Economics of Transporting Poultry Litter from Northwest Arkansas to Eastern Arkansas Croplands

Kenneth Young[1], R.I. Carreira[2], H.L. Goodwin[3], Eric Wailes [4]

Abstract

Applying baled litter from northwest Arkansas shipped by truck with backhauls, supplemented with chemical fertilizers provided the most cost-efficient method to supply nutrients to crops in eastern Arkansas, according to a GAMS optimization. Shipping raw litter by truck and barge is the optimal choice when backhauls or baling is unavailable.

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

Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Little Rock, Arkansas, February 5-9, 2005

This paper is a draft and includes preliminary results. Please contact the author for an updated version of this paper.

[1] Senior Research Associate, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, young@uark.edu
[2] Research Associate, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, rcarrei@uark.edu
[3] Professor, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, haroldg@uark.edu
[4] Professor, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR 72701, ewailes@uark.edu

Introduction

Northwest Arkansas has unique environmental concerns because of the local Karst formation, the excessive application of poultry litter over a long time period, and a rapidly growing population that reduces the area available for spreading litter. As a result of increased phosphorus runoff, new waste disposal regulations were proposed in 2003 requiring the potential export of both sewage biosolids and excess poultry litter outside this region. Nutrient management plans are currently being developed for poultry litter which will dictate the quantity to be exported. The Arkansas Soil and Water Corporation Commission and local poultry integrators have offered to help subsidize the transport of excess poultry litter to eastern Arkansas.

The two key poultry counties in northwest Arkansas, Benton and Washington, produce over two million broilers. This concentrated production comprises over half of all broilers produced in Arkansas (USDA Agricultural Census). Over 100,000 tons of excess litter from these two counties will have to be exported per year. Other concentrated poultry production is located near these two Arkansas countries including counties in eastern Oklahoma and southwest Missouri.

The basic transport problem for poultry litter centers on the relatively low nutrient value of litter compared with the transport and handling cost. Raw litter is a dirty product to handle and requires specialized walking floor or end dump trailers for transport. Truck backhauls are difficult because of the required specialized trailers and sanitary considerations. Department of Transport regulations have reduced daily working hours for drivers, thus it is more difficult to clean trailers now in transit. Transport and handling cost can be reduced with pelleting or granulation of raw litter but this extra processing cost is expensive for farm markets. A new technology consisting of baling and plastic wrapping of litter is under development with an expected processing cost of less than $5 per ton (Mammoth Corporation, 2004). Bales offer some special advantages for handling litter including the use of open field storage, better opportunities for truck back hauls, and preservation of nutrients, mainly nitrogen. Other forms of litter generally require inside storage, particularly for long term storage.

The purpose of this paper is to evaluate alternative transport and handling options for marketing the excess poultry litter from northwest Arkansas to crop farmers in eastern Arkansas. Both broiler and turkey litter are evaluated from three town sources in Benton and Washington counties. Farm markets are evaluated at county seats in Lonoke, Arkansas, Monroe, Poinsett, Jackson, and Mississippi counties in eastern Arkansas. Raw litter and baled litter are compared. Transport by truck and a combination of truck and barge are compared.

Background and Literature Review

The structure of animal agriculture in the U.S. has changed dramatically over the past two decades as the industry became highly vertically integrated, resulting in increased problems with the utilization and disposal of animal waste (Kellogg et al., 2000). Enormous amounts of nutrient rich animal manures are now produced in relatively concentrated regions. In the past, N-based application of animal manures to the soil, including poultry litter in northwest Arkansas, was a cheap and advantageous method of disposing of nutrients, while enhancing soil properties and crop yields. Unfortunately, long term use of this practice may have resulted in soil P accumulation (Sharpley et al., 1991) and water quality concerns. Many areas of the U.S. have experienced disposal problems including swine waste in North Carolina and poultry litter in the Delmarva Region, Virginia and Arkansas. The fundamental problem impairing inter-regional movement of animal manures is the relatively high transport cost to move waste materials compared with the nutrient value. Poultry litter is more economical to transport than swine waste but it is still bulky to handle and requires specialized walking floor or end dump trailers for transport.

Several disposal alternatives that help prevent pollution from excess animal waste application in one area have included processing raw litter into a more easily handled form such as poultry litter pellets and other new ways of utilization such as composting, energy production and forest fertilization (Lichtenberg, et al., 2002). In most cases, high subsidies have been required to dispose of manure or litter surpluses in a region.

A litter pelleting plant was recently constructed in Delaware with a subsidy of $20 per ton or more to dispose of excess poultry litter from the Delmarva Peninsula. However, both pelleting and granulation are expensive processing methods, in the range of $40 to $50 per ton. Litter pellets from Delaware are currently exported as far as eastern Arkansas and are priced about $110 per ton by some local fertilizer dealers. However, our contacts with fertilizer dealers handling pelletized litter in Arkansas indicate that the agricultural market is very limited at this price.

We started collaboration with Mammoth Corporation in 2004 to develop a litter baler and received a USDA grant to develop a baler to compress and plastic wrap poultry litter. Expected cost of baling litter is about $5 per ton which is considerably less than other processing methods and baling offers more advantages: many different types of trailers can be used in the transportation of bales precluding the need for clean up costs, baled litter is much more dense than raw litter, nutrients are preserved preventing odor problems, bales provide biosecurity protection, and bales can be stored outside at the destination field without cover.

Methodology

This analysis uses a linear programming model executed with the MINOS algorithm available in GAMS. The objective of the model is to minimize the cost of supplying nutrients to crops in eastern Arkansas. This cost includes chemical fertilizer costs and poultry litter costs assuming litter is exported from northwest Arkansas to eastern Arkansas. 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) are evaluated in the optimization. Using barges to transport litter is an innovative transportation method which relies on the Arkansas and Mississippi River Systems servicing eastern Arkansas.

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. 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

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

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

$$\begin{aligned}&\sum_i \sum_s \sum_m \sum_r \left[\left(LRT_{ismr} + LBT_{ismr}\right) \mathrm{I}\left(s \in w\right)\right] \\ &+ \sum_i \sum_s \sum_u \sum_n \sum_m \sum_r \left[\left(LRB_{isunmr} + LBB_{isunmr}\right) \mathrm{I}\left(s \in w\right)\right] \le \overline{L_{iw}}, \forall i, w;\end{aligned} \tag{2}$$

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

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

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

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

a minimum level of litter removal at each watershed constraint

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

and the following non-negativity constraints

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

The variables in the model are defined as

Z total dollar cost of supplying nutrients to county markets in the form of poultry litter or 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_{isunmr} 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_{isunmr} 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:

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

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

γ_{sunm} 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*;

δ_{sunm} 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*;

η_f cost per ton of fertilizer providing nutrient of type *f*;

θ cost per ton of applying fertilizer;

ρ_f available nutrient of type *f* in chemical fertilizer;

ξ_{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 all costs pertaining to supplying crops (corn, silage, soybeans, rice, wheat, cotton, and sorghum) at each market (Lonoke, Arkansas, Monroe, Jackson, Poinsett, and Mississippi counties in Arkansas) with nitrogen (N), phosphorus (P), and potassium (K) by applying poultry litter or chemical fertilizer (urea, phosphate, or potash). 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. In the baseline model, 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 the 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 that 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 (Mike Traylor, 2004). 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.

Scenarios for Sensitivity Analysis

Four alternative scenarios are considered in the sensitivity analysis of the model: (*i*) a 50% reduction in the current prices of commercial fertilizer, (*ii*) 50% N availability instead of the 75% assumed in the baseline model, (*iii*) exclusion of litter baling, and (*iv*) unavailability of backhauls for trucking baled litter, which increases trucking rates for bales from $1.50 to $2.50 per loaded mile.

Results

Optimal Solution

The estimated least-cost optimal baseline solution is to transport baled litter by truck from only Prairie Grove in the IRW and from Decatur in the ESW. The stipulated minimum export requirement is non-binding and all litter produced in the watersheds is exported, nearly 312,000 tons at an average supply cost of $42.77 per ton, including field spreading and incorporation costs (Table 1). The litter is applied to all crops except for silage and soybean in the more distant markets from northwest Arkansas such as Mississippi County.

Table 1. Sensitivity Analysis of Transport Costs

Scenario	Litter Exported (tons)	Litter Form	Transport Method	Cost per Ton of Litter
Baseline Model	311,906	Bales	Truck	$42.77
Reduced Fertilizer Cost	127,212	Bales	Truck	$41.59
Reduced N Availability	311,906	Bales	Truck	$42.77
No Bales	311,906	Raw	Truck/Barge	$46.45
No Backhaul Rate	311,906	Raw	Truck/Barge	$46.45

Sensitivity Analysis

Reducing the commercial fertilizer price by half for urea, potash, and phosphate fertilizers causes litter exports to be reduced substantially and the minimum removal constraint becomes binding. The estimated marginal cost of removing one more ton of broiler litter from ESW watershed is $4.19. For IRW, the marginal cost is $1.64. However, the maximum litter supply constraint is binding for turkey litter but not for broiler litter (Table 2). Turkey litter has slightly more nutrients than broiler litter thus turkey litter is exported before broiler litter. The shadow price for turkey litter is negative indicating that the cost of providing nutrients to the markets could be reduced by using more turkey litter instead of broiler litter. The litter supply cost per ton drops slightly to $41.59 compared with $42.77 in the baseline solution as less litter is applied, so closer markets to northwest Arkansas receive litter. Reducing N-availability in litter from 75% to 50% does not change the litter export level of the baseline model, meaning that litter is still more cost efficient than commercial fertilizer. The scenarios where backhauls were not available (truck transportation cost is increased from $1.50 to $2.50 per loaded mile) and where baling is not an option both favor the shipment of raw litter with the truck/barge transport combination. With raw litter transport, litter supply cost is increased to $46.45 per ton, about $4 per ton above the baseline cost with bale transport.

Table 2. Sensitivity Analysis of Marginal Costs Associated with Litter Supply Constraint

Scenario	Constraint Binding?	Eucha-Spavinaw Watershed		Illinois River Watershed	
		Broiler	Turkey	Broiler	Turkey
Baseline Model	Yes	($17.53)	($18.74)	($20.08)	($21.29)
Reduced Fertilizer Cost	B-No/T-Yes[a]	--	($0.71)	--	($0.71)
Reduced N Availability	Yes	($11.34)	($12.55)	($13.89)	($15.10)
No Bales	Yes	($13.04)	($14.25)	($16.16)	($17.37)
No Backhaul Rate	Yes	($13.04)	($14.25)	($16.16)	($)17.37

Note a) The litter supply constraint is binding for turkey litter but not for broiler litter.

Impact on Crop Fertilizer Cost

The estimated total crop acreage in the market counties evaluated in this study is roughly 2.1 million acres (Table 3). The baseline solution estimated a total litter supply cost of $13.3 million and a total commercial fertilizer supply cost of $125.9 million to satisfy crop nutrient requirements. When this total nutrient supply cost is compared with the total crop acreage in all market counties, the average nutrient supply cost per acre is $6.29 for litter use and $59.31 for commercial fertilizer (Table 3). Of course, only part of the total crop acreage is supplied with poultry litter. When the chemical fertilizer price is dropped by half, the average cost per crop acre for litter averaged over all market counties in eastern Arkansas is only $2.49, while the cost of chemical fertilizer is $41.11. In this case, the minimum removal constraint is binding for broiler litter, so we are using more broiler litter than the cost efficient level.

Table 3. Sensitivity Analysis of Crop Fertilizer Cost

Scenario	Crop Acreage	Total Litter Cost		Fertilizer Supply Cost	
		Millions	Per Acre	Millions	Per Acre
Baseline Model	2,122,296	$13.3	$6.29	$125.9	$59.31
Reduced Fertilizer Cost	2,122,296	$5.3	$2.49	$87.2	$41.11
Reduced N Availability	2,122,296	$13.3	$6.29	$127.8	$60.22
No Bales	2,122,296	$14.5	$6.83	$125.8	$59.31
No Backhaul Rate	2,122,296	$14.5	$6.83	$125.8	$59.31

Impact of Litter Export Constraints

As shown in Table 2, increased litter exports in the baseline solution would reduce the minimum cost to meet crop nutrient needs in eastern Arkansas by the equivalent of $17.53 to $21.29 per ton of litter. Litter exports are constrained at the maximum level in the baseline solution. With a 50% reduction in commercial fertilizer costs, litter exports are reduced to the minimum export level for broiler litter but not for turkey litter. As explained above, turkey litter is preferable to broiler litter as it has higher nutrient value.

Summary and Conclusions

The objective of this study was to evaluate the economies of supplying excess poultry litter from northwest Arkansas to eastern Arkansas farm counties that are nutrient deficient. Innovative transport and handling options were assessed including baling the litter before long distance transport and using a combination of truck and barge transport methods. Litter is valued in terms of its nutrient value for crops as an alternative to regular commercial fertilizer. Litter supply cost includes all transport, special handling and storage, field spreading, and field incorporation costs. No payment is included to purchase the litter in northwest Arkansas as growers are expected to have a disposal problem due to pending new regulations. Expected processing costs for baling are included. Recent increases in prices for chemical fertilizers are used in the analysis.

Results indicate that poultry litter export is cost efficient given the currently high fertilizer prices but this result did not hold when the fertilizer costs fell by half. The baling option with backhaul trucking rates is estimated to be the least cost supply method. Without baling or backhaul trucking rates, it is still cost-efficient to transport raw litter with a truck-barge combination at current high fertilizer costs.

Some caveats in this research are that the litter baler is still under development and the costs and performance still have not been tested under real life conditions. Crop growers may not be willing to pay the nutrient value of litter because of other considerations such as the volatility of N content in litter and N availability to crops (which is very sensitive to management issues), the lack of spreading equipment in eastern Arkansas, and the general lack of market services to supply litter compared to commercial fertilizers.

References

Goodwin, H.L. 2003. "Feasibility Assessment of Establishing the Ozark Poultry Litter Bank: Research proposal submitted to the Arkansas Soil and Water Conservation Commission." Department of Agricultural Economics and Agribusiness, Dale Bumpers College of Agricultural, Food and Life Sciences, University of Arkansas.

Goodwin, H.L. 2004. "Preliminary Estimates, Total Number of Houses, Annual Bird Placements and Tons of Litter Produced, By Source and Type of Poultry, Ozark Plateau, 2002." Deliverable submitted to the Arkansas Soil and Water Conservation Commission.

Kellogg, R.L., C.H. Lander, D.C. Moffitt and N. Gollehon. 2000. *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients*. USDA-NRCS-ERS. Washington, DC.

Lichtenberg, E., D. Parker and L. Lynch. 2002. *Economic Value of Poultry Litter Supplies in Alternative Uses. Center for Agricultural and Natural Resource Policy*. University of Maryland, College Park, MD.

Mammoth Corporation. 2003. Packaging of Poultry Litter for Economically Viable Storage and Transportation, USDA-SBIR Proposal, Spokane, WA.

Mammoth Corporation. Personal Communication with Ross Schlotthauer, Director of Engineering, May 2004, Spokane, WA.

Sharpley, A.N. B.J. Carter, B.J. Wagner, S.J. Smith, E.L. Cole, and G.A. Sample. 1991. "Impact of Long-Term Swine and Poultry Manure Application on Soil and Water Resources in

Eastern Oklahoma." Agricultural Experimental Station, Oklahoma State University, Technical Bulletin T-169.

Traylor, Mike. Personal Communication, October 2004, Prairie Grove, AR.

USDA-NASS. 1997. US Census of Agriculture. Washington, DC.

______. 2004. US Census of Agriculture. Washington, DC.