Assessment of Multimodal Transport of Baled Poultry Litter and Dewatered Biosolids from Northwest Arkansas

Project 7015

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MACK-BLACKWELL TRANSPORTATION CENTER

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Final Report

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Part I: Technical and Logistics Assessment

Introduction

Increased poultry production along with recent high population growth in northwest Arkansas has resulted in a major buildup of local soil nutrients (Sharpley et al.). The primary environmental concern is with excess phosphates and phosphate runoff. Poultry production in Benton and Washington counties of Arkansas has been estimated at 237 million broilers (USDA, 2000), which is equivalent to about 20 percent of all broiler production in the state. Poultry litter has been land applied in this area for over forty years. In order for the farmers to achieve the proper amounts of nitrogen for production, an over-application of litter lead to excess phosphorus in the environment (Goodwin 2007). The human population in northwest Arkansas has increased 48 percent from 1990 to 2000 (US Census).Benton and Washington counties 2006 estimated population is 196,045 and 186,521 respectively (U. S. Census Bureau).

Problem

Various stakeholder groups in the Ozarks region have expressed concerns regarding the degradation of surface water quality. Several point and non-point sources have been suggested as contributors to this degradation; among these are the poultry industry and local municipal wastewater plants. Exporting poultry litter and municipal biosolids is a possible immediate approach to ameliorate the excess nutrient situation in the region. Crop farmers contacted through focus groups conducted by the University of Arkansas' Division of Agriculture expressed a strong interest in buying poultry litter (Goodwin 2007). The Ozark Poultry Litter Bank (Goodwin 2005) is an ideal location for litter collection. The Northwest Arkansas Conservation Authority (NACA), created in response to the “Joint County and Municipal Solid Waste Disposal Act”, is also seeking economic alternatives to landfill disposal of municipal biosolids. One option proposed is one facility to handle biosolid management for northwest Arkansas’ participating water treatment facilities. There are five major wastewater treatment plants operating in northwest Arkansas; Fayetteville, Springdale, Rogers, Bentonville and Siloam Springs. The raw sewage output per day in dry tons was as follows in 2002: Fayetteville (7.8), Springdale (11.5), Rogers (5.6), Bentonville (2.7), and Siloam Springs (1.0) (CB, CDM Report). The total amount of biosolids was 28.6 dry tons per day (10,439 tons per year). Assuming an 80% moisture content for the ‘dewatered biosolids’, this equals 52,195 tons in 2002. Having a centralized locations for the area’s municipal solid waste and poultry litter could make exporting bales of poultry litter and biosolids more feasible.

There is approximately 107,400 tons of broiler and turkey litter produced in Benton County and 204,506 tons produced in Washington County (Goodwin 2004). Handling and transporting raw poultry litter and dewatered biosolids for export is costly. Processing approaches such as pelleting and granulating reduce both litter and biosolid volume by approximately 10 percent but are very expensive. A less expensive processing and transport combination must be found if poultry litter and biosolids are to be marketed sustainably as a crop nutrient source with less subsidization. Recent increase in natural gas prices have made nitrogen-based fertilizers more expensive to produce. Using litter and biosolids to supply part of crop nutrient needs would decrease use of natural gas resources used to produce fertilizers.

Mammoth Corporation (Spokane, WA) and the University of Arkansas Division of Agriculture collaborated in a joint research project to develop technology for producing plastic-wrapped bales and to evaluate the quality of the bales. (USDA-SBIR 2004). Poultry litter of varying moisture contents (approximately 25%, 40%, and 55% produced in Washington state) was plastic-wrapped using a modified municipal solid waste baler and stored outside for a period of three months. The bales were transported from Spokane to Prairie County, AR, on a flatbed truck; the baled litter was land-applied under typical field conditions. Baled poultry litter may be land-applied at planting without needing an additional pass to be soil incorporated. Field handling and spreading posed no particular difficulties, especially at moisture levels around 40 percent. The 25% moisture blend was very dry and dusty to spread. The 55% moisture blend was too wet and prone to clumping in the litter spreader. The bales were manually opened and poured into the spreader. Technology is still being developed to mechanically open the plastic-wrapped bales for the loading process. Once wrapped, the bales of litter are airtight and leak proof. Litter bales produced with the Mammoth baler have been test dropped without incurring any damage. These plastic-wrapped bales can be transported in a variety of tractor-trailers; thus, truckers can take advantages of more backhaul opportunities. The ultra-violet resistant plastic-wrapped bales can be stored outside at their destination, reducing the need for storage and double handling costs at the end-use point..

Preliminary pathogen assessments revealed no presence of either *Salmonella* or *E. coli* in samples extracted from the baled poultry litter. The average N-P-K nutrient content of northwest Arkansas broiler litter on an as-is-basis was 60-57-52 in pounds per ton; the average nutrient content of the baled litter on an as-is-basis was, on average, 65-67-61, 50-52-46 and 36-37-34 for 28%, 40% and 56% moisture, respectively. Using December 2006 commercial fertilizer prices, raw Northwest Arkansas poultry litter has an estimated chemical nutrient value of nearly $50 per ton (Goodwin, et al, 2007). The nutrient test for dewatered biosolids on a dry basis was 27-152-24 (Armstrong 2007).

Co-processing poultry litter and minicipal biosolids has not been done as in this project. The process is expected to be a cost-efficient and cutting-edge method to fully take advantage of the potential nutrient benefits of both products, while eliminating potential biosecurity and sanitary threats to other sectors from pathogens. The Mammoth baling process is expected to eliminate pathogens and reduce potential nitrogen losses.

Two types of transport methods will be investigated: truck and a combination of truck and barge. Young et al. compared these two transportation options in the shipment of poultry litter in raw and baled forms from Northwest Arkansas to Eastern Arkansas and found that although truck transport of bales is most cost effective to supply nearer nutrient markets, a truck and barge combination is most cost effective over very long distances especially if the market county is located near the Arkansas or Mississippi rivers. Truck transport of baled litter/Dewatered Municiple Biosolids (DMB) may be of strong interest to truckers because of the heavy freight volume coming to northwest Arkansas from destinations such as Little Rock and Memphis. The packaged products can easily be back hauled to farm markets along the truck routes on return trips.

The Process

The cost of biosolids disposal in northwest Arkansas will likely continue to increase as the population grows and landfill space is depleted. The University of Arkansas' Center for Business and Economic Research estimates that Northwest Arkansas' population will increase from 364,000 in 2005 to almost 580,000 by

2020. Nutrients found in biosolids are needed by crop farmers in nutrient-deficient areas such as eastern Arkansas but are currently being land filled.

Renee Langston, Springdale Water Utilities Director, coordinated the City of Springdale's cooperation with the University of Arkansas' Division of Agriculture for this project. He related that the Springdale wastewater treatment system utilizes a series of digestion ponds seeded by microbial concentrations to aid in treatment. The biosolids left after treated water is released are sent through belt filter presses used to dewater the biosolids from approximately 97.5 percent moisture to 80-85 percent moisture for landfill disposal. This moisture reduction results in a semi-solid form which is easier to transport. In 2006, Springdale Wastewater Treatment plant estimated $20/ton to locally landfill[1] the dewatered biosolids which are considered to be Class B biosolids which have limited pathogens and require a spreading permit. Class A has no pathogens or restrictions on use. The normal prescribed pathogen removal treatments include lime treatment or aerobic digestion for Class B and composting or drying for Class A.

Estimated 2003 Treatment Costs for Dewatered Biosolids

Treatment	**Cost**
Lime Stabilization	$34/ton
Windrow Composting	$18/ton
Direct Drying	$38/ton
Indirect Drying	$33/ton
Bioset Lime + Acid treatment	$34/ton

Note: Dewatered biosolids are 20% dry matter
Source: 2003 CB-CDM report

DMB cannot legally be land applied without pathogen treatment. Composting is the cheapest pathogen treatment for DMB with an estimated cost of $18 per ton.

[1] Local landfill is approximately 16 miles from the Springdale Wastewater Treatment plant

This research project evaluates co-processing of litter and biosolid materials for baling capability, pathogen control, nutrient retention, and elimination of ammonia emissions. Varying blends of poultry litter and dewatered biosolids were co-processed before being compressed and plastic-wrapped. Three different blends of poultry litter and DMB and one blend of poultry litter and water were co-processed for testing. The actual mixing of litter, DMB and water and packing into the barrels was conducted at the University of Arkansas Department of Animal Science feed mill. This site was chosen because of its large open floor plan for barrel storage and the availability of an electrically powered horizontal feed ration mixer with an extrication spout at the bottom. To achieve the varying moisture levels and co-processed blend ratios, litter and DMB were weighed and added in the proper proportions.[2] Once in the mixer, the litter and DMB were allowed to incorporate for five minutes. During this stage, large paddle blades in the mixer broke-up any clumps to produce a fine, textured product. A spout at the bottom of the mixer was opened to allow the mixture to be captured in buckets, which were then dumped into barrels lined with single extra-tall 55-gallon, 8 mil poly bags and compacted using a hand tamper. This process was repeated until the barrel was full and sealed to exclude additional air by twisting the end of the inner bag and securing it with zip ties and duct tape. Each barrel contained three thermocouple leads one each at the bottom, middle, and top of the barrel. These leads were constructed under the advice of Dr. Chris Brye (Crop Soil and Environmental Sciences, U of A) and used to take daily temperature reading of the sealed mixtures. Readings were taken by using a thermocouple reader, in which the leads were inserted and the corresponding daily

[2] The actual levels of the four ratios used in this experiment will remain unidentified until the patent process in final.

temperature readings in degrees Celsius were recorded for the study period of nine weeks (figure 1).

This experiment was conducted with thirty-two barrels of three different ratios litter/DMB mixtures and one litter/water mixture. There were eight barrels mixed for each of the four mixtures. Within each eight-barrel set, the barrels were labeled in sets of two corresponding to the sample period and the mixture ratio. The first two barrels are labeled 3.1A and 3.2A defined as: third week, barrel one and mixture A. The remaining barrels were labeled 5.1A, 5.2A, 7.1A, 7.2A, 9.1A, and 9.2A for sampling weeks 5, 7, and 9 respectively. This labeling system works the same for mixtures B, C, and D.

All sample data was recorded along with the three temperatures within the barrels, the temperature of the thermocouple reader itself and the ambient air temperature. Samples were analyzed and recorded for the reduction or removal of indicator pathogens and nutrient contents of the product. Samples of raw and pre-mixed materials were tested at the Poultry Health Lab (pathogens) and the Poultry Waste Management Lab (nutrients, etc)[3]. These results are summarized in Table1.

Throughout the course of the experiment the 8 mil poly bags held their integrity, being airtight and keeping inside gases from escaping. Once the litter and DMB were inside the bags there were no objectionable odors noticed from any of the vessels. Lab results obtained from trial mixture samples indicated a substantial removal of indicator pathogens within the first three weeks and complete removal of indicator pathogens in all litter/DMB blends by week 5. Pathogen reduction was not due to heating, however, as shown by the temperature readings (figure 1), but may be attributed to either gas buildup or an anaerobic bacteria buildup (as occurs in silage bales) inside of the bags.

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[3] The Poultry Waste Management Lab is an EPA approved lab on the University of Arkansas campus.

It was found that 100 percent of *Salmonella* eliminated from the mixtures (table 1). This was expected, as *Salmonella* can only live for 72 hours outside a living host. The other indicator pathogen tested for in the mixture samples was *E. coli*, a much more hearty and resilient bacteria than its counterpart *Salmonella,* one that can survive for extended periods of time without a live host. Nearly 90 percent of all samples came back negative for the presence of any *E. coli*; all were below the threshold of 1,000 colony forming units *E. coli* set as a standard for Class A biosolids (USDA/EPA) (table1). The absence of both of these pathogens is extremely important in getting approved for use on food crops. All baled mixtures would meet the Class A requirements.

Conversion of DMB to Class A biosolids by employing these mixing, compacting and wrapping methods is a very important step in the road to a suitable solution to the nutrient problem; other methods of reaching the Class A requirement are lengthy and very costly. The process utilized in this research is substantially less intensive and costly. Estimated costs as of January, 2007 for blended litter and DMB were approximately $4.98 per ton excluding overhead; this includes costs to weigh and load materials into a mixer ($2.00 per ton), blending labor ($.40 per ton), and combined utility charges and overhead costs ($.75 per ton).

Nutrient content of the samples in raw and mixed forms is summarized in Table 2. The top part of the table shows the individual materials and the mixtures' moisture level as a percent and N, P, K, Ca, and C as pounds per ton of material. The bottom part shows the same for N, P, K, Ca, and C as a monetary value in dollars per ton of material, the total value of nutrients N, P, K, and Ca in dollars per ton and the carbon in pounds per ton (table 2). Carbon is an important aspect of the mixtures and their overall performance on the land and crops. Based upon organic matter, a major benefit in use of litter and DMB, the mixtures that were evaluated can replace valuable organic matter that has been lost to farming practices or to laser leveling. These figures also indicate the packaging does in fact trap the ammonia gas which helps the mixture retain nearly all its nitrogen (table 2).

After review of all research and experimental data it has been concluded that the optimal mix of the litter and DMB is mixture B. This is based not only on the physical attributes of this mix, but it seemed to have the best texture and aroma at the end of the experiment. It did not clump when removed from the bags which mean that it would spread easily from a fertilizer buggy or litter truck. This particular mixture is also the most economically valuable based on the amount of nutrients present (Table 2).

Transporting the Baled Litter

Coordinating backhaul loads for walking floor and end dump trailers can be difficult. There is no backhaul load guarantee from eastern Arkansas unless the available products are demanded in northwest Arkansas. Corn and rice hulls are two products produced in eastern Arkansas needed for poultry production in northwest Arkansas. There is a ready market for corn in local poultry feed mills and for rice hulls and/or pine shavings as poultry bedding. Georges, Inc. is a proactive company, utilizing the backhaul of those products to move raw litter fertilizer to eastern Arkansas. George's company-owned poultry operations (about 100 houses) have a litter output of 10,000-15,000 tons per year. Litter is hauled year-round to fertilize pastureland, but only spring and fall to fertilize row crops. Part of the litter is moved to stacking sheds on George's farms because of timing with delivery or weather problems affecting the cleanout and resultant supply litter. The cleanout stacking sheds are typically 50 ft. by 150 ft. and hold litter from de-caking. A storage facility was built in eastern Arkansas to keep litter until demanded due to delivery issues during the wet season. George's recently constructed a storage shed in eastern Arkansas to hold 1,000 tons of litter for a cost of $40,000 not including site preparation. They received 53% cost share for the building from BMP Inc. from the subsidy program. They were also receiving $8/ton subsidy for transporting the litter to eastern Arkansas.[4] Farmers in the area also had to store litter for up to a month or so before spreading due to timing issues.

Economically, the price of corn in eastern Arkansas is not generally competitive with Midwest corn, which lessens the backhaul load availability. Backhauling products in walking floor or end dump trailers after hauling loose poultry litter requires trailer sanitization. This process is estimated to cost $50 per truck load ($2 per ton). Bales of co-processed litter are sealed with air tight plastic wrap, so no trailer clean-up/sanitization is required. The type of trailer used to haul bales of litter can easily be used for other cargo such as steel I-beams or other construction materials.

Baled Litter as Fertilizer

The delivery windows for loose litter marketing are generally spring and fall for row crop farmers. Poultry litter can be spread on grazing pastures anytime of year except in very wet weather. Because of delivery restrictions to crop farmers, weather protection needs to be provided for loose litter storage to accommodate sales over the year in eastern Arkansas. The baling and plastic wrapping preserves nutrients so the baled product should have a higher fertilizer value than loose poultry litter which is subject to ammonia losses. Soil incorporation after spreading the baled product should not be necessary as for

[4] Frank Ellis, Fertilizer dealer, Pocahontas, AR. Personal interview, July 2006.

loose poultry litter which has a high ammonia loss after spreading. This would save the farmer about $6 per ton assuming an application rater of one ton per acre. Some additional labor may be required but the expected cost should not exceed $1 per ton over the cost of loading loose poultry litter on a field spreader.

Michael Andrews, extension agent in Pocahontas, AR, stated the litter shipped in from NW Arkansas costs approximately $23 per ton. Spreading costs are $5-7. However, to supplement the spreading of litter, NRCS/extension office purchased a litter spreader which rents for $75 per day. If a farmer rented this spreader and could spread 100 tons the cost would be 75 cents for the spreader plus fuel and labor per ton.

Eastern Arkansas row crop producers are using litter on newly cut ground (leveled) and as primary nutrient source on crops such as corn, rice and soybeans. The high cost of commercial fertilizer may begin a trend toward farmers using more litter. The University of Arkansas' Division of Agriculture currently has some test plots to determine how much litter should be used on forages, wheat, cotton and soybeans under various research projects funded by USDA-NRCS and others. In addition, evaluation of poultry litter compared to commercial fertilizer in quality and quantity of crop, economic results of use and soil-building capacity is currently underway.[5]

[5] Michael Andrews, extension agent, Pocahontas, AR, personal interview, August 2006.

Figure 1: Barrel and Ambient Air Temperature - B Group

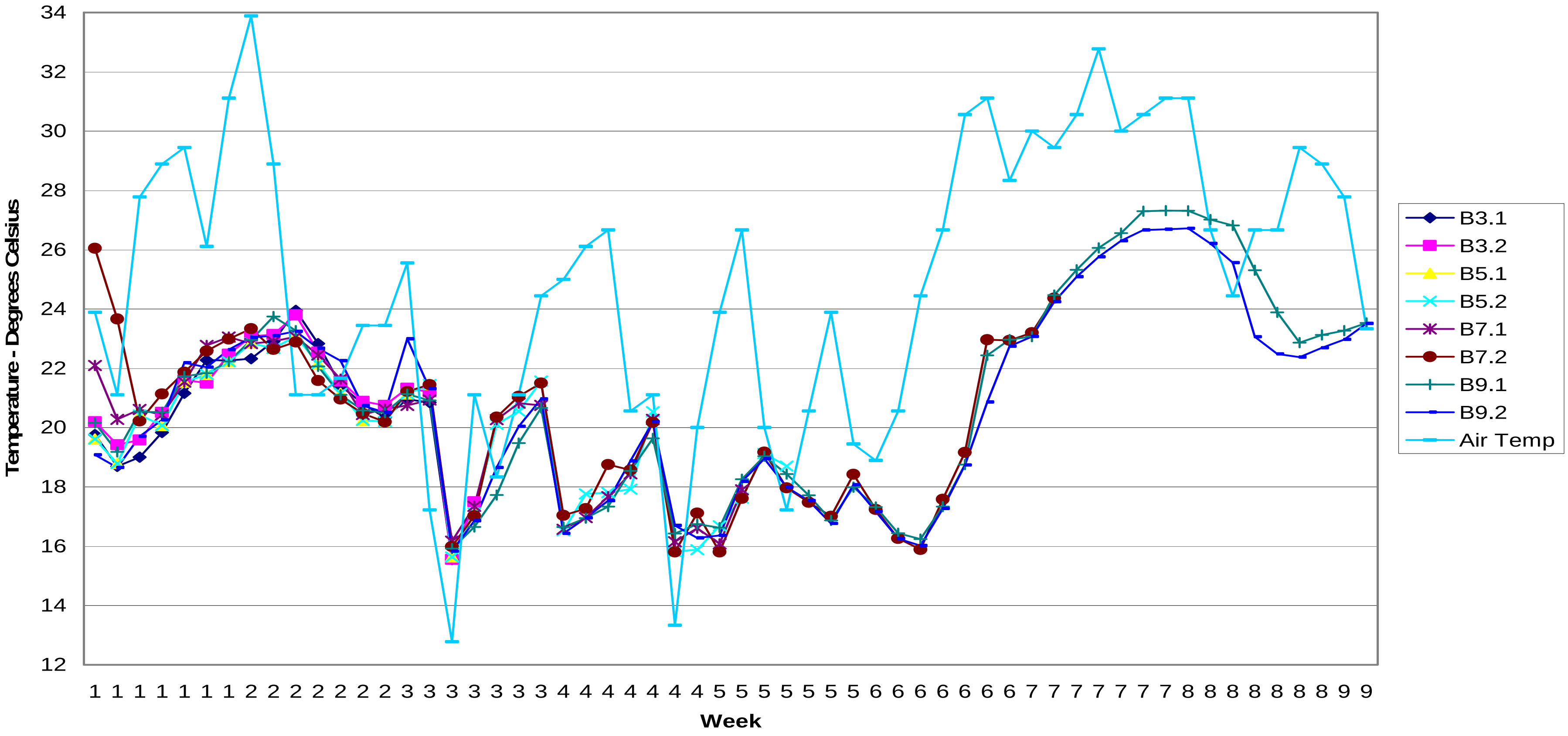

Table 1: EPA Indicator Pathogen Results Percentages Table

Mixture	A Salmonella	B Salmonella	C Salmonella	D Salmonella	A E. Coli	B E. Coli	C E. Coli	D E. Coli
Barrel								
3.1	100%	100%	100%	100%	80%	100%	100%	90%
3.2	100%	100%	100%	100%	90%	100%	100%	100%
5.1	100%	100%	100%	100%	90%	90%	30%	100%
5.2	100%	100%	100%	100%	100%	30%	80%	70%
7.1	100%	100%	100%	100%	100%	100%	100%	100%
7.2	100%	100%	100%	100%	40%	100%	100%	100%
9.1	100%	100%	100%	100%	100%	90%	100%	100%
9.2	100%	100%	100%	100%	90%	90%	100%	100%

Table 2: EPA Nutrient Results Table and Corresponding Value Based Upon Commercial Fertilizer Prices

Experiment	Material	% H2O	N lbs/ton	P lbs/ton	K lbs/ton	Ca lbs/ton	C lbs/ton
Pre-Trial	Raw Litter	26%	65.30	66.70	61.32	44.60	555.00
Pre-Trial	Biosolid	82%	26.70	151.80	24.24	25.70	141.90
A	DWBS-PL 2:1	46%	56.40	77.97	64.44	50.10	397.10
B	DWBS-PL 3:1	40%	59.30	88.32	68.40	55.90	444.50
C	DWBS-PL 4:1	32%	66.10	62.79	62.76	44.20	488.10
D	PL & H2O	40%	60.60	63.94	66.12	42.80	455.30

		N $/ton	P $/ton	K $/ton	Ca $/ton	Total Value N-P-K $/ton	Total Value N-P-K-CA $/ton
Pre-Trial	Raw Litter	24.84	20.01	12.88	0.45	57.73	58.18
Pre-Trial	Biosolid	10.16	45.54	5.09	0.26	60.79	61.05
A	DWBS-PL 2:1	21.46	23.39	13.53	0.50	58.38	58.88
B	DWBS-PL 3:1	22.56	26.50	14.36	0.56	63.42	63.98
C	DWBS-PL 4:1	25.15	18.84	13.18	0.44	57.17	57.61
D	PL & Water	23.05	19.18	13.89	0.43	56.12	56.55

N=Nitrogen, P=Phohsphorus, K=Potassium, Ca=Calcium, C=Carbon
DWBS=Dewatered Municipal Biosolids (DMB), PL=Poultry Litter

Part II: Economic Assessment Results

Introduction

The current work expands on the model developed for the transport of poultry litter in loose or baled form out of the northwest Arkansas region to be used in the fertilization of crops in eastern Arkansas. That study was implemented in the previously MBTC funded research entitled "Developing a Viable Poultry Litter Transport Option for the Ozark Region." The description of that model is reported in Carreira et al.

Background

Appendix I contains figures relevant to the background of the problem. Figures I.1 and I.2 illustrate the logistic infrastructure in Arkansas for the transport of materials from northwest Arkansas to eastern Arkansas. Figure I.1 provides a detail of main U.S. interstate highways and state highways serving the state. Figure I.2 overlaps information on county borders, cities, U.S. interstate highways, and navigable rivers. Shipping materials via waterways can be accomplished through the Arkansas River, a small portion of the White River in Eastern Arkansas, and the Mississippi River along the border of Arkansas and Mississippi.

If shipping by truck only, the departure cities considered in northwest Arkansas are Siloam Springs (Benton County, Illinois River Watershed (IRW)), Prairie-Grove (Washington County, IRW), and Decatur (Benton County, Eucha-Spavinaw Watershed). If transportation is done by truck and barge, the materials will be transported from those cities to the Port of Catoosa on the outskirts of Tulsa, Oklahoma or the Port of Fort Smith. Arrival ports in eastern Arkansas are Little Rock, Pine Bluff, Pendleton, and Hickman. The final destination counties in eastern Arkansas are Lonoke, Arkansas, Monroe, Jackson, Poinsett, and Mississippi.

Figure I.3 illustrates the distribution of poultry production in Arkansas. Benton and Washington counties are the most prolific broiler producers but other production is available throughout the western part of the state. So it is possible that northwest Arkansas litter and biosolids will be competing with materials from other regions. Figures I.4 and I.5 illustrate areas in Arkansas with excess nutrients compared to crop needs based on 1997 data as reported in 2002 by ERS-USDA (Daberkow and Huang). Current excess nutrient levels are most likely different.

Figures I.6 to I.11 illustrate crop production acreage (corn, soybean, rice, wheat, cotton, sorghum) in Arkansas by county as reported in the 2002 Census of Agriculture. As can be seen in these images, eastern Arkansas is the main crop growing region of the state and thus has the greatest potential to utilize the nutrients in poultry litter and biosolids. The comparative advantage of eastern Arkansas also holds compared to other broiler producing states (Alabama, Mississippi, Georgia and North Carolina) as discussed in Carreira, Smartt and Goodwin.

Objectives of the Model

A mathematical programming model was developed to assess the economic feasibility of using a combination of poultry litter and biosolids produced in northwest Arkansas to fertilize crops in eastern Arkansas. The goal of the model is to allocate the different nutrient sources such that crops in Eastern Arkansas are fertilized at a minimum cost.

Description of the Model, Objective Function and Constraints

The objective function of the model minimizes the cost of supplying nutrients to crops in eastern Arkansas. The nutrients can be supplied as commercial fertilizer (CF), poultry litter (PL), or a combination of litter and Dewatered municipal biosolids (PL-DMB). When using PL or PL-DMB, we assumed that the nutrients were applied to meet the phosphorus requirements of each crop; if additional nitrogen or potassium were needed, they would be met with CF.

The nutrient cost function accounts for the costs of using PL, DMB, and CF; depending on the material, these costs can refer to handling, processing, transport, application, and/or market price. In the optimization we evaluate the transport of PL in loose form and also after being plastic-wrapped into bales; when using PL-DMB, we assume the materials were always plastic-wrapped into bales. The transportation methods investigated were truck-only vs. a truck-barge combination. We assumed that when PL and/or DMB were used to fertilize crops in eastern Arkansas, the raw materials would be both produced and packaged in northwest Arkansas. Table II.1 (Appendix II) illustrates the different variables considered in the study.

Besides the non-negativity constraints, the model includes a baling constraint, a supply constraint and a market constraint. The baling constraint limits the amount of baled PL or PL-DMB such that it cannot exceed the annual baling capacity set at 100,000 tons. The supply constraint states that the amount of loose PL transported out of northwest Arkansas cannot exceed the amount of litter produced in the region (broiler and turkey) and estimated to be 107,400 tons for the Eucha-Spavinaw Watershed and 204,506 tons for the Illinois River Watershed. For simplicity, we assume that broiler and turkey litter are perfect substitutes in terms of nutrient content as the difference between the two is rather small. Finally, the market constraint ensures that PL, PL-DMB and CF are allocated in combinations that meet the nutrient requirement of the crops in eastern Arkansas.

Parameters

In Appendix II, Table II.2 contains the parameters pertaining to the storage and handling costs of baled PL and PL-DMB. Table II.3 contains the parameters pertaining to the storage and handling costs of loose (also referred to as raw or unbaled) PL, and Table II.4 contains the parameters pertaining to the cost of transporting the materials either in loose or baled form. The cost parameters also take into account the $8/ton subsidy available to transport poultry litter out of the excess nutrient region in the northwest Arkansas area and the $15/ton tipping fee for biosolids. Both of these are negative costs, indicating that they reduce the actual cost of using the materials in the fertilization of eastern Arkansas crops.

Distances used to compute the transportation costs by truck are shown in Tables III.5-8. Table III.9 contains the acreage by crop available to apply PL and PL-DMB. Table III.10 contains the parameters used for crop production by watershed. Crop nutrient requirements in terms of nitrogen, phosphate and potash appear in Table II.11, with specific nutrient availability in PL and PL-DMB being in Table II.12. We did not account for losses of N with loose PL because we assumed that under continuous used of PL, all nutrients eventually become available to plants. Thus, we assumed that loose PL had been used for at least three years so that on the fourth year the crops would be utilizing N in poultry litter from past years while the N applied that year that would not be available that same year, would become available in subsequent years, assuming adequate management. Tables III.13-14 contain parameters pertaining to CF: costs of nutrient content and application.

Sensitivity Analysis Scenarios

In addition to the benchmark model, four different scenarios were evaluated to see how sensitive the benchmark model solution is to changes in assumptions. The sensitivity analysis scenarios considered were: (i) no availability of backhauls, (ii) no baling, (iii) no application of PL and DMB to rice, and (iv) no baling and no application of PL and DMB to rice. The first scenario implies that the trucking rate for baled materials is not as favorable (the rate with backhauls was $2/loaded mile), that is, it is the same as when loose PL is transported ($3.35/loaded mile for distances up to 150 miles or $2.70/loaded mile for greater distances). The second scenario assumes that there is no baler, which means that only loose poultry litter can be transported to eastern Arkansas. The third scenario assumes that rice is not one of the crops onto which PL or PL-DMB can be applied. Earlier University of Arkansas research has suggested that because rice is flooded, poultry litter applications yield the best results at the stage when the soil is being prepared before flooding occurs (Slaton et al.). The fourth scenario is a combination of scenarios (ii) no baling and (iii) no rice.

Results

The results of the analysis are reported in Appendix III. The use of PL and/or PL-DMB was economically feasible in all scenarios considered.

Benchmark Model Solution

Tables III.1.a-c show the solution for the benchmark model. The most cost efficient way to provide nutrients to crops would be to use baled PL-DMB shipped by truck and barge to fertilize rice in Arkansas and Jackson counties (131,920 acres), loose PL shipped by truck to fertilize rice in Lonoke, Monroe, Arkansas, and Poinsett (234,862 acres), and provide remaining crop nutrients with CF. The details of the allocation are reported in Tables III.1.a-c.

The litter supply constraint (Table III.6) is binding indicating that an additional ton of PL applied to rice would yield savings over using CF. These savings would be $1.19/ton for litter produced in ESW and $5.48/ton for litter produced in IRW. The difference in cost between the two watersheds is due to differences in distance—Decatur (ESW) is usually the farthest city from the markets (see Tables II.6-7). Although there are two source locations in IRW, there is only one in the ESW.

The baling constraint is binding, which indicates that if one more ton of PL-DMB could have been baled and used to fertilize rice, the cost of supplying nutrients would have been reduced by $9 (Table III.7) compared to using CF. These savings are due to differences in truck rates because of backhaul opportunities and to storage cost savings.

The DMB constraint (Table III.8) is also binding indicating that using an additional ton of DMB would decrease the cost of fertilizing rice by almost $41. This amount can be broken into several components. First, each additional ton of DMB yields a tipping fee of $15, which lowers the cost of the PL-DMB mix[6]. Second, because PL-DMB has a higher nutrient content overall, less PL-DMB would be applied and the remaining nutrients would be met with CF. Because most of the costs of PL-DMB are on a per-ton basis, using less proportionately decreases costs. CF costs have two components, which are in different units: the actual cost of the fertilizer ($/ton) and the application rate ($/acre). On one hand, increasing the amount of fertilizer used increases the actual cost of fertilizer paid but does not affect the application rate unless an additional application at a different time is needed. On the other hand, using PL or PL-DMB as a start-up fertilizer eliminates one or more applications of CF compared to using only

[6] According to Springdale Water Utilities management, the current tipping fee for land filling DMB is $20 per ton.

CF, thus reducing the overall application cost of CF. The application costs of CF to rice are quite high. UA budgets recommend four applications per growing season, which amount to over $21/acre. To reflect this issue, we assume that if PL or PL-DMB is used, the application events of fertilizer are reduced by half[7], that is, the remaining nutrients are applied with two CF applications instead of the four used when only CF is used (see Table II.14).

Sensitivity Analysis

1. Scenario with No Backhauls

In the first sensitivity analysis scenario, we dropped the assumption that backhauls would be available to transport baled litter. The results for this scenario are in Tables III.2.a-c. If no backhauls are available, the optimal solution is comprised of the following PL transport activities: in loose form via truck to be applied to rice in Lonoke, Monroe, and Poinsett counties; in bales to be applied to rice in Arkansas County; and mixed and baled with DMB to be applied rice in Arkansas and Monroe counties. The savings per acre of this strategy would vary between nearly $5 and $12 compared to using CF. Nearly 367,000 acres would be fertilized with the combination of PL and PL-DMB.

The litter supply constraint was binding indicating that if more litter had been available, more savings could have been achieved by using PL. The amount of potential savings is the same as in the benchmark model: $1.19/ton for PL shipped from ESW and $5.48/ton for litter shipped from IRW. The baling capacity constraint is also binding indicating that shipping baled PL would have been more cost-efficient than loose PL. The biosolids constraint is also binding indicating that shipping baled PL-DMB is preferable to baled PL.

[7] Note that according the UA extension budgets, not all CF applications to rice are priced the same.

2. Scenario with No Baling

In the second sensitivity analysis scenario, we dropped the assumption that PL could be baled, and thus DMB could not be transported. The results for this scenario are in Tables III.3.a-b. If PL cannot be baled, the optimal solution is to transport PL is in loose form via truck to be applied to rice in Lonoke, Monroe, Arkansas, and Poinsett counties. The savings per acre of this strategy would vary between nearly $4 and $12 compared to using CF. Almost 346,000 acres would be fertilized with loose PL.

The litter supply constraint was binding indicating that if more litter had been available, more savings could have been achieved by using PL. The amount of potential savings is the same as in the benchmark model: $1.19/ton for PL shipped from ESW and $5.48/ton for litter shipped from IRW compared to using CF.

3. Scenario with No Rice

In the third sensitivity analysis scenario, we dropped the assumption that rice could be fertilized with PL and or PL-DMB. The results for this scenario are in Tables III.4.a-c. If PL cannot be applied to rice, the solution is comprised of the following activities for litter transport: in loose form via truck to be applied to corn, wheat, cotton, and sorghum in Lonoke County; in bales transported by truck to be applied to sorghum in Lonoke County; in bales transported by truck and barge to be applied to corn and sorghum in Arkansas and Monroe counties; mixed and baled with DMB transported by truck to be applied to wheat in Lonoke county; and mixed and baled with DMB transported by truck and barge to be applied to wheat in Arkansas and Monroe counties. The savings per acre of this strategy would vary between $3 and $9 compared to using CF. Over 190,300 acres would be fertilized with the combination of PL and PL-DMB.

The litter supply constraint was not binding indicating that not all the litter was shipped out of northwest Arkansas: only 112,396 tons were economically feasible to be exported. The baling capacity constraint is binding indicating that shipping baled PL would have been more cost-efficient than loose PL and the savings could amount to almost $5/ton. However, the biosolids constraint was binding, indicating that shipping baled PL-DMB is preferable to baled PL with a savings of up to nearly $42/ton compared to using CF.

4. Scenario with No Baling & No Rice

In the third sensitivity analysis scenario, we dropped two assumptions: that rice could be fertilized with PL and or PL-DMB and that PL and PL-DMB could be baled. The results for this scenario are in Tables III.5.a-b. If PL cannot be applied to rice, the optimal way to transport PL is in loose form via truck to be applied to corn, wheat, cotton, and sorghum in Lonoke and Arkansas counties. The savings per acre of this strategy compared to using CF would vary between almost break-even with CF (that is $0.38/acre) and $4.56. Almost 64,000 acres would be fertilized with loose PL.

The litter supply constraint was not binding as only 51,427 tons were economically feasible to be exported.

Conclusions

The results of the present analysis indicate that under the right circumstances, export of PL and a combination of PL-DMB is an economically feasible venture. However in some cases, the savings may be so minute that using PL or PL-DMB almost breaks even with using CF, which may explain why farmers in eastern AR have not been more receptive to the use of PL.

The transport of PL also depends on current fuel prices, thus any fluctuation in truck or barge rates can be critical. This case in point was made when we tested the assumption of backhauls, which meant changing the truck shipping rates, which made an additional ton of PL almost break even with CF (see description of litter supply constraint).

The combination of PL and DMB seems to have greater advantages than to just use PL because one would be taking advantage of the DMB tipping fee and we would be able save money by exploiting the fact that part of the cost of using CF is on a per-acre basis and not a per-ton basis. Thus although we would apply less PL-DMB and more CF, we would still pay the same amount of application fees for CF.

In terms of crop allocation, rice is the crop where using PL and PL-DMB can yield the greatest savings compared to CF. By taking advantage of the fact that nitrogen in PL and PL-DMB is released slower to the crops, we could save on application fees, which are a big component of the cost of fertilizing rice. But even if rice is not available as a market for the nutrients in PL and PL-DMB, smaller savings compared to using CF could be obtained if litter would be applied to corn, wheat, cotton, and sorghum.

In all of the scenarios considered, we found that part or all of the nutrients from PL and PL-DMB could be economically utilized in a few number of eastern Arkansas counties. The practice of using PL and PL-DMB according to the crops nutrient needs is environmentally and financially sound. Thus we conclude that it would be in the best interest of farmers and the public to take a closer look at PL and PL-DMB as an alternative to CF. Policy makers should ensure that the market contains enough incentives for the practice to be established in the long run. The results could aid the poultry industry in northwest Arkansas, poultry growers, public, and eastern Arkansas farmers.

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Appendix I:

Figures

Figure I.1. State of Arkansas (Source: Google Maps)

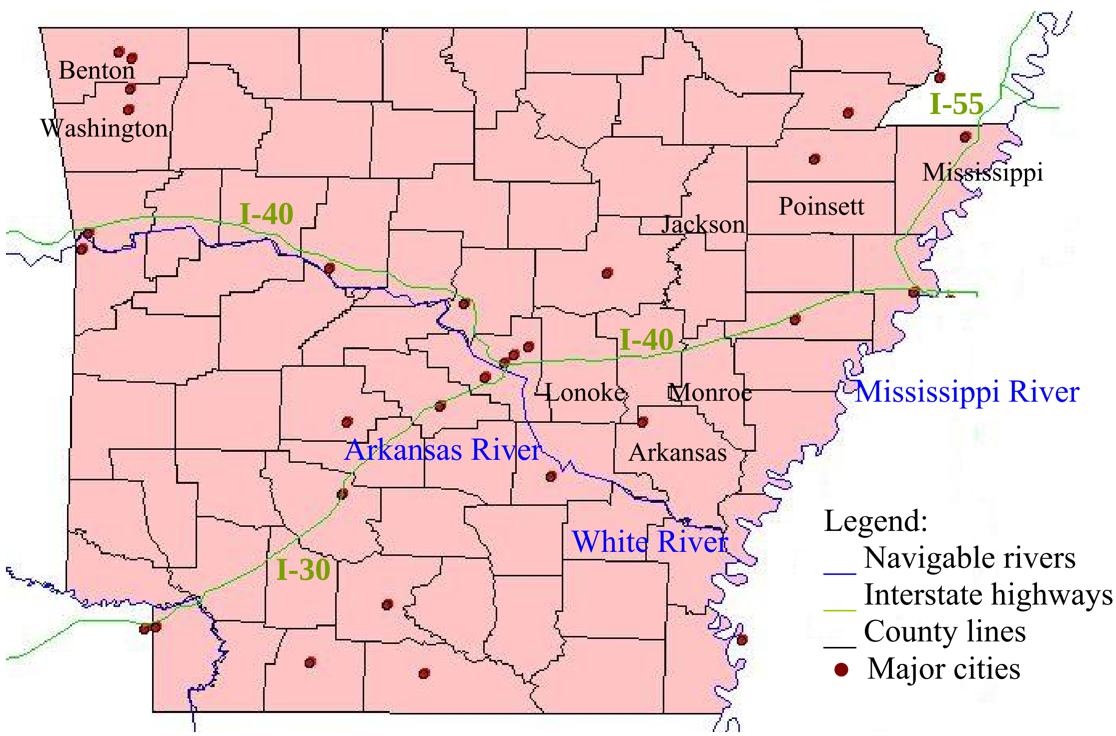

Figure I.2. Arkansas Infrastructure

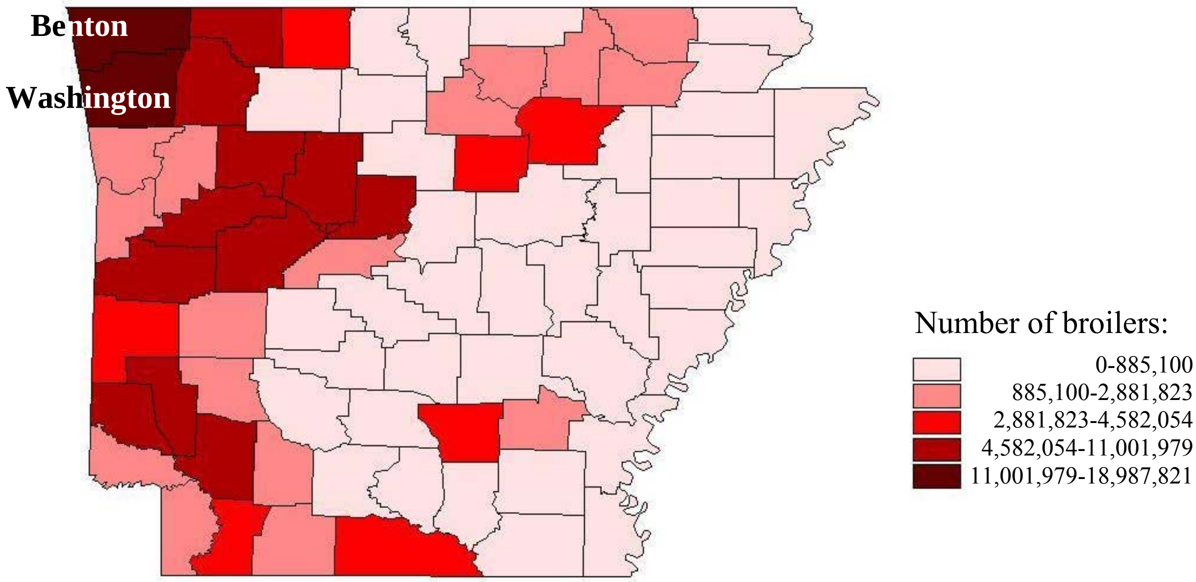

Figure I.3. Number of broilers in Arkansas by county (Source: 2002 US Census of Agriculture)

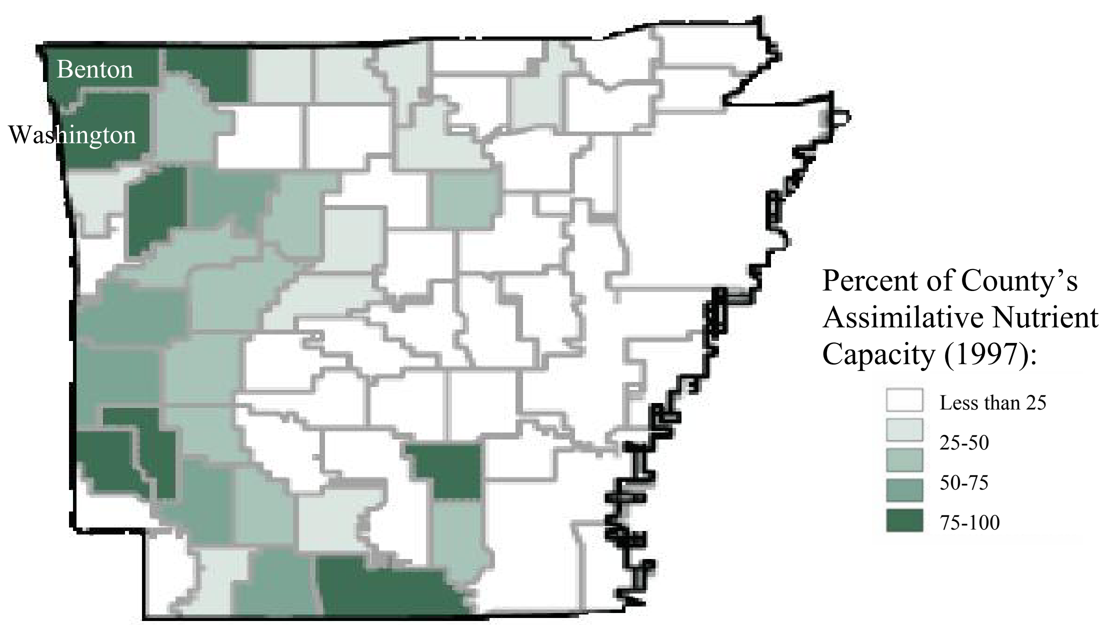

Figure I.4. Manure excess nitrogen in Arkansas by county, some counties are combined to meet disclosure criteria (Source: Daberkow and Huang, 2002)

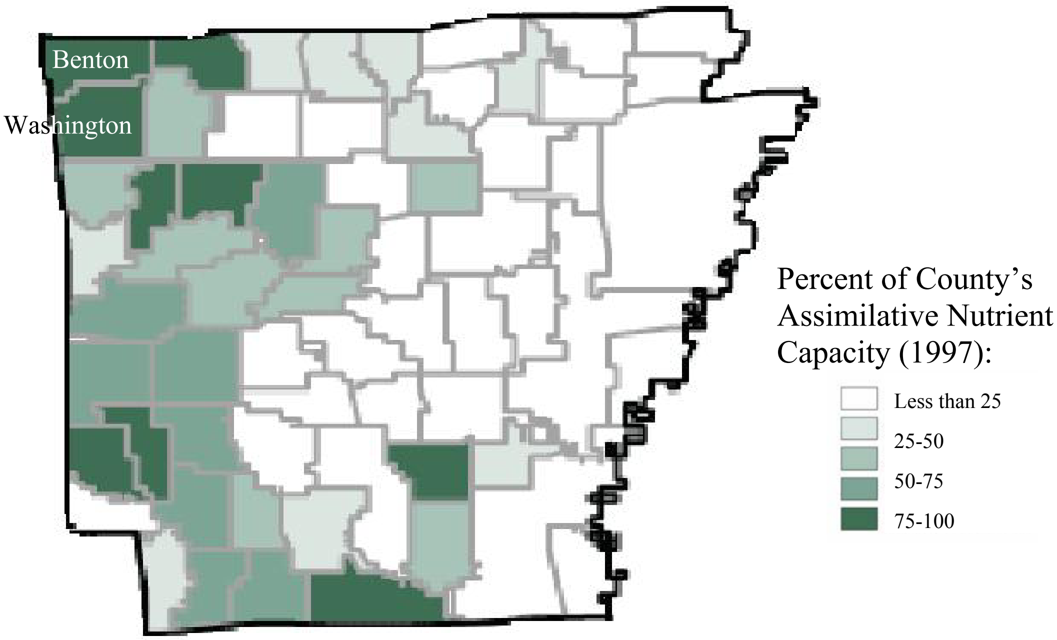

Figure I.5. Manure excess phosphorus in Arkansas by county, some counties are combined to meet disclosure criteria (Source: Daberkow and Huang, 2002)

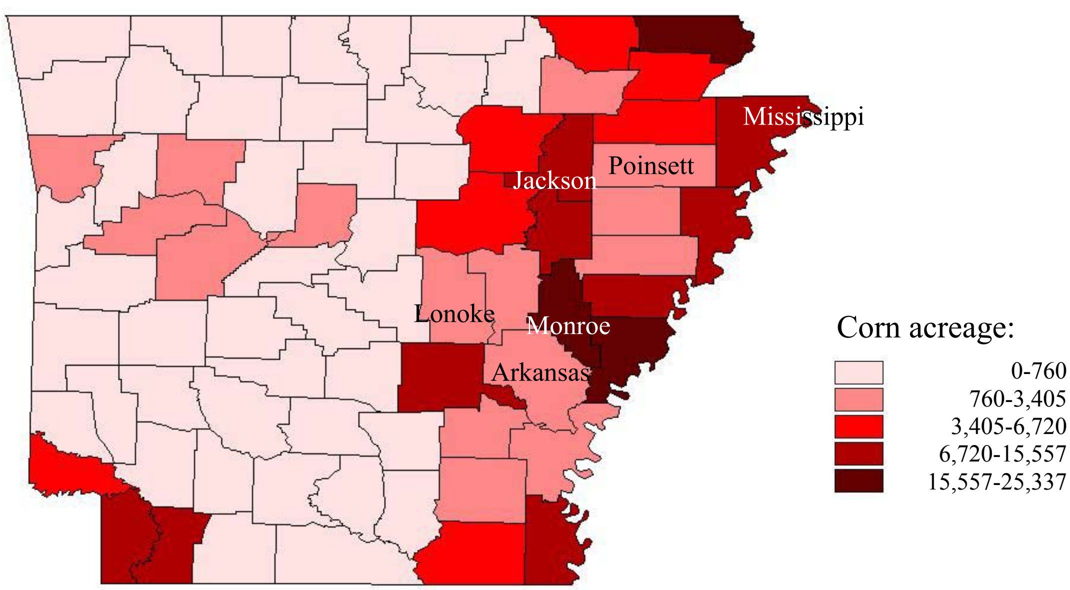

Figure I.6. Corn acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

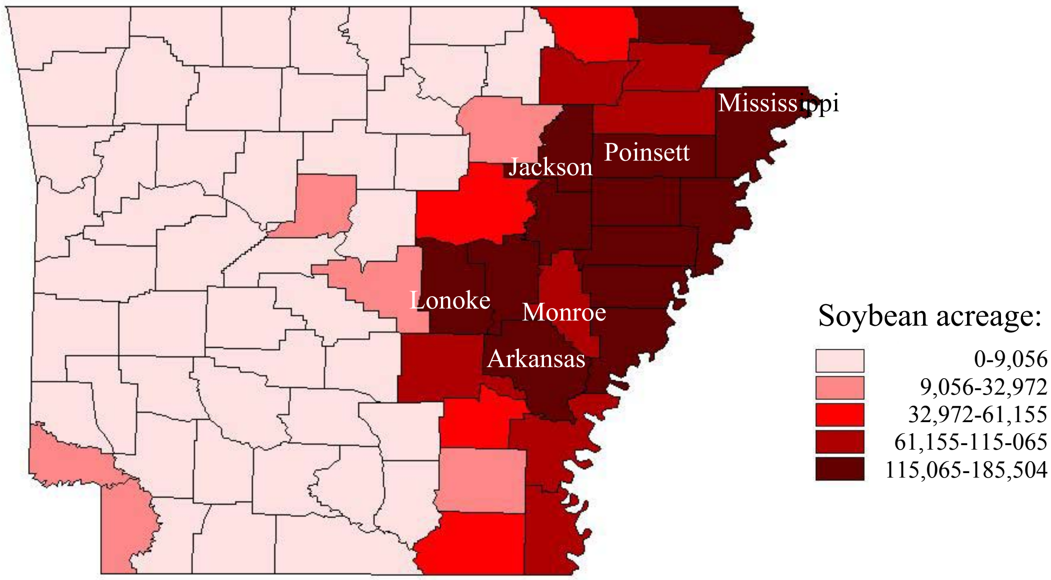

Figure I.7. Soybean acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

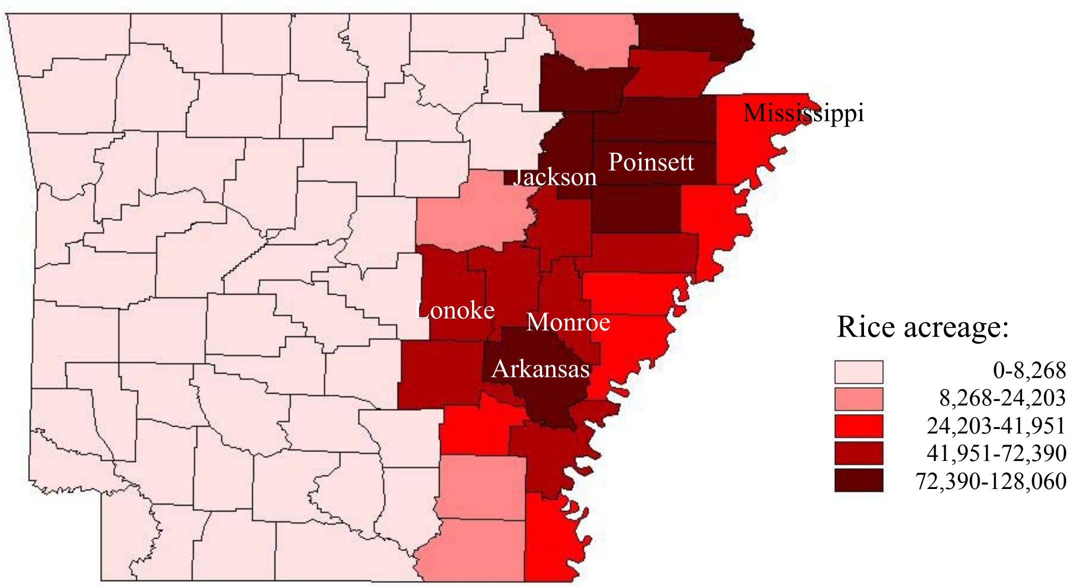

Figure I.8. Rice acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

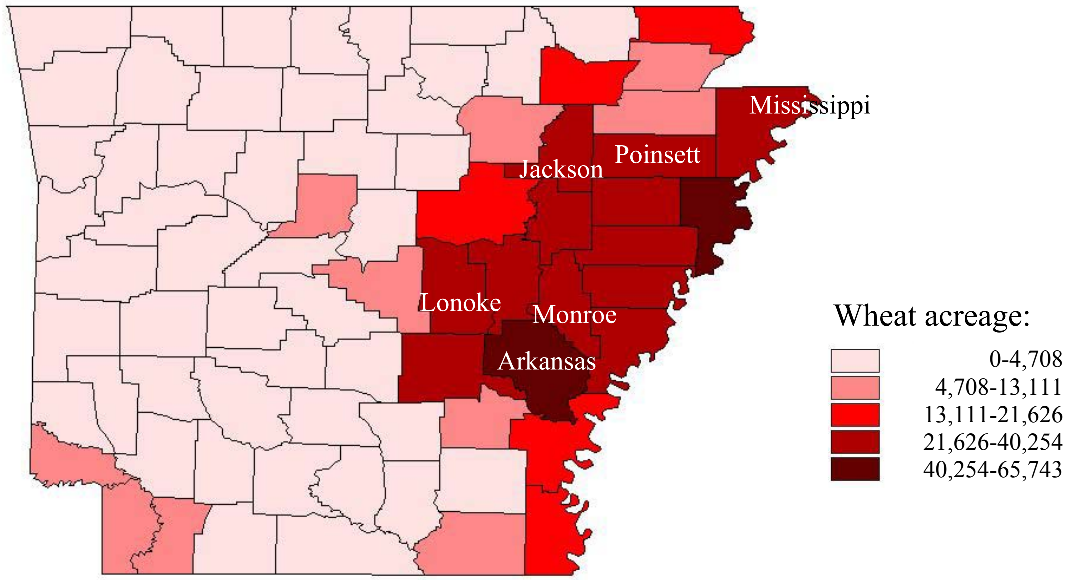

Figure I.9. Wheat acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

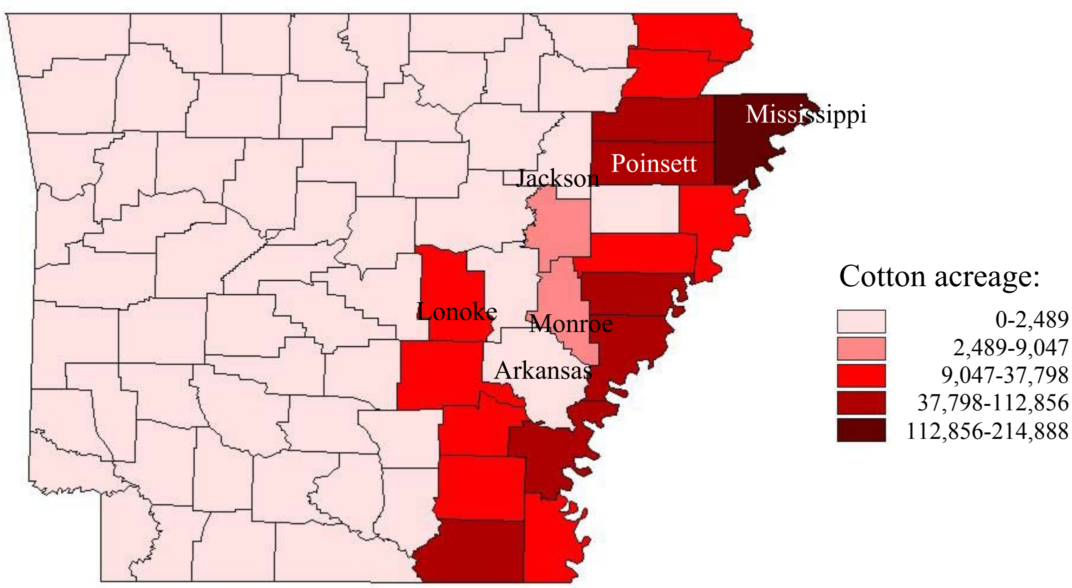

Figure I.10. Cotton acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

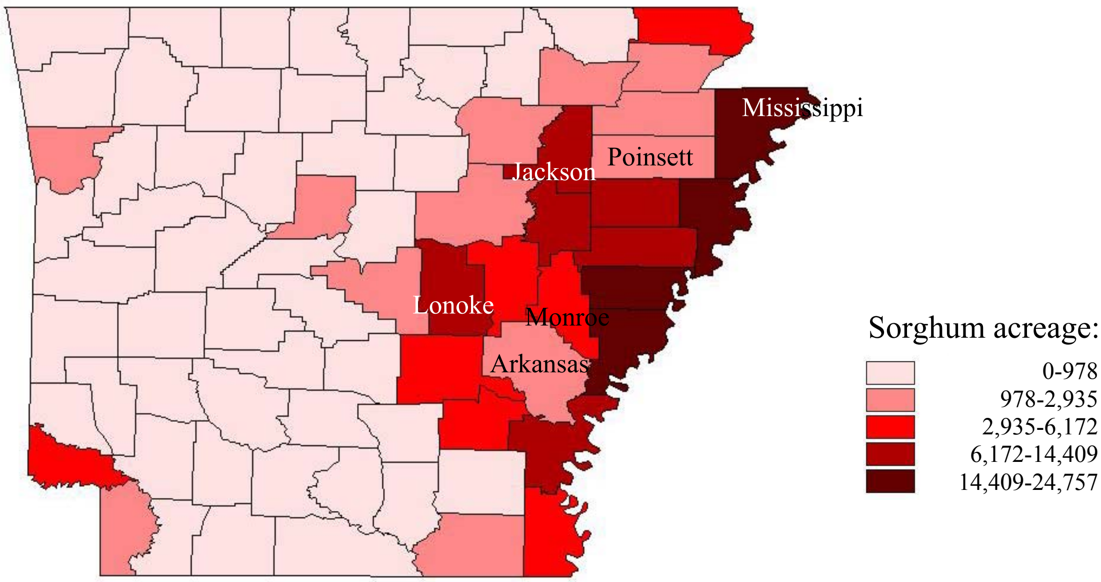

Figure I.11. Sorghum acreage in Arkansas by county (Source: 2002 US Census of Agriculture)

Appendix II:

Model Parameters

Table II.1. Variable Assumptions Investigated

Variable	Variable Values/Alternatives Investigated
Watersheds	Eucha-Spavinaw Watershed (ESW)
	Illinois River Watershed (IRW)
Poultry Production Types	Turkey, Broiler
Possible Town Sources	Siloam Springs (Benton county, IRW), Prairie-Grove (Washington county, IRW), Decatur (Benton county, ESW)
Possible County Markets	Lonoke, Arkansas, Monroe, Jackson, Poinsett, and Mississippi
Types of Litter Processing	Raw litter, baled litter, baled litter and biosolids
Transport Methods	Truck only, truck and barge combination
Outgoing Ports for Barges	Catoosa, Fort Smith
Incoming Ports for Barges	Little Rock, Pine Bluff, Pendleton, Hickman
Types of Nutrients	Nitrogen, Phosphorus, Potassium
Types of Crops	Corn, Soybean, Rice, Wheat, Cotton, Sorghum
Type of Land	Non-cut land

Table II.2. Summary of Cost Data Parameters of Utilizing Poultry Litter and Biosolids in Bales

Item	Unit	Value	Item	Unit	Value
Capital Costs			*Operating Costs*		
Litter baler	$/ton	1.33	Hauling litter to baler site	$/ton	9.00
Conveyor	$/ton	0.09	Loading litter to baler	$/ton	2.00
Bobcat	$/ton	0.13	Utility costs	$/ton	0.15
Trailer	$/ton	0.03	Baling labor	$/ton	0.40
Truck for trailer	$/ton	0.08	Plastic cost	$/ton	2.81
Front loader	$/ton	0.06	Equipment maintenance	$/ton	0.15
Generator	$/ton	0.11	Equipment operation	$/ton	0.45
Fork lift	$/ton	0.05	Record keeping	$/ton	0.20
Site Costs if Developed			Supervision	$/ton	0.50
Baler building	$/ton	0.28	Field foreman	$/ton	0.24
Office	$/ton	0.02	*Other Costs*		
Scales	$/ton	0.04	Obtaining litter from farm	$/ton	7.00
Land	$/ton	0.18	Load bales	$/ton	2.00
Infrastructure	$/ton	0.12	Unload bales from truck	$/ton	2.00
Litter and Biosolids Blend Parameters			Unload baled litter to spreader	$/ton	3.00
Building to store biosolids	$/ton	0.04	Land apply litter	$/ton	7.00
Conveyor	$/ton	0.04	*Litter Transport Subsidy*		
Weigh and load	$/ton	2.00	Subsidy	$/ton	8.00
Blender	$/ton	0.20	*Biosolids Tipping Fee*		
Blending labor	$/ton	0.40	Fee	$/ton	15.00
Utility & overhead	$/ton	0.75			

Sources: Litter baling costs obtained from Mammoth, Inc. Equipment costs obtained from University of Arkansas Extension budgets and from local dealers: Eagle Body, Inc. (Springdale, AR); Williams Tractor, Inc. (Fayetteville, AR), and Landers Toyota North (Fayetteville, AR). Land costs obtained from NWARMLS Board of REALTORS® Broker Reciprocity Real Estate Search engine (http://www.qtimls.com/nwarmls/) and from Tom Skipper, a local real estate agent (http://www.tomskipper.com).

Table II.3. Summary of Cost Data Parameters of Utilizing Poultry Litter Unbaled (Loose or Raw)

Item	Unit	Value	Item	Unit	Value
Capital Costs			*Operating Costs*		
Conveyor	$/ton	0.09	Record keeping	$/ton	0.20
Bobcat	$/ton	0.13	Supervision	$/ton	0.50
Trailer	$/ton	0.03	Field foreman	$/ton	0.24
Truck for trailer	$/ton	0.08	*Other Costs*		
Site costs			Obtaining litter from farm	$/ton	7.00
Office	$/ton	0.02	Load litter in truck	$/ton	2.00
Scales	$/ton	0.04	Unload litter from truck	$/ton	2.00
Land	$/ton	0.18	Cleaning fee for trucks	$/ton	2.00
Infrastructure	$/ton	0.12	Storage in hoop building	$/ton	3.00
Litter Transport Subsidy			Unload litter to spreader	$/ton	2.00
Subsidy	$/ton	8.00	Application	$/ton	7.00
			Disking	$/ton	6.00

Sources: Equipment costs obtained from University of Arkansas Extension budgets and from local dealers: Eagle Body, Inc. (Springdale, AR); Williams Tractor, Inc. (Fayetteville, AR), and Landers Toyota North (Fayetteville, AR). Land costs obtained from NWARMLS Board of REALTORS® Broker Reciprocity Real Estate Search engine (http://www.qtimls.com/nwarmls/) and from Tom Skipper, a local real estate agent (http://www.tomskipper.com).

Table II.4. Transport Parameters for Barge and Trucks

Transport	Unit	Value
Barge transport costs:		
Barge capacity	ton	1,500
From Catoosa to Little Rock	$/ton	8.07
From Catoosa to Pine Bluff	$/ton	9.04
From Catoosa to Pendleton	$/ton	9.44
From Catoosa to Hickman	$/ton	16.37
From Fort Smith to Little Rock	$/ton	8.50
From Fort Smith to Pine Bluff	$/ton	9.34
From Fort Smith to Pendleton	$/ton	9.74
From Fort Smith to Hickman	$/ton	16.97
Truck transport costs:		
Large truck capacity	ton	23.50
Baled PL or PL-DMB with backhaul	$/loaded mile	2.00
Loose litter (up to 150 miles)	$/loaded mile	3.35
Loose litter (more than 150 miles)	$/loaded mile	2.70

Sources: Barge rates are averages of quotes provided by D. Choate, W. Schmidt, and J. Weber. Trucking costs are averages of quotes provided by M. Traylor and L. Mitchell.

Notes: Barge rates already include a $500 allowance for cleanup costs.

Table II.5. Average Distance from Poultry Farms to Town Source for Each Watershed (Miles)

Watershed\Sources	Siloam Springs	Prairie Grove	Decatur
ESW	14.73	30.97	5.92
IRW	14.91	13.79	20.25

Table II.6. Average Distance from Town Source to County Market Seat (Miles)

Sources\Markets	Lonoke	Arkansas	Monroe	Jackson	Poinsett	Mississippi
Siloam Springs	236.30	276.59	280.73	330.67	301.52	396.23
Prairie Grove	208.05	248.35	252.49	302.42	273.27	367.98
Decatur	245.48	285.77	289.91	339.84	310.7	405.41

Table II.7. Average Distance from Town Source to Ports of Origin (Miles)

Sources\Ports	Port of Catoosa (OK)	Port of Fort Smith (AR)
Siloam Springs	76.93	68.53
Prairie Grove	103.83	58.42
Decatur	90.67	81.29

Table II.8. Average Distance from Ports of Arrival to Markets (Miles)

Ports\Markets	Lonoke	Arkansas	Monroe	Jackson	Poinsett	Mississippi
Little Rock	22.53	46.89	66.97	87.97	114.20	182.47
Pine Bluff	67.73	37.23	57.15	131.92	158.14	227.66
Pendleton	93.92	49.89	69.06	179.06	156.57	216.48
Hickman	174.31	177.46	149.3	140.8	85.61	8.00

Table II.9. Acreage Available for PL and PL-DMB Application by Crop

Market\Crop	Corn	Soybean	Rice	Wheat	Cotton	Sorghum
Lonoke	1,788	123,993	70,693	29,614	21,416	7,260
Arkansas	1,364	185,504	118,452	65,031	0	2,466
Monroe	25,337	92,249	57,527	31,007	9,047	5,037
Jackson	10,307	150,974	88,436	37,908	1,187	7,207
Poinsett	3,099	150,157	128,060	27,506	54,902	2,935
Mississippi	10,804	150,935	41,951	34,974	214,888	18,807

Source: U.S. Census of Agriculture, 2002

Table II.10. Poultry Production in Benton and Washington Counties (Tons)

Watershed	Broiler	Turkey	Total
Eucha-Spavinaw(ESW)	94,132	13,268	107,400
Illinois River IRW	164,696	39,810	204,506

Source: Goodwin, 2004

Table II.11. Crop Nutrient Requirements for Eastern Arkansas (Lbs/Acre; Source)

Crop\Nutrient	N	P_2O_5	K_2O
Corn	219.8	60	90
Soybean	0	36	72
Rice	153.18	60	90
Wheat	101.20	46	0
Cotton	99.84	60	120
Sorghum	209.96	60	90

Source: UA-CES, 2006

Table II.12. Nutrient Content by Material (Lbs/Ton)

Nutrient\Material	Loose PL	Baled PL	Baled PL-DMB
Nitrogen: N	65.3	60.6	59.3
Phosphate: P_2O_5	66.5	63.6	87.9
Potash: K_2O	61.6	66.4	62.4

Table II.13. Nutrient Content and Cost of Commercial Fertilizer

Nutrient	Content (Lbs/Ton)	Cost ($/Ton)
Nitrogen: N	920	352.46
Phosphate: P_2O_5	920	282.80
Potash: K_2O	1200	250.00

Source: UA-CES, 2006

Table II.14. Commercial Fertilizer Application costs ($/Acre)

Crop	As a PL/PL-DMB Supplement	CF only
Corn	4.75	9.50
Soybean	4.75	4.75
Rice	9.50	21.40
Wheat	4.00	15.00
Cotton	2.75	6.00
Sorghum	4.75	9.50

Source: UA-CES, 2006

Appendix III:

Model Results

Table III.1.a. Cost of Fertilizing Selected Acreage for the Benchmark Model

		PL & DMB Cost		PL, DMB & CF Cost		Only CF	Savings
Market	Crop	Total ($)	$/acre	Total ($)	$/acre	$/acre	$/acre
Lonoke	Rice	3,731,545	52.79	7,462,999	105.57	117.28	11.71
Arkansas	Rice	6,523,472	55.07	12,797,246	108.04	117.28	9.24
Monroe	Rice	3,301,591	57.39	6,338,091	110.18	117.28	7.10
Jackson	Rice	3,560,687	40.26	9,092,666	102.82	117.28	14.46
Poinsett	Rice	1,886,093	59.55	3,557,999	112.33	117.28	4.95

Table III.1.b. Amount of Litter and Biosolids Transported by Truck for the Benchmark Model

Town Source	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL Tons	DMB Tons
Prairie Grove	Lonoke	PLRaw	Rice	70,693	63,783	0
Prairie Grove	Arkansas	PLRaw	Rice	66,766	60,240	0
Prairie Grove	Monroe	PLRaw	Rice	57,527	51,904	0
Prairie Grove	Poinsett	PLRaw	Rice	31,674	28,578	0
Decatur	Arkansas	PLRaw	Rice	8,202	7,400	0
Total				234,862	211,906	0

Table III.1.c. Amount of Litter and Biosolids Transported by Truck and Truck Barge Combination for the Benchmark Model

Town Source	Out Port	In Port	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL & DMB Tons	DMB Tons
Decatur	Fort Smith	Little Rock	Arkansas	PLBale	Rice	38,160	36,000	0
Decatur	Fort Smith	Little Rock	Arkansas	MixBale	Rice	5,324	3,634	909
Decatur	Fort Smith	Little Rock	Jackson	MixBale	Rice	88,436	60,366	15,091
Total						131,920	100,000	16,000

Table III.2.a. Cost of Fertilizing Selected Acreage for the Model with No Backhauls

		PL & DMB Cost		PL, DMB & CF Cost		Only CF	Savings
Market	Crop	Total ($)	$/acre	Total ($)	$/acre	$/acre	$/acre
Lonoke	Rice	3,731,545	52.79	746,299	105.57	117.28	11.71
Arkansas	Rice	5,738,880	48.45	12,745,057	107.60	117.28	9.68
Monroe	Rice	3,167,555	55.06	6,335,632	110.13	117.28	7.15
Poinsett	Rice	7,152,116	59.55	13,492,018	112.33	117.28	4.95

Table III.2.b. Amount of Litter and Biosolids Transported by Truck for the Model with No Backhauls

Town Source	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL Tons	DMB Tons
Prairie Grove	Lonoke	PLRaw	Rice	70,693	63,783	0
Prairie Grove	Monroe	PLRaw	Rice	35,857	32,352	0
Prairie Grove	Poinsett	PLRaw	Rice	120,110	108,370	0
Decatur	Monroe	PLRaw	Rice	8,202	7,400	0
Total				234,862	211,905	0

Table III.2.c. Amount of Litter and Biosolids Transported by Truck and Truck Barge Combination for the Model with No Backhauls

Town Source	Out Port	In Port	County Market	Type of Material	Crop Fertilized	Acres Fertilized	Biomaterials Tons	Biosolids Tons
Decatur	Fort Smith	Pine Bluff	Arkansas	PLBale	Rice	38,160	36,000	0
Decatur	Fort Smith	Pine Bluff	Arkansas	MixBale	Rice	80,292	54,807	13,702
Decatur	Fort Smith	Pine Bluff	Monroe	MixBale	Rice	13468	9193.17	2298.29
Total						131,920	100,000	16,000

Table III.3.a. Cost of Fertilizing Selected Acreage for the Model with No Baling

		PL & DMB Cost		PL, DMB & CF Cost		Only CF	Savings
Market	Crop	Total ($)	$/acre	Total ($)	$/acre	$/acre	$/acre
Lonoke	Rice	3,731,545	52.79	7,462,999	105.57	117.28	11.71
Arkansas	Rice	7,206,849	60.84	13,459,210	113.63	117.28	3.65
Monroe	Rice	3,303,852	57.43	6,340,353	110.22	117.28	7.06
Poinsett	Rice	5,896,487	59.55	11,123,351	112.33	117.28	4.95

Table III.3.b. Amount of Litter and Biosolids Transported by Truck for the Model with No Baling

Town Source	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL Tons	DMB Tons
Prairie Grove	Lonoke	PLRaw	Rice	70,693	63,783	0
Prairie Grove	Monroe	PLRaw	Rice	56,944	51,378	0
Prairie Grove	Poinsett	PLRaw	Rice	99,024	89,345	0
Decatur	Arkansas	PLRaw	Rice	118,452	106,874	0
Decatur	Monroe	PLRaw	Rice	583	526	0
Total				345,696	311,906	

Note: Under this scenario it is not optimal to transport litter using a combination of truck and barge.

Table III.4.a. Cost of Fertilizing Selected Acreage for the Model with No Rice

		PL & DMB Cost		PL, DMB & CF Cost		Only CF	Savings
Market	Crop	Total ($)	$/acre	Total ($)	$/acre	$/acre	$/acre
Lonoke	Corn	94,380	52.79	225,899	126.34	130.90	4.56
Lonoke	Wheat	847,434	28.62	1,743,784	58.88	67.91	9.03
Lonoke	Cotton	1,130,448	52.79	1,812,524	84.63	87.69	3.06
Lonoke	Sorghum	368,867	50.81	872,347	120.16	127.13	6.97
Arkansas	Corn	69,651	51.06	168,888	123.82	130.90	7.08
Arkansas	Wheat	1,831,176	28.16	3,839,437	59.04	67.91	8.87
Arkansas	Sorghum	125,922	51.06	296,039	120.05	127.13	7.08
Monroe	Corn	1,328,316	52.43	3,171,702	125.18	130.90	5.72
Monroe	Wheat	896,546	28.91	1,854,092	59.80	67.91	8.11
Monroe	Sorghum	264,069	52.43	611,547	121.41	127.13	5.72

Table III.4.b. Amount of Litter and Biosolids Transported by Truck for the Model with No Rice

Town Source	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL (Tons)	DMB (Tons)
Prairie Grove	Lonoke	PLRaw	Corn	1,788	1,613	0
Prairie Grove	Lonoke	PLRaw	Wheat	3,356	2,322	0
Prairie Grove	Lonoke	PLRaw	Cotton	21,416	19,323	0
Prairie Grove	Lonoke	PLRaw	Sorghum	3,304	2,981	0
Prairie Grove	Lonoke	PLBale	Sorghum	3,956	3,732	0
Prairie Grove	Lonoke	MixBale	Wheat	26,258	13,741	3,435
Total				60,078	43,712	3,435

Table III.4.c. Amount of Litter and Biosolids Transported by Truck and Truck Barge Combination for the Model with No Rice

Town Source	Out Port	In Port	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL & DMB Tons	DMB Tons
Prairie Grove	Fort Smith	Little Rock	Arkansas	PLBale	Corn	1,364	1,287	0
Prairie Grove	Fort Smith	Little Rock	Arkansas	PLBale	Sorghum	2,466	2,326	0
Prairie Grove	Fort Smith	Little Rock	Arkansas	MixBale	Wheat	65,031	34,032	8,508
Prairie Grove	Fort Smith	Little Rock	Monroe	PLBale	Corn	25,337	23,903	0
Prairie Grove	Fort Smith	Little Rock	Monroe	PLBale	Sorghum	5,037	4,752	0
Prairie Grove	Fort Smith	Little Rock	Monroe	MixBale	Wheat	31,007	16,227	4,057
Total						130,242	82,527	12,565

Table III.5.a. Cost of Fertilizing Selected Acreage for the Model with No Rice and No Baling

		PL & DMB Cost		PL, DMB & CF Cost		Only CF	Savings
Market	Crop	Total ($)	$/acre	Total ($)	$/acre	$/acre	$/acre
Lonoke	Corn	94,380	52.79	225,899	126.34	130.90	4.56
Lonoke	Wheat	1,198,439	40.47	1,952,578	65.93	67.91	1.98
Lonoke	Cotton	1,130,448	52.79	1,812,524	84.63	87.69	3.06
Lonoke	Sorghum	383,221	52.79	889,873	122.57	127.13	4.56
Arkansas	Corn	77,697	56.96	178,029	130.52	130.90	0.38
Arkansas	Sorghum	140,470	56.96	312,565	126.75	127.13	0.38

Table III.5.b. Amount of Litter and Biosolids Transported by Truck for the Model with No Rice and No Baling

Town Source	County Market	Type of Material	Crop Fertilized	Acres Fertilized	PL (Tons)	DMB (Tons)
Prairie Grove	Lonoke	PLRaw	Corn	1,788	1,613	0
Prairie Grove	Lonoke	PLRaw	Wheat	29,614	20,485	0
Prairie Grove	Lonoke	PLRaw	Cotton	21,416	19,323	0
Prairie Grove	Lonoke	PLRaw	Sorghum	7,260	6,550	0
Prairie Grove	Arkansas	PLRaw	Corn	1,364	1,231	0
Prairie Grove	Arkansas	PLRaw	Sorghum	2,466	2,225	0
Total				63,908	51,427	0

Note: Under this scenario it is not optimal to transport litter using a combination of truck and barge.

Table III.6. Sensitivity Analysis of Marginal Costs Associated with Litter Supply Constraint

Scenario	Supply Constraint Binding?	Eucha-Spavinaw Watershed	Illinois River Watershed
Benchmark Model	Yes	-1.185	-5.484
No Backhauls	Yes	-1.185	-5.484
No Baling	Yes	-1.185	-5.484
No Rice	No	--	--
No Baling & No Rice	No	--	--

Table III.7. Sensitivity Analysis of Marginal Costs Associated with Baling Capacity Constraint

Scenario	Baling Capacity Constraint Binding?	Loose Litter	Baled Litter	Baled Litter & Biosolids
Benchmark Model	Yes	--	--	-9.217
No Backhauls	No	--	--	-0.207
No Baling	N/A	N/A	N/A	N/A
No Rice	Yes	--	--	-4.696
No Baling & No Rice	N/A	N/A	N/A	N/A

Table III.8. Sensitivity Analysis of Marginal Costs Associated with Biosolids Supply Constraint

Scenario	Biosolids Constraint Binding?	Loose Litter	Baled Litter	Baled Litter & Biosolids
Benchmark Model	Yes	--	--	-40.926
No Backhauls	Yes	--	--	-38.341
No Baling	N/A	N/A	N/A	N/A
No Rice	Yes	--	--	-41.995
No Baling & No Rice	N/A	N/A	N/A	N/A