springs and wells, and water supplies. Site-specific land management plans should be followed for the best application of poultry litter as crop nutrients at the crop field.

Conclusions

Three possible scenarios for poultry litter disposal and control were outlined in this manuscript. Cotton cultivated in the state is potentially able to utilize all the broiler litter produced even when littler is applied according to the phosphorus content and crop requirements. Farmers are not applying poultry litter as extensively as this result would indicate because they have imperfect information about the total cost and benefit associated with poultry litter application. The complete adoption of poultry litter as a nutrient source may take several years unless the government provides some incentives for increased litter utilization.

The first alternative is for producers to dispose of poultry litter so that he/she can achieve the highest profit. In the present market scenario, farmers can sell poultry litter as cattle feed in the highest price. At the current market price of poultry litter ($16 per ton) it is cheaper for farmers to use litter for crop nutrients than to use chemical fertilizers.

Permits should be distributed to poultry farmers so that the aggregate production does not exceed the environmentally safe level of phosphorus in soil. Permits also contain all properties that an effective policy should have. A permit system is, therefore, a preferred system for inducing poultry farmers to produce the right level of phosphorus. Detailed economic and environmental impacts of poultry litter need to consider the impact that contaminated water may have on recreational benefits. This study also did not address the odor related issues in calculating the permit prices or taxes. All of these should be considered to find the economically profitable and environmentally responsible poultry litter production in Georgia.

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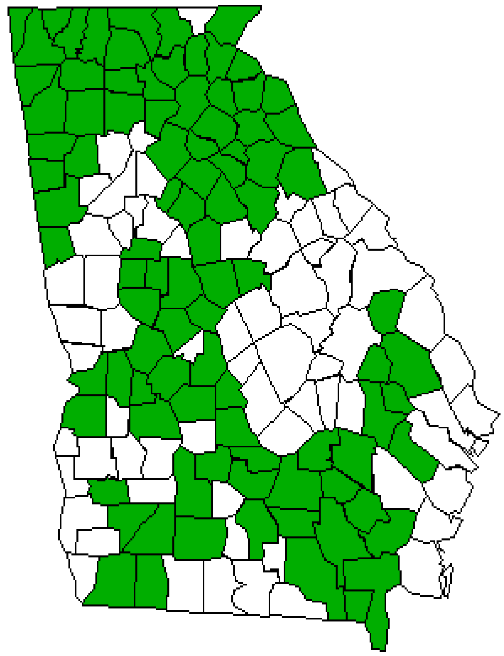

Figure 1. Counties in Georgia that collects more than million dollars from poultry industry

(Source: www.uga.edu/~poultry/gapoultry/gpf2/sld012.htm)

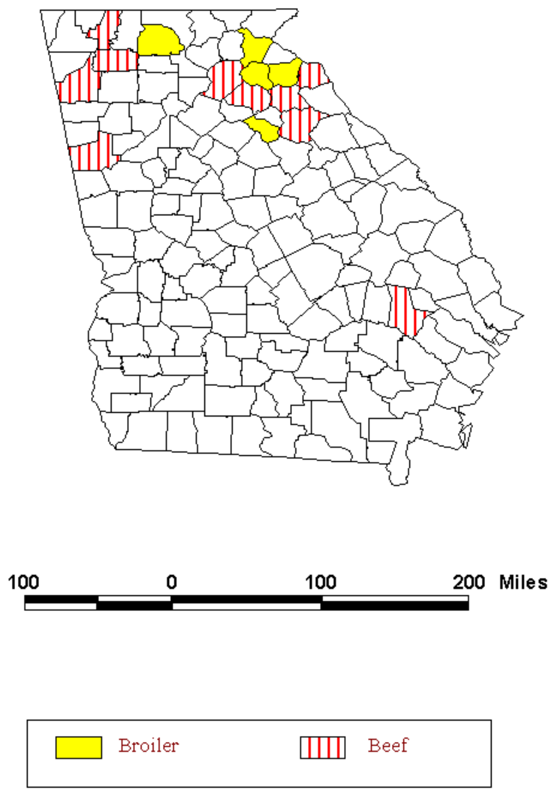

Figure 2. Top ten counties in Georgia based on the income generated from beefs and broilers

Table 1. Poultry birds, their numbers, and total litter produced per year in Georgia in 1997

Type of Poultry	Number (000)	Litter per bird[a] (Pounds)	Approximate nutrient content ($N-P_2O_5-K_2O$)	Total litter produced (000 tons)
Laying Chicken	16,295	40	38-56-30	325,912
Broiler	1,182,800	2.5	66-50-40	1,478,500
Turkey	107	31	57-72-40	48,500
Replacement Pullet	87,795	8	38-56-30	35,178

Source: Census of Agriculture - State Data for Georgia 1997
[a] Source: Vest, Merka, and Segars (1994)
[b] Based on annual Cleanout

Table 2. Land Use Pattern in Georgia 1997 (Total Acreage=10,671,246)

Land use	Percentage of total acreage
Crop land	50.3
Woodland	35.4
Pastureland and rangeland	7.7
Other land	6.6

Table 3. Top ten counties producing broiler, crops (harvested), and cattle in Georgia in 1997

Broiler	Harvested crop acreage	Cattle
Franklin	Mitchell	Carroll
Banks	Burke	Madison
Madison	Bulloch	Gordon
Gordon	Colquitt	Hart
Habersham	Dooly	Oglethorpe
Jackson	Worth	Jackson
Hall	Decateur	Hall
Gilmer	Early	Whitfield
Tattnall	Sumter	Floyd
Oconee	Coffee	Tattnall

Table 4. Acreage Under Three Major Row Crops, the Recommended Fertilizer Rate, And Phosphorus Consistent Poultry Application Rate For Three Years in Georgia (Based On 1997) [A]

Crop[b]	Acreage (000)	Recommended $NP_2O_5K_2O$ pounds per acre	Phosphorus consistent poultry litter application, tons per acre[d]			
			1[st] year	2[nd] year	3[rd] year	Three years total
Cotton (dryland)	1164	70:50:80	1.11(38.1)	1.11 (43.8)	1.11 (46.2)	3.33
Cotton (irrigated)	276	90:60:90	1.33 (45.7)	1.33 (52.5)	1.33 (55.3)	3.99
Corn (dryland)	300	120:40:40	0.8 (27.5)	0.8 (31.6)	0.8 (33.3)	2.4
Corn (irrigated)	150	180:60:80	1.33 (45.7)	1.33 (45.7)	1.33 (45.7)	3.99
Wheat [d]	350	80:40:40	0.8 (27.5)	0.8 (27.5)	0.8 (27.5)	2.4

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

[b] Soybeans(0:40:80 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] Parenthesis provides the nitrogen supplied by the given amount of nitrogen. The rates get higher in the second and third year because of the residual left.

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

Table 5. Net Return, Total Cost and Break Even Distance of Poultry Litter Transfer in Dry Land No-till Cotton

Fertilizer source	Net return ($)	Total cost ($)	Break-even mileage ($0.10/mile)
Chemical Fertilizer	71.22	458.39	
Poultry litter (1st year) + chemical Fertilizer	89.12	440.49	179
Poultry litter (2nd year) + chemical Fertilizer	91.08	438.53	198.6
Poultry litter (3rd year) + chemical Fertilizer	91.9	437.71	206.8

Table 6. Nutrient Content of Broiler Litter as Obtained from 106 Samples

Components, dry basis	Average
Moisture	19.5
Dry matter %	80.5
Total Digestible Nutrients %	50
Crude Protein %	24.9
Bound Nitrogen %	15
Crude fiber %	23.6
Ash (minerals)	24.7

Source: Ruffin and McCaskey (1992)

Table 7. Prevailing prices and percentage of poultry litter in different kinds of cattle feed sold in Georgia

Feed type	% of poultry litter in the feed	Price per ton ($)
Stretcher (for beef cows)	40	134
Stocker	50	154
Creeper (for calves)	75	165
Supercuber	100	105

Source: Collected from the local Store located in Lavonia, GA

Table 8. Total Variable Cost, Fixed Cost, Total Cost, and Net Return from Two Alternative Raising system of Stockers (65 heads for 200 days) Common in Georgia

Items	Winter annual grass raised	Poultry litter raised
Total variable cost	30,424.66	27,855.51
Total fixed cost	1,449.54	1,853.71
Total cost	31,874.20	29,709.22
Net return	3,115.80	4,410.46

Appendix A. Sample Enterprise budget for the first year cotton with poultry liter.
Dry land cotton budget; NO-TILL AND Chemical Fertilizer; Per acre of land for year 1998; Yield in Bales/acr; 1.41 (10 year average yield); Recommended Fertilizer amount = 70:50:80 lbs NPK / acre

Cotton yield		Amount	Price	Revenue
Cotton (lbs)		679.20	0.68	41.86
Seed (tons)		0.45	150.00	67.75
Total revenue				529.61
	Unit	No. Units	Price/Unit	Cost
Variable Cost				
Seed	lbs	9.00	0.77	6.93
Lime	ton	0.33	24.00	7.92
Fertilizer				
Nitrogen	lbs	70.00	0.29	20.30
Phosphorus	lbs	50.00	0.22	11.00
Potash	lbs	80.00	0.13	10.40
Herbicides	Acre	1.00	28.00	65.95
Insecticides	Acre	1.00	41.00	41.00
Application of insecticides				
Machinery and labor	Appl	1.00	9.50	9.50
Defoliant and Harv aid	Acre	1.00	9.50	9.50
Scouting and service	Acre	1.00	6.00	6.00
Boil weevil eradication	Acre	1.00	6.00	6.00
Machinery Pre-harvest				
Fuel	Gal	3.90	0.85	3.32
Repair and maintenance	Acre	1.00	9.51	9.51
Machinery and harvest				
Fuel	Gal	4.25	0.85	3.61
Repair and maintenance	Acre	1.00	33.96	33.96
Labor	Hour	2.35	6.50	15.28
Interest in Op. Cap.	Dol	260.17	0.10	13.01
Ginning	Lb	679.20	0.09	61.13
Market prep charges	Bale	1.41	15.00	21.22
Total variable costs				355.53
Income above variable costs				174.08
Fixed costs				
machinery, depreciation, taxes				
Investment and housing				
Pre-harvest	Acre	1.00	19.81	19.81
Harvest	Acre	1.00	47.50	47.50
General overhead	Dol	355.53	0.05	17.78
Management	Dol	355.53	0.05	17.78
Total fixed costs				102.86
Total costs				458.39
Net return to land				71.22

Appendix B-I

Enterprise budget for stockers raised with winter annual grass (65 stockers for 200 days)

Items		Quantity	Price or cost in dollars /unit	Income or cost
Gross receipts	**Weight per animal**			
Feeder cattle (Pounds)	804	64	0.68	34,990.00
Variable costs				
Stocker calves (cwt)		292.5	71.00	20,767.50
Winter grazing (acres)		59	76.83	4,532.00
Hay (ton)		9.75	60.00	585.00
Grain and supplemental		97.5	10.50	1,023.75
Other variable costs [b]				4,100.44
Fixed costs [c]				1,449.54
Total costs				**31,874.20**
Net return				**3,115.88**

[a] Following assumptions are made in addition to others described in the text
1.5 percent death loss
30 days of supplemental feed required
200 days of feeding period
450 beginning weight
1.11 animal stocked per acre
Farmer owns his own pasture land
[b] other variable cost includes cost of salt and minerals, vet and med, marketing fee, national promotion fee, machinery repair and interest in operating capital.
[C] fixed cost includes the annualized value of fixed cost of farm machinery, general overhead, and fixed cost of pasture associated with winter grazing .
(Source: Modified from Prevatt and Marshall 1999)

Appendix B-II
Enterprise budget for stockers raised with poultry litter and winter annual grass (65 Stockers and 200 days)

Items		Quantity	Price or Cost in dollars / Unit	Income or Cost
Gross Receipts	**Weight per animal**			
Feeder Cattle (Pounds)	853	64	0.68	37122.56
Variable Costs				
Stocker Calves (cwt)		292.5	71.00	19240.00
Winter Grazing (acres)		33	76.83	2535.39
Starter feed (cwt)		45.5	11.65	530.08
Litter Grain Ration				
Litter (tons)		24.38	25.00	609.38
Grain (tons)		24.38	92.00	2242.50
Borvatec and Vit A				418.64
Other variable costs [b]				2496.24
Total variable cost				28,656.77
Fixed costs				1,853.71
Total costs				**30288.96**
Net return				**6612.08**

[a] Following assumptions are made in addition to others described in the text
1.5 percent death loss
30 days of supplemental feed required
200 days of feeding period
450 beginning weight
2.1 pounds weight gain/head/day
2 head stocked per acre
7.5 pounds of feed/head/day
Farmer owns the pasture land
[b] other variable cost includes cost of salt and minerals, vet and med, marketing fee, national promotion fee, machinery repair and interest in operating capital.
[c] fixed cost includes general overhead, fixed cost associated with grazing, interest and depreciation on building and equipment
(Source: Modified from Prevatt and Marshall 1999)