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# **Too Litter, Too Late: Economic Logistics of Transporting Nutrient-Rich Poultry Litter Out of Nutrient-Saturated Regions**

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## **Abstract**

Export of excess litter from concentrated animal production regions has become a pressing issue. A break even price for poultry litter in nutrient-deficient areas was identified through a math programming model using willingness to pay data from crop producers. Results indicate that a \$16 subsidy is needed to sustain a long-term poultry litter market.

Keywords: GAMS optimization, baled poultry litter, manure transportation, excess nutrients, northwest Arkansas

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## **Introduction**

Poultry and egg production account for 52.9 percent of total volume of agricultural sales in Arkansas, some \$2.6 b (USDA/NASS). The state ranks second in the US in broiler production, producing 1.2 b birds out of the 8.6 b produced in 2002 (ibid.). Most of the Arkansas poultry industry is located in the northwest region, where until recently the abundant poultry litter was considered a valuable resource used to enhance the quality of the poor and naturally rocky soil, and greatly improving forage production, which was then used to feed cattle (Leonard). The long term application of chicken litter to the soil may have contributed to excessive soil phosphorus levels, which alarmed conservationists and public officials concerned with the potential for phosphorus runoff into nearby water sources.

The implementation of an Ozark Poultry Litter Bank (OPLB) is being evaluated as a way to reduce the threat of the poultry litter problem to the poultry industry in Arkansas and to the environmental resources of the affected region (Goodwin, 2002). The OPLB is a non-profit organization geared toward marketing the excess poultry litter produced in northwest Arkansas. The OPLB is also responsible for implementing a subsidy system to incentivize litter shipments to eastern Arkansas. The objective of this study is to improve the economic feasibility of utilizing a poultry litter bank to attenuate the environmental stress of litter in watersheds with a nutrient surplus. Specifically, we wish to maximize the expected net revenues of the Ozark Poultry Litter Bank, while minimizing the cost of meeting crop nutrient requirements with litter and/or chemical fertilizer, such that a successful and sustainable litter marketing plan can be established. The result of this study should indicate the optimal level of subsidy to be provided by the OPLB.

## **Background and Literature Review**

The poultry litter industry is organized such that farmers (growers) are contracted by larger corporations (contractors or integrators) to grow chicks. Contractors determine feed contents and other inputs and retain ownership of the animals but ownership of the litter belongs to the growers. Until recently, this was a beneficial situation for both parties, as litter was used to fertilize the growers' soil, thus constituting an additional source of revenue for growers. Presently, in Northwest Arkansas, litter cannot be land applied if the amount of phosphorus in the soil is already excessive. Changes in regulation have increased the costs of managing poultry litter (Lichtenberg, Parker and Lynch). Removing the litter out of the nutrient surplus region is an added cost for growers, who do not have the economic means to bear it (ibid.).

The level of phosphorus concentration in shared rivers, presumably resulting from excess poultry litter application, has been at the heart of a heated debate between Arkansas and Oklahoma, which now involves several pieces of litigation. The results of this legal battle are being closely monitored nationally, as similar problems have occurred in other concentrated animal production regions (Kellogg, Lander, Moffitt, Gollehon). Some of the states affected so far are Georgia, West Virginia, Alabama, Maryland, Missouri and Iowa. The solution to the problem usually involves transporting excess litter out of poultry production region, which is phosphorus saturated, to other locations where litter can be applied to nutrient-deficient soils, enhancing crop yields (Jones and D'Souza). Previous focus group meetings with potential poultry litter buyers in eastern Arkansas, as well as meetings with poultry growers from northwest Arkansas, have identified some major issues that condition the movement of litter out of northwest Arkansas, including cost competitiveness of poultry litter vs. commercial fertilizer and transportation/application logistics of poultry litter to/at demand market. The poultry litter

problem could become an important production cost, presenting a threat to the global competitiveness of the American poultry industry (FSA/USDA). Although, the US had been the largest exporter of broilers in the world, Brazil emerged as the new leader in 2004 and 2005 forecasts—its advantage lies greatly on lower production costs (ibid.).

Young et al. looked into selecting an optimal allocation of litter and fertilizer such that the nutrient application cost to crops was minimized. Despite litter application being constrained such that it could not exceed one ton/acre, the results indicated that poultry litter supplemented with chemical fertilizer was a cost efficient way to meet crop nutrient needs, given current fertilizer prices.

## **Methodology**

This analysis uses a linear programming model executed with the MINOS algorithm available in GAMS. The objective of the model is to maximize the net revenues of the OPLB, while minimizing the cost of supplying crop nutrients with litter and/or chemical fertilizer, given the nutrient needs of crops (corn, corn for silage, soybean, rice, wheat, cotton, and sorghum). Poultry litter users were contacted to obtain estimates of the price usually paid for poultry litter in each county. The costs considered in the study pertain to chemical fertilizer costs (fertilizer and application) and poultry litter costs (transport, handling and storage costs—litter is assumed to be FOB at the origin), with litter being exported from northwest Arkansas to selected eastern Arkansas counties (Lonoke, Arkansas, Monroe, Jackson, Poinsett, Mississippi, and Conway), Vernon County in Missouri, and Muskogee County in Oklahoma. We consider different types of litter (turkey and broiler), different forms of litter (raw and compressed plastic-wrapped bales), and different transportation methods (truck only and truck-barge combination). Barge transport

of litter is an innovative method which relies on the Arkansas and Mississippi River Systems servicing eastern Arkansas; although the barge rate includes a \$500 cleaning fee, the rates are rather competitive especially for longer trips. Short distance truck transport is also evaluated to move raw litter from northwest Arkansas poultry farms to a central baler and to move raw litter from storage buildings in eastern Arkansas to farm fields when farmers want to spread the raw litter. Long-distance truck transport of baled litter is assumed to be done at a more competitive rate than raw litter due to backhaul opportunities. Baled litter is assumed to be stored outside in farm fields prior to spreading as the bales take little space and do not need to be covered. The cost of litter includes spreading and incorporation costs and is compared with the cost of using commercial fertilizer.

The mathematical programming model is defined as

$$\begin{aligned}
 \max_{LRT_{ismr}, LBT_{ismr}, LRB_{isunmr}, LBB_{isunmr}, E_{mf}} Z = & \sum_m \left\{ \pi_m \left[ \sum_i \sum_s \sum_r (LRT_{ismr} + LBT_{ismr}) \right. \right. \\
 & \left. \left. + \sum_i \sum_s \sum_u \sum_n \sum_r (LRB_{isunmr} + LBB_{isunmr}) \right] \right\} \\
 & - \left\{ \sum_i \sum_s \sum_m \sum_r (\alpha_{sm} LRT_{ismr} + \beta_{sm} LBT_{ismr}) \right. \\
 & \left. + \sum_i \sum_s \sum_u \sum_n \sum_m \sum_r (\gamma_{sum} LRB_{isunmr} + \delta_{sum} LBB_{isunmr}) \right. \\
 & \left. + \sum_i \sum_s \sum_m [E_{mf} (\eta_f + \theta)] \right\} \tag{1}
 \end{aligned}$$

subject to a litter supply constraint at each watershed ( $w$ ) for each bird type ( $i$ )

$$\begin{aligned}
 & \sum_i \sum_s \sum_m \sum_r [(LRT_{ismr} + LBT_{ismr}) I(s \in w)] \\
 & + \sum_i \sum_s \sum_u \sum_n \sum_m \sum_r [(LRB_{isunmr} + LBB_{isunmr}) I(s \in w)] \leq \bar{L}_{iw}, \forall i, w; \tag{2}
 \end{aligned}$$

a nutrient demand constraint for each crop ( $r$ ) at each market ( $m$ ) and for each nutrient ( $f$ )

$$\sum_i \sum_s \left\{ \left[ LRT_{ismr} + LBT_{ismr} + \sum_u \sum_n (LRB_{isummr} + LBB_{isummr}) \right] \xi_{if} \right\} + E_{mrf} \rho_f \geq \overline{D_{fmr}}, \forall f, m, r; \quad (3)$$

an acreage constraint for litter application assuming an application rate of one ton per acre

$$\sum_i \sum_s \left[ LRT_{ismr} + LBT_{ismr} + \sum_u \sum_n (LRB_{isummr} + LBB_{isummr}) \right] \leq \overline{A_{mr}}, \forall m, r; \quad (4)$$

a minimum level of litter removal at each watershed constraint

$$\begin{aligned} & \sum_i \sum_s \sum_m \sum_r [(LRT_{ismr} + LBT_{ismr}) I(s \in w)] \\ & + \sum_i \sum_s \sum_u \sum_n \sum_m \sum_r [(LRB_{isummr} + LBB_{isummr}) I(s \in w)] \geq \overline{R_w}, \forall w; \end{aligned} \quad (5)$$

and the following non-negativity constraints

$$LRT_{ismr}, LBT_{ismr}, LRB_{isummr}, LBB_{isummr}, E_{mrf} \geq 0, \forall i, s, u, n, m, r, f. \quad (6)$$

The variables in the model are defined as

**Z** Net revenue from using poultry litter to supply nutrients to crops net of cost of supplying remaining nutrients to county markets with chemical fertilizer

$LRT_{ismr}$  tons of raw litter of bird type  $i$  transported by truck from source  $s$  to market  $m$  to be applied to crop  $r$ ;

$LBT_{ismr}$  tons of baled litter of bird type  $i$  transported by truck from source  $s$  to market  $m$  to be applied to crop  $r$ ;

$LRB_{isummr}$  tons of raw litter of bird type  $i$  transported by truck and barge from source  $s$  to market  $m$  going through ports  $u$  and  $n$  to be applied to crop  $r$ ;

$LBB_{isummr}$  tons of baled litter of bird type  $i$  transported by truck and barge from source  $s$  to market  $m$  going through ports  $u$  and  $n$  to be applied to crop  $r$ ;

$E_{mrf}$  tons of chemical fertilizer of nutrient  $f$  applied to crop  $r$  at market  $m$ .

The parameters in the model are defined as:

$\pi_m$  price per ton paid for litter in market  $m$ ;

$\alpha_{sm}$  cost per ton of using raw litter from source  $s$  in market  $m$  when litter is transported by truck;

$\beta_{sm}$  cost per ton of using baled litter from source  $s$  in market  $m$  when litter is transported by truck;

$\gamma_{sumn}$  cost per ton of using raw litter from source  $s$  in market  $m$  when litter is transported by truck and barge going through ports  $u$  and  $n$ ;

$\delta_{sumn}$  cost per ton of using baled litter from source  $s$  in market  $m$  when litter is transported by truck and barge going through ports  $u$  and  $n$ ;

$\eta_f$  cost per ton of fertilizer providing nutrient of type  $f$ ;

$\theta$  cost per ton of applying fertilizer;

$\rho_f$  available nutrient of type  $f$  in chemical fertilizer;

$\xi_{if}$  available nutrient of type  $f$  in litter of type  $i$ ;

$\overline{L}_{iw}$  maximum production of litter of type  $i$  in watershed  $w$ ;

$\overline{D}_{fmr}$  minimum demand of nutrient of type  $f$  for crop  $r$  at market  $m$ ;

$\overline{A}_{mr}$  maximum acreage available for litter application to crop  $r$  at market  $m$ ;

$\overline{R}_w$  minimum litter removal in watershed  $w$ .

The objective function of the GAMS model, equation (1), includes the revenue obtained from selling the litter net of all costs pertaining to supplying crops (corn, silage, soybeans, rice,

wheat, cotton, and sorghum) at each market (Conway, Lonoke, Arkansas, Monroe, Jackson, Poinsett, and Mississippi counties in Arkansas; Vernon in Missouri; and Muskogee in Oklahoma) with nitrogen (N), phosphorus (P), and potassium (K) by applying poultry litter or chemical fertilizer (urea, phosphate, or potash). The inclusion of fertilizer costs allows us to do the optimization taking into account the cost of a close substitute of poultry litter; this is an important consideration as we expect litter adopters to be rational agents. Poultry litter is transported out of the Eucha-Spavinaw Watershed (ESW) from Decatur and out of the Illinois River Watershed (IRW) from Siloam Springs and/or Prairie Grove. The nutrient supply costs include litter transportation, raw litter storage and handling, processing costs for baled litter, application and incorporation costs of litter as well as costs of chemical fertilizers and respective application. Transportation of baled litter has a lower cost of \$1.50 per loaded mile due to the availability of truck backhaul opportunities. Backhauls are much more difficult when raw litter is transported because of trucks must be cleaned before transporting other materials. When shipping by barge, the choice of outgoing ports for litter is Catoosa (Oklahoma) and Fort Smith (Arkansas). The incoming ports evaluated for litter in eastern Arkansas are Pendleton, Pine Bluff, and Little Rock on the Arkansas River and Hickman on the Mississippi River in Mississippi County.

The first constraint in the model (equation 2) ensures that the supply of litter does not exceed litter production. Equation (3) addresses the issue of meeting crop requirements for nitrogen, phosphorus and potassium either by applying litter or commercial fertilizer. The fourth constraint limits litter application so not to exceed the crop acreage available. Litter is assumed to be spread at the rate of 1 ton per acre and commercial fertilizer is used to supplement the litter to meet crop nutrient requirements. Recently, a court order mandated that at least 67,500 tons of

litter be removed from the IRW. Equation (5) captures this IRW guideline and applies a similar guideline to the ESW (the minimum bound is set at 59,712 tons for ESW).

## **Data Inputs**

### *Litter Supply in Northwest Arkansas*

Goodwin (2004) estimated that about 94,132 tons of broiler litter are produced in the ESW annually and 164,696 tons in the IRW. Turkey litter production is estimated to be about 13,268 tons in ESW and 39,810 tons in IRW. These production levels are set as the upper bound on the litter supply constraint (equation 2). Nutrient values differ slightly for broilers versus turkey litter. On average, the N content is comparable, about 60 lbs per ton of litter. Our model assumed that 75% of N in litter is available to meet the crop's nutrient requirements. For commercial fertilizer, we assumed 100% N availability. Turkey litter in Arkansas contains slightly more P than broiler litter on average (66 lbs per ton vs. 57 lbs per ton), but broiler litter contains more K than turkey litter on average (52 lbs per ton vs. 45 lbs per ton).

### *Litter Transport Costs*

Litter baling is assumed to be done at a central location in northwest Arkansas at a cost of \$5 per ton for baling, \$4 per ton for assembling the raw litter, and \$2 per ton for temporary storage and handling at the baling site. Long-distance bale transport by truck with a 22-ton trailer is \$1.50 per loaded mile with bales delivered directly to farmers to the field (Traylor). Long distance raw litter transport is priced at the dead head rate of \$2.50 per loaded mile because it is difficult to backhaul other loads after transporting raw litter. Short distance truck transport of less than 100 miles with a 22-ton load with either bales or raw litter is priced at \$3 per loaded

mile. There is a \$100 minimum charge per truckload. These short haul truck rates are applied to all trips to and from the barge ports.

#### *Other Litter In-Transit Costs*

Barge loading and unloading costs are \$2.50 per ton at each port based on the standard cost of using crane and clam shell equipment. Barge freight charges are priced at the published rate of \$0.01338 per ton per mile on the navigation route, e.g. about \$4 per ton from Fort Smith to the Pine Bluff port. No in-transit costs are assumed for long-distance trucking.

#### *Other Litter Handling Costs*

Baled litter is assumed to be delivered direct to farm fields in eastern Arkansas for outside storage prior to spreading as the bales are fully plastic wrapped to protect against the weather. Raw litter is delivered to inside storage in eastern Arkansas with a storage cost of \$3 per ton plus additional transport and handling costs from storage to the farm field of \$7 per ton, including storage cleanout costs. Field spreading costs per ton are \$7 for raw litter and \$8 for baled litter. A special front end loader attachment is needed to open the bales. Litter incorporation in the field to prevent ammonia N losses after spreading is \$6 per ton.

#### *Commercial Fertilizer Costs*

Commercial fertilizer prices reported for eastern Arkansas in January 2005 were \$280 per ton of urea, \$302 per ton of phosphate, and \$250 per ton of potash.

### *Nutrient Demand*

Recommended N-P-K requirements for corn, silage, soybean, rice, wheat, cotton, and sorghum crops are assumed to be satisfied with either chemical fertilizer or poultry litter. The nutrient requirements are based on application rates recommended by extension publications of the University of Arkansas. Crop acreage at each county market was obtained from the 1997 Census of Agriculture. An application rate of one ton of litter per acre is assumed as a practical and safe average amount that can be applied with a typical manure spreader. There should be no concern with possible excess P buildup with only one ton applied to cropland.

## **Results**

### *Optimal Solution*

According to the model described above, poultry litter will only be applied if it is cost efficient relative to chemical fertilizer. The allocation results are presented in Tables 1 and 2 and indicate that all litter considered in the model should be transported and applied to crops even at the rate of one ton per acre with the remaining nutrient requirements being provided by chemical fertilizer. Of course, this result relies heavily on the assumption that nutrients from chemical fertilizer and poultry litter are perfect substitutes or at least yield response to nutrients from poultry litter is as good as the response to chemical fertilizer nutrients. The transport of baled litter is more cost efficient using truck transportation (Table 1), a clear consequence of the assumption that a lower shipping rate can be obtained through the availability of backhauls. Raw litter can be cost efficiently transported to distant markets such as Mississippi County (Table 2), located in the Northeastern part of Arkansas, with a truck-barge combination. One of the reasons

why transport to this county can be cost efficient is that the county seat is relatively close to the Mississippi River.

**Table 1.** Cost Efficient Allocation of Baled Litter Transported by Truck from Northwest Arkansas to County Markets According to the GAMS Optimization

Town Source	County Market	Litter Type	Crop	Tons of Litter
Prairie Grove	Lonoke	Turkey	Silage	48.79
Prairie Grove	Lonoke	Turkey	Rice	3,544.90
Prairie Grove	Lonoke	Turkey	Cotton	4,554.12
Jay	Muskogee	Broiler	Corn	7,966.68
Jay	Muskogee	Broiler	Silage	395.44
Jay	Muskogee	Broiler	Sorghum	2,701.89
Decatur	Lonoke	Broiler	Corn	2,522.33
Decatur	Lonoke	Broiler	Rice	27,988.64
Decatur	Lonoke	Turkey	Rice	13,268.00
Decatur	Vernon	Broiler	Corn	30,582.94
Decatur	Vernon	Broiler	Silage	766.87
Decatur	Vernon	Broiler	Sorghum	21,207.21
			TOTAL	115,547.81

The crops selected to receive litter are those that require more intensive nutrient fertilization: corn grain and corn for silage, rice, cotton, and sorghum. Soybean and wheat do not require as many nutrients, thus their fertilization can be more cost efficiently obtained through chemical fertilizer application.

**Table 2.** Cost Efficient Allocation of Raw Litter Transported by Truck and Barge from Northwest Arkansas to County Markets According to the GAMS Optimization

Town Source	Out Port	In Port	County Market	Litter Type	Crop	Tons of Litter
Prairie Grove	Fort Smith	Hickman	Mississippi	Broiler	Cotton	164,696.00
Prairie Grove	Fort Smith	Hickman	Mississippi	Turkey	Corn	12,886.10
Prairie Grove	Fort Smith	Hickman	Mississippi	Turkey	Rice	9,755.45
Prairie Grove	Fort Smith	Hickman	Mississippi	Turkey	Cotton	2,882.77
Prairie Grove	Fort Smith	Hickman	Mississippi	Turkey	Sorghum	6,137.86
					TOTAL	196,358.18

In terms of costs, the average cost of fertilizing each acre considered in the study using only chemical fertilizer is \$69.14 (Table 3). However this estimate can be rather misleading. Given current high chemical fertilizer costs and assuming the nutrient requirements recommended by University of Arkansas Extension publications, the cost of fertilizing one acre of corn for grain can be as much as \$162 on average, while soybean fertilization can cost around \$44/acre. Cotton, rice, silage, and sorghum all are estimated to cost over \$84/acre to fertilize. Looking at simple averages can be misleading as each crop has a different acreage on the total study area. Based on our study, poultry litter fertilization is recommended for crops that are expensive to fertilize such as corn for grain, corn for silage, cotton, rice, and sorghum (Tables 1 and 2). Thus when looking at the average cost of fertilizing the area receiving litter (Table 3), the average cost per acre (\$90.14) will be much higher than the overall average cost (\$66.40).

**Table 3.** Sensitivity Analysis of Marginal Costs Associated with Litter Supply Constraint

Description	Total Cost	Cost per Acre
Cost of nutrients if using chemical fertilizer only	\$160,460,648	\$69.14
Minimum cost of supplying nutrients (GAMS solution)	\$154,090,799	\$66.40
Chemical fertilizer cost (total)	\$140,523,094	\$60.55
Poultry litter cost *	\$13,567,705	\$43.50
Chemical fertilizer cost in area also receiving litter *	\$14,549,996	\$46.64
Total nutrient cost in area receiving litter*	\$28,114,702	\$90.14
Estimated Net Revenue of OPLB	(\$4,839,634)	(\$15.52)

Note: \* Cost per acre averages taken over land receiving poultry litter

In terms of the net revenue of the OPLB, that is the difference between the cost of using the litter and what litter users are willing to pay for it, given the study area considered, there is on average a deficit of \$15.52/ton (or per acre, as we assume a constant application rate of 1 ton/acre). This deficit implies that litter users are not paying the actual cost of using litter, although this cost is

lower than the cost of using commercial fertilizer. If the assumption that litter nutrients and chemical fertilizer nutrients is correct, then a deficit indicates that there is a market failure as farmers do not value the two types of nutrients the same. Thus a subsidy may be needed to incentivize litter adoption or an information campaign should be implemented to educate farmers.

### **Summary and Conclusions**

The objective of this study was to compare the costs of using chemical fertilizer versus a mix of poultry litter and chemical fertilizer to supply nutrients to selected crops in selected counties in Arkansas, Oklahoma and Missouri. Because handling and transporting litter can be expensive, different handling (raw form or baled form) and transportation (truck or truck barge combination) procedures were investigated. At the moment, research is needed to further evaluate the process of baling litter, but initial outcomes are rather promising. Our model results indicate that poultry litter offers significant cost advantages compared to chemical fertilizer for crops that are nutrient intensive such as corn, silage, rice, sorghum, and cotton. The GAMS model used in this study also allowed us to compare the cost of using litter with the price currently paid by litter users in the study area; the results indicate that, on average, litter prices are lower than litter costs by \$16. Such a deficit and the fact that litter nutrients are now cheaper than chemical fertilizer nutrients indicate that farmers do not value poultry litter as they value chemical fertilizer, although it can produce significant savings to farmers. The market structure necessary to market litter as a crop nutrient source is very precarious, thus we believe subsidizing poultry litter adoption and/or further educating farmers might steer the crop nutrient market into a more efficient allocation of resources. Future research should focus on quantifying the impact

of such a subsidy on the welfare of poultry litter users. Because we assumed that litter was FOB at the production site, no monetary compensation was given to poultry litter producers. Future research should focus on relaxing this assumption and on quantifying the impact of subsidizing poultry litter adoption on the welfare of poultry producers.

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