How Far Can Poultry Litter Go:
Cost Efficiency of New Technologies to Transport Litter to
Fertilize Distant Crops

by

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Introduction

Man has relied on animal manures to maintain fertility of agricultural soils for over three millennia. In the 19th century, von Liebig found that chemical fertilizers could be beneficial for plant use; the commercial fertilizer industry emerged around 1840 (Beaton). Scientific and technological improvements over the last two centuries increased the popularity of commercial fertilizers to the detriment of animal manures and other biomaterials (ibid.). Manure use also decreased in popularity because its application is more time-consuming, may create odor problems, and is not as widely available as commercial fertilizer or, at least, it has had limited marketability at the regional or even national level because it is expensive to transport over long distances. Although Parker convincingly praises the benefits of a manure marketing system, certain regions still face nutrient excess problems. The structure of animal agriculture in the U.S. has changed dramatically over the past two decades as the industry became highly vertically integrated. Because animal production has become very concentrated in recent years, so has the availability of manure in certain regions, where there can be situations of excess nutrients compared to soil and crop requirements (Gollehon et al., Kellogg et al.). Many areas of the U.S. have experienced excess nutrient problems including swine manure in North Carolina and poultry litter in the Delmarva Region and Arkansas (Kellogg et al.).

Concurrent to the concentration trend in the poultry industry and as chemical fertilizer prices declined compared to litter use costs, farmers’ perception of manure management has evolved from crop fertilization to waste disposal (Parker). Manure benefits the soil but if used at
inappropriate rates, it can create environmental stress. In particular, poultry manure benefits the soil by supplying organic matter, nutrients, enzymes and bacteria, and it helps maintain soil pH at desirable acidic levels (Zhang and Hamilton). But if litter is applied at rates that exceed the plant removal rate, certain nutrients, such as phosphorus (P), may accumulate in the soil (Gollehon et al.). This has happened in several regions in the US, including northwest Arkansas.

Over the last twenty years, as poultry production exploded in northwest Arkansas (Govindasamy and Cochran), the availability of poultry manure was considered a major benefit to poultry growers who relied on this resource to improve pasture yield for their cattle production. Because the application rates were nitrogen-based and nutrient removal was very limited, soil phosphorus levels increased over time. Initially, this was not perceived to be a problem as soil phosphorus was thought to be relatively immobile; but research conducted over the last 20 years showed otherwise (Sharpley et al.). Even in recent years, what was perceived to be a best management practice (BMP) may be by today’s standards an unsustainable practice. For example, in 1995, Govindasamy and Cochran cited a BMP rate for litter application to pasture land between 4 and 5 tons/acre; today, this rate is considered too excessive. In northwest Arkansas, surface water is abundant and an accumulation of soil phosphorus causes concern. Other contributors to the potential phosphorus problem are municipal and industrial sewage treatment plants, septic tanks, and storm water runoff from lawns, construction sites and recreational facilities.

The two key poultry counties in northwest Arkansas, Benton and Washington, produce over 237 million broilers per year (USDA), which corresponds to 20% of the total broiler production in the state. The production of turkeys and layers is also important to the region. Over 100,000 tons of surplus poultry litter from these two counties will be available to be exported
each year, if a phosphorus based application rate is implemented. Other concentrated poultry production is located near these two Arkansas countries, such as in adjacent counties in eastern Oklahoma and southwest Missouri. The survival of the poultry industry in northwest Arkansas requires addressing the excess nutrient problem.

One of the most promising solutions is to transport the surplus litter to nutrient-deficient regions (Gollehon et al). Currently there is no organized marketing structure supporting the long-distance distribution of poultry litter (unlike what exists for commercial fertilizer), thus information regarding transport costs and storage is usually inconsistent and many times unavailable—this, in turn, hinders the development of a poultry litter marketing system. Following Adam Smith’s logic, the absence of a market for poultry litter could indicate that nobody has the opportunity of bettering themselves in such a market. But given the undesirable accumulation of nutrients in regions that cannot efficiently use them, the absence of a poultry litter market indicates a market failure that could warrant public intervention (Gollehon et al.). Parker advances that the absence of a market may be due to high transaction costs on the part of sellers and buyers.

In an effort to reduce potential phosphorus runoff from agriculture in sensitive watersheds, the 2003 Arkansas General Assembly enacted three laws effective in defined sensitive watersheds: 1) Arkansas Soil Nutrient Management Planner and Certification Act, 2) An Act to Register Poultry Feeding Operations, and 3) An Act to Require Proper Application of Nutrients and Utilization of Poultry Litter in Nutrient Surplus Areas. Nutrient management plans are currently being developed for poultry litter that will estimate the excess quantity available for export. The Arkansas Soil and Water Conservation Commission and local poultry integrators in northwest Arkansas have offered to help subsidize the transport of excess poultry litter to eastern
Arkansas, which is a nutrient-deficient crop area that relies on chemical fertilizers for its nutrient supply. Recent increases in the price of natural gas, a key input in the production of nitrogenous fertilizers, have pushed commercial fertilizer costs upwards and revived the interest in manure, particularly poultry litter, as a crop nutrient source.

Background and Previous Studies

Similar to the methodology of this paper, Parker defines the value of litter as the cost savings that can be obtained by using litter instead of chemical fertilizer. But despite these savings, a solution at the individual level may not be feasible and a manure brokerage system, with or without the intervention of poultry integrators, may need to be implemented to ensure the success of a manure market in the US (Parker). Although land-application of raw litter has been the most common practice traditionally, several manure utilization alternatives that help prevent pollution from excess animal manure application in one particular region have been evaluated in previous studies including 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.).

Transporting and handling poultry litter can be costly and its adoption discouraged because commercial fertilizer costs have been low historically (Parker) and chemical fertilizer is readily available through a well-defined marketing infrastructure. Raw litter transport requires attention with respect to sanitary conditions and the use of specialized walking floor or end dump trailers; hence backhaul opportunities, which can reduce transportation costs, although available, are difficult to implement. Recent Department of Transport regulations have reduced daily
working hours for truck drivers, hampering the ability of truckers to stop to clean the litter trailers in transit.

Transport and handling costs of processed forms of litter such as granules or pellets is more economical than raw litter but the extra processing cost is expensive for agricultural markets, in the range of $40 to $50 per ton, and most likely requires subsidies as is done in the Delmarva Peninsula. A litter pelleting plant was recently constructed in Delaware with a subsidy of at least $20 per ton to export excess poultry litter from the Delmarva Peninsula. Part of these subsidized litter pellets are currently exported as far as eastern Arkansas and are priced about $110 per ton by some local fertilizer dealers, who have indicated that the agricultural market is very limited at this price. Other regions in the US face surplus litter transporting issues and studies have concluded that subsidies were necessary to export the litter from the excess nutrient region. For the case of Virginia, Pelletier, Pease and Kenyon examined the impact of a subsidy of no more than $11/ton on the litter adoption rate and concluded that 374,000 tons could be transported annually a distance of 170 miles with an average subsidy rate of $7.90/ton. If the litter only was to be transported 100 miles, then 135,000 tons could be transported at an annual subsidy cost of $559,000.

Govindansamy and Cochran’s study of the feasibility of transporting poultry litter from northwest Arkansas to the Delta concluded that under certain conditions, such long-distance transport is favorable via truck but not rail, meaning that it maximized increased net revenue from litter use. The results were sensitive to the litter supply prices considered and to the crop price. However, the study did not compare the effect of fertilizer costs on the net revenue of litter use. Gollehon et al. also concluded that transportation costs largely determine the economic feasibility of off-farm transport.
Some of the disadvantages of using raw litter can be offset if the litter is compressed and wrapped in UV-resistant-plastic bales. This is a new technology that is under development with an expected processing cost of less than $5 per ton (Mammoth Corporation). Bales offer some special advantages over loose raw litter for handling and transporting including the use of open field storage after farm delivery, better opportunities for truck backhauls to reduce transport cost, preservation of nitrogen (N), and reduced odor problems. However, cutting the plastic and opening the bales at the application site does require a special tractor attachment. Initial field experiments with 40%-moisture-content-baled-litter indicate that after the litter had been stored in the bales up to three months, the N content was converted into inorganic N, pathogen presence was eliminated, odor was reduced to a negligible level, and the consistency of litter had improved enough that it became easier to spread.

In Arkansas, an alternative to conventional truck transport of litter is the use of a combination of truck and barge transport. Barge rates along the Arkansas and Mississippi rivers are very competitive for long-distance transport compared to truck rates. Previous research on poultry litter transport in the U.S. has been largely limited to assessing only the trucking costs for litter without taking into account handling, storage, and processing costs. Jones and D’Souza’s approach used a goal-focused model to determine optimal litter shipments among watersheds in the eastern panhandle of West Virginia; they assumed unprocessed litter was transported by truck. The purpose of this paper is to evaluate the cost efficiency of 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 available from three town sources in Benton and Washington counties, located in northwest Arkansas are evaluated. Farm markets for litter are evaluated at county seats in Lonoke, Arkansas, Monroe, Poinsett, Jackson, and Mississippi.
counties in eastern Arkansas. These eastern Arkansas counties were earlier identified as potential markets for litter through focus group meetings. Innovations in the present study include a comparison of marketing loose raw litter and plastic wrapped baled litter, and a comparison of transport and handling costs by truck and a combination of truck and barge. The transport of litter using barges relies on the Arkansas and Mississippi River Systems servicing eastern Arkansas.

Method of Analysis

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. The nutrient cost function accounts for chemical fertilizer costs and poultry litter costs assuming litter is exported from northwest Arkansas to eastern Arkansas. Different types of litter (turkey and broiler), forms of litter (raw and compressed plastic-wrapped bales), and transportation methods (truck only and truck-barge combination) are evaluated in the optimization.

Short distance truck transport is also evaluated to move raw and baled litter to and from barge ports, 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 delivered and stored outside in farm fields in eastern Arkansas prior to spreading, as the bales take little space and do not need to be covered, as evidenced in field tests. 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
\[
\begin{align*}
\min & \quad Z = \sum_{s} \sum_{m} \sum_{r} \left( \sum_{i} \left( \alpha_{sm} LRT_{ism} + \beta_{sm} LBT_{ism} \right) + \sum_{u} \sum_{n} \left( \gamma_{sunm} LRB_{sunmr} + \delta_{sunm} LBB_{sunmr} \right) \right) \\
& \quad + \sum_{i} \sum_{s} \sum_{m} \left[ E_{mrf} (\eta_f + \theta) \right]
\end{align*}
\]

subject to

\[
\sum_{i} \sum_{s} \sum_{m} \left[ (LRT_{ism} + LBT_{ism}) I(s \in w) \right] \\
+ \sum_{i} \sum_{s} \sum_{u} \sum_{n} \sum_{m} \sum_{r} \left[ (LRB_{sunmr} + LBB_{sunmr}) I(s \in w) \right] \leq L_{iw}, \forall i, w;
\]

\[
\sum_{i} \sum_{s} \left[ LRT_{ism} + LBT_{ism} + \sum_{u} \sum_{n} (LRB_{sunmr} + LBB_{sunmr}) \right] \xi_{if} \right] + E_{mrf} \rho_f \geq D_{fmr}, \forall f, m, r;
\]

\[
\sum_{i} \sum_{s} \left[ LRT_{ism} + LBT_{ism} + \sum_{u} \sum_{n} (LRB_{sunmr} + LBB_{sunmr}) \right] \leq A_{mr}, \forall m, r;
\]

\[
\sum_{i} \sum_{s} \sum_{m} \sum_{r} \left[ (LRT_{ism} + LBT_{ism}) I(s \in w) \right] \\
+ \sum_{i} \sum_{s} \sum_{u} \sum_{n} \sum_{m} \sum_{r} \left[ (LRB_{sunmr} + LBB_{sunmr}) I(s \in w) \right] \geq R_{w}, \forall w;
\]

and

\[
LRT_{ism}, LBT_{ism}, LRB_{sunmr}, LBB_{sunmr}, E_{mrf} \geq 0, \forall i, s, u, n, m, r, f.
\]

The first equation illustrates the objective function of the model that minimizes the cost of supplying nutrients to crops in the form of poultry litter or chemical fertilizer and it is subject to equation (2), which is a litter supply constraint at each watershed \((w)\) for each bird type \((i)\); equation (3), which is a nutrient demand constraint for each crop \((r)\) at each market \((m)\) and for each nutrient \((f)\); equation (4), which constrains the acreage for litter application assuming an application rate of one ton per acre; equation (5), which imposes a minimum level of litter removal at each watershed constraint, and the non-negativity constraints as expressed in equation (6).
The variable $Z$ in the objective function represents the total dollar cost of supplying nutrients to county markets in the form of poultry litter or chemical fertilizer; $LRT_{ismr}$ represents tons of raw litter of bird type $i$ transported by truck from source $s$ to market $m$ to be applied to crop $r$; $LBT_{ismr}$ represents tons of baled litter of bird type $i$ transported by truck from source $s$ to market $m$ to be applied to crop $r$; $LRB_{ismnr}$ represents 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 $r$; $LBB_{ismnr}$ represents 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 $r$; and $F_{smrf}$ represents tons of chemical fertilizer of nutrient $f$ applied to crop $r$ at market $m$.

The parameters in the model are $\alpha_{sm}$ defined as the cost per ton of using raw litter from source $s$ in market $m$ when litter is transported by truck; $\beta_{sm}$, the cost per ton of using baled litter from source $s$ in market $m$ when litter is transported by truck; $\gamma_{sm}$, the 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 $n$; $\delta_{smu}$, the 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 $n$; $\eta_{f}$, the cost per ton of applying fertilizer providing nutrient of type $f$; $\theta$, the cost per ton of applying fertilizer; $\rho_{f}$, the available quantity of nutrient of type $f$ in chemical fertilizer; $\xi_{iy}$ the available quantity nutrient of type $f$ in litter of type $i$; $\overline{L}_{iw}$, the maximum production of litter of type $i$ in watershed $w$; $\overline{D}_{fmr}$, the minimum demand of nutrient of type $f$ for crop $r$ at market $m$; $\overline{A}_{mr}$, the maximum acreage available for litter application to crop $r$ at market $m$; and $\overline{R}_{w}$, the minimum litter removal in watershed $w$. 
The objective function of the GAMS model, equation (1), includes all costs pertaining to supplying crops (corn, corn silage, soybeans, rice, wheat, cotton, and grain sorghum) at each market (Lonoke, Arkansas, Monroe, Jackson, Poinsett, and Mississippi counties in Arkansas) with N, P, and K by applying poultry litter or chemical fertilizer (urea, super phosphate, or potash fertilizer). Poultry litter is transported out of the Eucha-Spavinaw Watershed (ESW) from Decatur in Benton County and out of the Illinois River Watershed (IRW) from Siloam Springs and/or Prairie Grove in Washington County. The nutrient supply costs in the GAMS model include litter transportation, raw litter storage and handling, processing costs for baled litter, and application and incorporation costs of litter as well as costs of chemical fertilizers and respective application. In the baseline model, truck transportation of baled litter has a lower cost of $1.50 per loaded mile due to the better availability of truck backhaul opportunities compared with transporting loose raw litter. Backhauls are much more difficult in loose raw litter transport because the trailers must be cleaned before transporting other materials. When shipping by barge, the choice of outgoing ports on the Arkansas River for litter from northwest Arkansas is Catoosa (Oklahoma) or Fort Smith (Arkansas). The incoming ports evaluated for receiving 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 in the two watershed areas of northwest Arkansas. Equation (3) addresses the issue of meeting crop nutrient requirements for N, P and K by applying either litter or commercial fertilizer. The fourth constraint limits litter application so as to not exceed the crop acreage available in the six eastern Arkansas counties. Litter is assumed to be spread at the rate of one ton per acre and chemical fertilizer is used to supplement the litter to meet crop
nutrient requirements. A recent proposal by poultry integrators has suggested that at least 67,500 tons of litter be exported from the IRW in the near future. 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

In 2004 we 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 broiler versus turkey litter. On average, the N content is comparable, about 60 lbs per ton of litter but turkey litter has a different P and K content. Our model assumes that only 75% of N in litter is available to meet the crop’s nutrient requirements. For chemical 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). Despite the nutrient value of litter, we assume that it leaves the grower farm FOB because of the excess nutrient situation and the new recent regulations that preclude its land application in northwest Arkansas.

[Insert Table 1 approximately here]

Litter baling is assumed to occur at a central location in northwest Arkansas at a cost of $5 per ton for baling as estimated by Mammoth Corporation engineers, $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 priced at the backhaul rate of $1.50 per loaded
mile with bales delivered directly to farmers for outside storage at the application field (Traylor). Long distance raw litter transport by truck 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 (Table 1). 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. We assume a $100 minimum charge per truckload for use of large trucks, regardless of distance. These short-haul trucking rates for baled and loose raw litter are applied to all trips to and from the barge ports.

Barge loading and unloading costs are $2.50 per ton at each river port based on the standard cost of using an overhead crane and clam shell equipment (Table 1). 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 the port at Fort Smith to the port at Pine Bluff. No extra in-transit costs are assumed for long-distance trucking.

Baled litter is assumed to be delivered directly to farm fields in eastern Arkansas for outside storage prior to spreading. No storage costs for baled litter are included as the bales are fully plastic wrapped to preserve nutrients, to provide an odor barrier and to protect against the weather. Loose raw litter is assumed to be delivered to an inside storage building in eastern Arkansas with a storage cost of $3 per ton plus additional transport and handling costs from the storage building to the farm field of $7 per ton, including storage cleanout and unloading costs (Table 1). 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 with a disk plow in the field to prevent ammonia N losses after spreading is $6 per ton for both the baled and loose raw litter.
Chemical fertilizer prices reported for eastern Arkansas in December 2004 were $280 per ton of urea, $302 per ton of super phosphate, and $250 per ton of potash fertilizer. Spreader costs for chemical fertilizer are estimated at $100 per ton or $0.05 per pound. The application rate of chemical fertilizer is usually less than 200 pounds per acre.

[Insert Table 2 approximately here]

Recommended N-P-K nutrient requirements for corn, corn silage, soybean, rice, wheat, cotton, and grain sorghum crops are supplied with chemical fertilizer and/or poultry litter. The crop 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 (Table 2). A basal application rate of one ton of poultry litter per acre is assumed as a practical and environmentally safe average amount that can be applied with a typical manure spreader. There should be no concern with excess P buildup with only one ton of litter applied to cropland. Total crop acreage is 2.1 million acres in the six eastern Arkansas counties evaluated in this study.

Four alternative scenarios are considered in the sensitivity analysis of the model: (i) a 50% reduction in the current relatively high prices of chemical fertilizer, (ii) reduction in N-availability in litter from 75% to 50%, (iii) exclusion of litter baling as an option, 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 and Sensitivity Analysis

[Insert Table 3 approximately here]
The estimated least-cost solution for the baseline model is to transport baled litter by truck from Prairie Grove in the IRW and from Decatur in the ESW to use as a crop nutrient in Lonoke (crops selected were corn for grain and silage, rice, cotton, and sorghum), Arkansas (crops selected were rice, cotton, corn for grain, and sorghum), Poinsett (corn for grain, rice, and cotton) and Monroe (crops selected were corn for grain, rice cotton, and sorghum) counties as can be seen in Table 3. The stipulated minimum export requirement is non-binding and all broiler and turkey litter available in the two watersheds is exported, nearly 312,000 tons at an average supply cost of $42.77 per ton (or per acre, as we assume a litter application rate of 1 ton/acre), including field spreading and incorporation costs (Table 4).

[Insert Table 4 approximately here]

It is estimated to be cost efficient to apply litter to all crops except wheat and soybean in markets more distant from northwest Arkansas such as Mississippi County. Because these two crops need less nutrients overall, their nutrient demands can be satisfied with commercial fertilizer at a lower cost. On the other hand, corn for grain and silage are the most expensive crops to fertilize from our crop selection and as such poultry litter is particularly valuable because it allows greater chemical fertilizer savings primarily for N and P. Poultry litter is also valuable in the production of rice, cotton, and grain sorghum. A comparison of the crop acreage available in each county market (Table 2) and the optimal litter distribution solution (Table 3) shows that for most crops the acreage available exceeds the acreage receiving litter thus the demand for litter is not totally satisfied. In fact supplying one more ton of litter instead of using fertilizer could reduce crop nutrient costs by $18/acre for broiler litter; for turkey litter the reduction in cost would be nearly $19/acre (Table 5).

[Insert Table 5 approximately here]
Reducing the price by half for urea, super phosphate, and potash fertilizers results in a substantial reduction of litter exports and the minimum removal constraints of 67,500 tons for IRW and 59,712 tons for ESW become binding. With the low chemical fertilizer price scenario, the estimated marginal cost of removing one more ton of broiler litter from ESW watershed is $4.19. For IRW, the marginal cost of broiler litter is $1.64. However, even with these low chemical fertilizer prices, the maximum litter supply constraint is binding for turkey litter but not for broiler litter (Table 5). Recall that turkey litter has slightly more nutrients than broiler litter (on average, turkey litter has 66 lbs of P and 45 lbs of K per ton of litter while broiler litter has 57 lbs of P and 52 lbs of K per ton of litter). Thus northwest Arkansas turkey litter is a more valuable nutrient than broiler litter, given the litter nutrient content considered. The shadow price for turkey litter is negative indicating that the cost of providing nutrients to the crop markets in eastern Arkansas could be reduced by using more turkey litter instead of broiler litter. Under the low fertilizer cost scenario, the litter supply cost per ton drops slightly to $41.59 with a fall in litter exports compared with $42.77 in the baseline solution as less litter is applied meaning that crop markets located closer 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 chemical fertilizer. The other two scenarios, where backhauls are 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 by truck and barge, litter supply cost is increased to $46.45 per ton, about $4 per ton above the baseline cost with bale transport by truck in the baseline solution.
The estimated total crop acreage in the six eastern Arkansas market counties evaluated in this study is roughly 2.1 million acres (Table 4). The baseline solution estimated a total litter supply cost of $13.3 million and a total chemical fertilizer supply cost of $125.9 million to satisfy all crop nutrient requirements in the six countries considered. The fact that litter application entered the baseline model solution and all litter available in northwest Arkansas was exported indicates that on average, the cost per acre of supplying nutrients using only chemical fertilizer exceeds the cost per acre of using a mix of poultry litter and chemical fertilizer. This result holds for all scenarios considered except for the scenario where the chemical fertilizer price is dropped by half. For this scenario, we are exporting more litter than the level that is cost-efficient because of the minimum export constraint: the total cost of using litter is $5.3 million, while the total cost of using chemical fertilizer is $87.2 million. By using baled litter and taking advantage of the more favorable trucking costs, the litter supply cost could be reduced by $1.2 million. Transport of loose raw litter is still cost efficient if a combination of truck and barge transport is used.

As shown in Table 5, an increase in the maximum level of litter exports in the baseline solution would reduce the minimum cost to meet crop nutrient needs in eastern Arkansas from $17.53 to $21.29 per ton of litter. Broiler and poultry litter exports are constrained at the maximum level in the baseline solution. With a 50% reduction in chemical 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. The unavailability of litter baling or of a lower cost backhaul trucking rate causes the truck and barge transport option to be the most cost efficient. However, the litter supply cost is increased with this option compared with the baseline solution. The option of transporting litter bales by truck
and barge is less cost efficient than transporting loose raw litter by truck and barge because the processing costs for baling exceed the storage cost savings with baled poultry litter.

Summary and Conclusions

The objective of this study is to evaluate the cost efficiency of supplying nutrients to crops in eastern Arkansas by using a mix of poultry litter and chemical fertilizer. This allows exporting excess poultry litter from northwest Arkansas to eastern Arkansas farm counties that are nutrient deficient. We assessed innovative transport and handling options: 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 chemical 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 assumed to have a surplus litter 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 and are current through December, 2004.

Results indicate that poultry litter export is cost efficient and, if litter users are willing to pay for the poultry litter nutrients what they pay for chemical fertilizer, it does not require a subsidy given the currently high chemical fertilizer prices; this result does not hold if chemical fertilizer costs were to be cut in 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 but the supply cost would increase by $1.2 million.
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 actual production conditions. Crop growers may not be willing to pay the full nutrient value of litter because of other considerations such as the volatility of both the N content in litter and the N availability to crops (which is very sensitive to management issues of raw litter but is not a problem when using baled litter), the lack of litter spreading equipment in eastern Arkansas, the general lack of market services to supply litter compared to chemical fertilizers, and the relative short window of application for most crops due to uncertainties in soil moisture conditions and labor shortages. Crop farmers may be willing to pay more for litter bales than loose raw litter because of better nutrient preservation and improved storage and handling properties.
References

Beaton, J. “Efficient Fertilizer Use—Fertilizer Use… A Historical Perspective.”

Goldhorn, N., M. Aillery and L. Christensen. “Cost of Land Applying Manure with Increased
Off-Farm Processing Capacity: A Regional Assessment.” Paper presented at the AAEA

Animal Production and Manure Nutrients.” Economic Research Service, USDA,

Environmentally Sensitive Areas to Delta Row Crop Production.” Agricultural and


Capacity of Cropland and Pastureland to Assimilate Nutrients. USDA-NRCS-ERS.

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


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


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<th>Litter</th>
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<tr>
<td>Litter storage/extra handling ($/ton)(^d)</td>
<td>$10</td>
<td></td>
</tr>
<tr>
<td>Field spreading ($/ton)(^e)</td>
<td>$7</td>
<td>$8</td>
</tr>
<tr>
<td>Field incorporation($/ton)</td>
<td>$6</td>
<td>$6</td>
</tr>
</tbody>
</table>

\(^a\) Direct long distance trucking from poultry house to storage in eastern Arkansas for raw litter and from baler site to farmer’s field in eastern Arkansas for baled litter.

\(^b\) Short distance trucking to haul raw litter or litter bales to and from river ports.

\(^c\) Includes $6 per ton to handle and transport raw litter to baler and $5 per ton for baling.

\(^d\) Includes $3 per ton for raw litter storage and $7 per ton for raw litter handling and transport from storage to a farmer’s field for spreading.

\(^e\) Requires front end loader cutter attachment to remove plastic from bales. Field spreading of chemical fertilizer is usually less than 200 pounds per acre or about $0.05 per pound.
**Table 2.** Crop Acreage Availability by County Seat of Litter Market Counties Considered

<table>
<thead>
<tr>
<th>County Seat</th>
<th>Corn</th>
<th>C. Silage</th>
<th>Soybean</th>
<th>Rice</th>
<th>Wheat</th>
<th>Cotton</th>
<th>Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lonoke</td>
<td>1,786</td>
<td>40</td>
<td>144,828</td>
<td>75,139</td>
<td>39,040</td>
<td>25,085</td>
<td>2,200</td>
</tr>
<tr>
<td>Arkansas</td>
<td>5,955</td>
<td>0</td>
<td>210,429</td>
<td>122,744</td>
<td>86,794</td>
<td>2,080</td>
<td>2,668</td>
</tr>
<tr>
<td>Monroe</td>
<td>5,885</td>
<td>0</td>
<td>116,944</td>
<td>48,481</td>
<td>31,892</td>
<td>17,575</td>
<td>3,995</td>
</tr>
<tr>
<td>Vernon</td>
<td>21,655</td>
<td>543</td>
<td>64,768</td>
<td>0</td>
<td>24,261</td>
<td>0</td>
<td>17,519</td>
</tr>
<tr>
<td>Muskogee</td>
<td>5,641</td>
<td>280</td>
<td>22,528</td>
<td>0</td>
<td>7,676</td>
<td>0</td>
<td>2,232</td>
</tr>
<tr>
<td>Jackson</td>
<td>4,019</td>
<td>0</td>
<td>165,337</td>
<td>84,704</td>
<td>38,346</td>
<td>1,151</td>
<td>5,216</td>
</tr>
<tr>
<td>Poinsett</td>
<td>1,709</td>
<td>0</td>
<td>162,986</td>
<td>127,171</td>
<td>18,711</td>
<td>63,117</td>
<td>3,069</td>
</tr>
<tr>
<td>Mississippi</td>
<td>10,565</td>
<td>0</td>
<td>209,904</td>
<td>17,885</td>
<td>46,132</td>
<td>212,843</td>
<td>5,871</td>
</tr>
<tr>
<td>Conway</td>
<td>2,104</td>
<td>893</td>
<td>21,204</td>
<td>0</td>
<td>7,190</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: US Census of Agriculture 1997
Table 3. Poultry Litter Allocation from the GAMS MINOS Baseline Solution of Crop Nutrient Optimization Problem

<table>
<thead>
<tr>
<th>Town Source</th>
<th>County Market</th>
<th>Bird Type</th>
<th>Crop</th>
<th>Baled Litter (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie Grove</td>
<td>Lonoke</td>
<td>Broiler</td>
<td>Corn Silage</td>
<td>40</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Lonoke</td>
<td>Broiler</td>
<td>Rice</td>
<td>47,456</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Lonoke</td>
<td>Broiler</td>
<td>Cotton</td>
<td>19,804</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Lonoke</td>
<td>Turkey</td>
<td>Corn</td>
<td>1,786</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Lonoke</td>
<td>Turkey</td>
<td>Sorghum</td>
<td>2,200</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Arkansas</td>
<td>Broiler</td>
<td>Rice</td>
<td>33,120</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Arkansas</td>
<td>Broiler</td>
<td>Cotton</td>
<td>1,642</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Poinsett</td>
<td>Broiler</td>
<td>Corn</td>
<td>1,709</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Poinsett</td>
<td>Broiler</td>
<td>Rice</td>
<td>60,925</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Poinsett</td>
<td>Turkey</td>
<td>Rice</td>
<td>16,749</td>
</tr>
<tr>
<td>Prairie Grove</td>
<td>Poinsett</td>
<td>Turkey</td>
<td>Cotton</td>
<td>19,075</td>
</tr>
<tr>
<td>Decatur</td>
<td>Arkansas</td>
<td>Broiler</td>
<td>Rice</td>
<td>44,402</td>
</tr>
<tr>
<td>Decatur</td>
<td>Arkansas</td>
<td>Turkey</td>
<td>Corn</td>
<td>5,955</td>
</tr>
<tr>
<td>Decatur</td>
<td>Arkansas</td>
<td>Turkey</td>
<td>Sorghum</td>
<td>2,668</td>
</tr>
<tr>
<td>Decatur</td>
<td>Monroe</td>
<td>Broiler</td>
<td>Corn</td>
<td>5,235</td>
</tr>
<tr>
<td>Decatur</td>
<td>Monroe</td>
<td>Broiler</td>
<td>Rice</td>
<td>30,620</td>
</tr>
<tr>
<td>Decatur</td>
<td>Monroe</td>
<td>Broiler</td>
<td>Cotton</td>
<td>13,875</td>
</tr>
<tr>
<td>Decatur</td>
<td>Monroe</td>
<td>Turkey</td>
<td>Corn</td>
<td>650</td>
</tr>
<tr>
<td>Decatur</td>
<td>Monroe</td>
<td>Turkey</td>
<td>Sorghum</td>
<td>3,995</td>
</tr>
</tbody>
</table>

Note: The optimal transportation method for this scenario was truck.
Table 4. Summary of GAMS Optimization Model Solutions of Using Northwest Arkansas Poultry Litter and Chemical Fertilizer to Supply Nutrients to Eastern Arkansas Crops

<table>
<thead>
<tr>
<th>Activity</th>
<th>Baseline</th>
<th>No Baling&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cheaper Fertilizer&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Reduced N Available&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter Use (tons)</td>
<td>311,906</td>
<td>311,906</td>
<td>127,212</td>
<td>311,906</td>
</tr>
<tr>
<td>Litter Form (raw/bales)</td>
<td>bales</td>
<td>raw</td>
<td>bales</td>
<td>bales</td>
</tr>
<tr>
<td>Transport Method</td>
<td>truck</td>
<td>truck/barge</td>
<td>truck</td>
<td>truck</td>
</tr>
<tr>
<td>Litter Supply Cost ($/ton)</td>
<td>$42.77</td>
<td>$46.45</td>
<td>$41.59</td>
<td>$42.77</td>
</tr>
<tr>
<td>Total Litter Cost ($ m)</td>
<td>$13.30</td>
<td>$14.50</td>
<td>$5.30</td>
<td>$13.30</td>
</tr>
<tr>
<td>Total Chemical Fertilizer Cost ($ m)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>$125.90</td>
<td>$125.80</td>
<td>$87.20</td>
<td>$127.80</td>
</tr>
<tr>
<td>Total Acres Fertilized (m)</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Crops Fertilized</td>
<td>Corn, Silage, Corn, Silage, Corn, Silage, Corn, Silage, Rice, Cotton, Rice, Cotton, Rice, Cotton, Rice, Cotton, Sorghum, Sorghum, Sorghum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> The same solution was obtained when we assumed no backhaul opportunities were available and a dead head trucking cost of $2.50 per loaded mile was used for hauling bales.

<sup>b</sup> Chemical fertilizer prices per ton reduced from $280 to $140 for urea, $302 to $151 for phosphate fertilizer, and $250 to $125 for potash fertilizer.

<sup>c</sup> Nitrogen availability from poultry litter reduced from 75% to 50%.

<sup>d</sup> Estimated total chemical fertilizer cost to meet crop nutrient requirements on 2.1 million crop acres in Lonoke, Arkansas, Monroe, Jackson, Poinsett and Mississippi counties in combination with use of poultry litter.
Table 5. Sensitivity Analysis of Marginal Costs Associated with Litter Supply Constraint

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Supply Constraint Binding?</th>
<th>Eucha-Spavinaw Watershed</th>
<th>Illinois River Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Broiler</td>
<td>Turkey</td>
</tr>
<tr>
<td>Baseline Model</td>
<td>Yes</td>
<td>($17.53)</td>
<td>($18.74)</td>
</tr>
<tr>
<td>Reduced Fertilizer Cost</td>
<td>B-No/T-Yes^a</td>
<td>--</td>
<td>($0.71)</td>
</tr>
<tr>
<td>Reduced N Availability</td>
<td>Yes</td>
<td>($11.34)</td>
<td>($12.55)</td>
</tr>
<tr>
<td>No Bales</td>
<td>Yes</td>
<td>($13.04)</td>
<td>($14.25)</td>
</tr>
<tr>
<td>No Backhaul Rate</td>
<td>Yes</td>
<td>($13.04)</td>
<td>($14.25)</td>
</tr>
</tbody>
</table>

Note: The litter supply constraint is binding for turkey litter (T) but not for broiler litter (B).