Creating Markets for Manure: Basin-wide Management in the Chesapeake Bay Region

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Selected Paper prepared for presentation at the joint Annual Meeting of the Northeast Agricultural and Resource Economics Association and the Canadian Agricultural Economics Society, Halifax, Nova Scotia, Canada, June 20 - 23, 2004

This research was partially supported by the Mid-Atlantic Water Quality Initiative, USDA CSREES Grant # 2002-51130-01522

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Historically, animal and crop production systems were often integrated on a single farm. The agricultural operation grew crops for sale and as feed, fed and grew animals, and spread animal manure on fields to fertilize the feed crop that would then be used to feed the animals on the farm. This integrated farming system recycled nutrients on the farm. Nutrients were exported off farm as crop and animal products, and losses occurred due to runoff, leaching, and atmospheric deposition. Larger animal operations sometimes supplemented crop feed production by importing additional feed products.

The Separation of Animal and Crop Production

With the introduction of cheap commercial fertilizers, farms were able to increase crop production by supplementing animal manure sources. As the cost of using commercial fertilizers relative to the cost of using animal manures as a crop input fell, the nutrient value of manure relative to its management and application costs became inconsequential. Thus, growers' assessment of animal manure began to shift from that as a crop fertilizer input to waste disposal.

Abandoning animal manure as a source of nutrients and switching to commercial fertilizer inputs to gain high crop yields allowed for the separation of animal production from feed production. Furthermore, the ensuing view that animal manures were a waste product that were not tied to crop production caused animal producers to look at feed as a separate input, growing animals independent of crop production.

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This separation of crop production from animal production allowed for specialization in each activity, leading to larger farms that could capitalize on economies of scale. In the animal production industry, this led to further concentration and integration. For crop producers, this has led to increased farm size and crop specialization.

Nutrient Management Planning

In the late 1980's, concerns over nonpoint nutrient pollution led university scientists to look for systems to reintegrate crop and animal systems. Focusing primarily on nitrogen, management systems were sought that would integrate the crop and animal systems into a whole farm concept which recycled on-farm nutrients while importing additional inputs (feed and/or fertilizer) to achieve on-farm nutrient balances. This process, known as nutrient management planning, could control nitrogen losses by crediting the nitrogen in animal manure against the crop's needs. Using this information, the nutrient management plan then derives imported nitrogen needs (usually met through commercial fertilizer inputs). More recently, reacting to concerns about phosphorus nonpoint source pollution, nutrient management planning has evolved to consider both nitrogen and phosphorus management. While "N-based nutrient management planning" generally refers to management of nitrogen only, "P-based nutrient management planning" refers to management of both nitrogen and phosphorus.

The nutrient management planning concept was initially introduced on those farms that still grew both crops and animals. In most cases, the fertilizer cost savings (realized through crediting the nitrogen, phosphorus and potassium already available in the animal manure) were greater than the additional management and animal manure handling costs. Thus, voluntary nutrient management programs gained acceptance primarily because they increased farm profits.

Nutrient management planning can successfully reduce commercial fertilizer inputs and nonpoint nutrient pollution, while increasing farm profits on those farms that have sufficient cropland to utilize the nutrients available in the animal manure generated on the farm. Through better management of inputs to production, nutrient management planning can even increase profits on farms that use only commercial fertilizer.

On farms that have more nutrients from their animal manure than their crops can use, nutrient management planning reveals an excess of animal manure. Since manure applications on most farms are unregulated, this excess manure is often applied to the crop fields, providing crops with more nutrients than they can use. This imbalance of nutrients is a major source of nonpoint nutrient water pollution. Requiring farms to follow nutrient management plans would force these farms to find alternative uses for their excess manure.

Regional Nutrient Balance

The on-farm nutrient imbalances created by the separation and concentration of crop and animal production systems suggest a need to move beyond the whole farm nutrient balance system to a regionalized nutrient balance system. Thus, instead of working with a single firm, the nutrient management planning system needs to be able to operate between firms, re-integrating the now separate crop and animal operations.

One method to integrate crop and animal producers is through market mechanisms. Manure marketing is not a new concept. For years manure has been transferred from animal production areas to crop land. A 1994 survey of poultry growers on the Delmarva Peninsula found that nearly two-thirds of poultry growers transferred at least a portion of their poultry litter off-farm (Michel, et. al., 1996). A more recent study in Tennessee found that 47% of poultry litter was exported off of the owners farming operation (Goan, et. al., 2002); while a University of Nebraska survey found that 36% of livestock owners export manure off-farm (Glewen and Koelsch, 2001).

Successful regional integration depends upon the farm economy of the local area, specifically the types of crops and animals being produced and the distances between these operations. The types of animals and the needs of the crops being grown determine the (nutrient) value of the manure. Transportation and transaction costs depend on the extent to which crop and animal operations are dispersed among each other.

Through the price of manure, markets can transmit information concerning the nutrient value of manure, supply and demand conditions, transportation costs, transaction costs, and manure application and management costs. A well-functioning market will integrate the local farm economy, leading to a better balance and cycling of nutrient inputs. This paper assesses the market potential and structural issues that are necessary for a successful market.

Input Value of Manure

The primary value of manure derives from its use as a soil amendment and nutrient source for crop production. Its nutrient value for crop production is equal to the opportunity cost of not using manure, which, in most cases, is equal to the cost of using commercial fertilizer to grow the crop. In other words, the nutrient value of manure is equal to the net fertilizer cost savings to the crop grower. Net fertilizer cost savings depends upon the per unit fertilizer price, the quantity of fertilizer saved, the application cost of fertilizer, and the transportation and application costs of manure (Parker, 2000).

Quantity of fertilizer savings is a function of the amount of nutrients in the manure and the quantity of manure used. The quantity of nutrients in manure varies by animal type (Table 1). Some control over the amount of nutrients in manure for each animal type can be exercised through feed rations and supplements such as phytase, and through manure storage and handling practices (which control nutrient losses to air and water pathways). The quantity of manure used depends upon the quantities available and the crop's nutrient needs. Crop type and rotation are important in determining nutrient needs.

The nutrient value of manure in terms of savings in commercial fertilizer use from the substitution of poultry litter in the Delmarva region (covering parts of Delaware, Maryland, and Virginia) are presented in Table 2. Holding the amount of nutrients in the manure constant, the savings vary as the nutrients are more fully utilized (P-based planning) and as the application costs vary (crop rotation).

The transportation costs of land-applied manure depend on the local farm economy and the distribution of animal and crop land. On the Delmarva Peninsula, crop land and animal producers are well distributed. In-county distances to move poultry litter to cropland range from 1 to 17 miles, while across-county distances average closer to 25 miles (Lichtenberg, Parker, and Lynch, 2002). In Arkansas, there is a greater separation between animal-producing areas and crop-producing areas. Poultry litter in this area may need to be hauled over 200 miles to find a sufficient amount of cropland to use all of the nutrients (Govindasamy and Cochran, 1995).

For the poultry industry on the Delmarva Peninsula, average in-county transportation costs are $2.85 per ton while cross-county transportation costs are $10 per ton. The net value of poultry litter before transportation costs ranges from $4 per ton to $16 per ton under nitrogen based nutrient management and from $14 per ton to $23 per ton under phosphorus based nutrient management (Lichtenberg, Parker, and Lynch, 2002). Other manures are considerably less nutrient-rich (Table 1) and thus have less value. This positive value of manure as a nutrient source for crop production suggests the potential for markets to help distribute manure to crop growers.

Manure Marketing Potential in Maryland

Through the use of nutrient budgets, we can see in which areas manure buying and selling may take place. Nutrient budgets assess local nutrient sources (animal and commercial fertilizers) and nutrient uses (crops). Areas that are nutrient deficient are good candidates for manure sales. Areas with high commercial fertilizer use are also good candidates, since most manures can act as a commercial fertilizer substitute. Historic nutrient budgets can also help us understand how nonpoint source pollution problems have been created and look for future solution.

Using data from the USDA Agricultural Census and the Maryland Department of Agriculture Agricultural Statistics we derive crop land and animal numbers. Constants from the literature allow us to convert these numbers into nutrient supplies and nutrient demands. Since phosphorus has become the limiting nutrient in many areas, this analysis will only look at phosphorus inputs and outputs. More information on nutrient budgeting is available at http://www.mawaterquality.org/.

The supply of phosphorus on Maryland's Eastern Shore increased rapidly in the 1960^s and 1970^s as the local poultry industry expanded (Figure 1). Dairy cows and other cattle saw a decline, followed by a leveling off, while other animal production (swine, sheep and horses) remains flat. In the rest of the state, Maryland has seen an even larger drop in dairy cows and other cattle phosphorus inputs (Figure 2). Poultry and other animal inputs remain insignificant in the rest of the state.

The demand for phosphorus also increased in the 1960^s and 1970^s (Figure 3). Most of the increase took place in the Northern Eastern Shore, Southern Eastern Shore and North Central Maryland. Surprisingly, commercial fertilizer phosphorus inputs increased mostly in the Northern Eastern Shore and in North Central Maryland (Figure 4). The lack of a large increase in fertilizer inputs on the Southern Eastern Shore is explained in Figure 5. Phosphorus from manure became very abundant in the Southern Eastern Shore region in the 1960^s and 1970^s. The tremendous growth of the poultry industry on the Southern Eastern Shore seems to have kept local commercial fertilizer use low. Figure 5 also shows us that the decline in the dairy and other cattle industries in the North Central region is mirrored by a decline in phosphorus availability from manure in that region.

The effect of cheap commercial fertilizer inputs on phosphorus balances is shown in Figure 6. Cheap commercial fertilizer has created an excess of phosphorus in all regions of the state. Furthermore, even in areas of declining animal production, such as the Northern Central region, there are still large amounts of excess phosphorus being used.

Another interesting aspect of Figure 6 is its documentation of the effect of manure type on phosphorus balances. Those regions with large amounts of dairy and other cattle manure have the largest nutrient excesses. This results because these manures are relatively poor supplies of phosphorus. Thus, even though there are large amounts of manure, many growers do not consider these good sources of phosphorus. Thus, these growers do not credit the phosphorus in the manure and apply a full supply of phosphorus in their commercial fertilizer.

The potential for manure marketing is best demonstrated in Figure 7. While the entire state had an excess of phosphorus from manure in the 1940s and 1950s, only the Southern Eastern Shore has an excess today. The Western portion of the state is about even in manure phosphorus outputs and crop removal. The Northern Eastern Shore has the greatest availability for manure phosphorus. The Southern region, along with the North Central region, has a minor amount of phosphorus capacity.

These nutrient budgets suggest that a manure market could operate between the Southern Eastern Shore and its three neighboring regions; the Northern Eastern Shore, the Southern region and the North Central region. The majority of the phosphorus manure nutrients could be marketed to the closest region, the Northern Eastern Shore.

Barriers to Decentralized Manure Markets

Several studies have addressed the use of manure on cropland (Moore et. al., 1995, Govindasamy and Cochran, 1995, Bosch and Napit, 1992). While not specifically modeling manure markets, the majority of these studies look at the movement of manure off-farm to alternative crop land bases. Thus, these studies imply that some type of marketing takes place to match producers of manure with users of manure. In Lazarus and Koehler (2002), custom application of swine manure at rates equal to crop nutrient needs is compared to application at rates greater than the crop nutrient needs (in order to minimize transportation costs). For short distances, they found that custom applications at lower rates (crop needs) are more profitable than applications at higher rates that are designed to minimize transportation costs. Jones and D'Souza (2001) look at transportation of poultry litter across watershed boundaries, weighted with an environmental index. The model assesses poultry litter transportation options that depend upon supply and demand conditions, and on environmental sensitivity. The article does not address all animal nutrient sources in the watershed (restricting the analysis to poultry litter), nor does it examine mechanism to create the transfers.

Several animal manures possess sufficient value to be transported a wide range of distances. Yet barriers exist that inhibit the creation of a market for manure. Start-up and entry costs are high for individuals seeking to move and land-apply manure to their own crop land. Trucks are needed to haul manure, and loaders are needed to load trucks at the animal producers' locations and to load spreaders at the crop producers' locations. Manure application equipment (spreaders) are also needed on the crop farm. Together, these equipment needs represent a significant capital investment. In addition, much of this equipment may only get occasional use on the farm.

There may also be a lack of education and information. Traditional crop growers, now separated from the animal producers, may not be aware of the value of manure. Without nutrient management planning, these individuals may not know how to integrate manure nutrients into their farm nutrient budgets.

Transaction costs, in the form of search costs for buyers and sellers, may also be too high. Individual savings may be small enough that neither side is willing to invest the time required in the initial search and discovery phase. The opportunity cost of the individual's time may be greater than the value of the nutrients to the buyer or the net value of moving manure off-farm to the seller (which is equal to its nutrient value to the buyer as long as disposal costs of excess manure are zero).

Finally, issues of timing further complicate market mechanisms. The crop grower needs to have the manure available when the cropland is ready to receive it. The animal producer, similarly, may need the cropland to be ready when manure disposal is necessary. Thus, while land may be available only at certain times of the year, manure may be available year-round, or may be available only at specific intervals when clean-outs are conducted. Some control over the timing of manure availability and disposal can be exercised through storage (which may be costly) and through scheduling of clean-outs (which may or may not be under the control of the animal grower in an integrated industry).

Creating Centralized Manure Markets

Recent changes to EPA CAFO rules, along with new laws in many states, has increased interest in how to create and organize a successful manure market. Programs to facilitate manure marketing, or transfers, exist in many states, including, Maryland, Delaware, Pennsylvania, Virginia, Colorado, Arkansas, Missouri, Oklahoma, Nebraska, as well as in the Canadian province of British Columbia. Efforts range from telephone and web-based matching services to cost-share assistance for transportation, loading, spreading, and storage of manures.

The Dutch have been experimenting with phosphorus and manure marketing for several years (Pennings et. al., 1996). As a result of the government 'Removing manure productions' Act, growers are modifying their operations through the phosphorus permit market, the manure market, and the animal market. The Dutch experience has shown that, to operate efficiently, contracts in a manure market should specify manure amounts, origin, delivery place and time, and nutrient and moisture contents.

It is becoming apparent that individual incentives may be too low to overcome the initial costs of buying, selling, and using manure. The high costs to entry suggest that a manure brokerage service, or some similar institution, may be necessary for creating manure markets. A centralized manure market (one that can coordinate information) may reduce transactions and start-up costs, and help alleviate issues of timing and storage.

A manure brokerage service will reduce transaction costs by centralizing information on buyers and sellers of manure. This can ease scheduling and minimize transportation distances by reducing the amount of cross traffic that may arise.

Sufficient equipment to sustain a manure marketing effort could be very costly and difficult to finance. Manure marketing will require loaders, trucks, and spreaders. A manure brokerage service could generate the volume necessary to justify financing this equipment. But, a credible market for manure may be necessary before financing for this equipment can be obtained.

Regulation of manure and commercial fertilizer, through the requirement of P-based nutrient management planning, may raise the opportunity cost of disposal of excess manure to the point that a market may emerge. As this market begins to emerge, brokers may rely on cost share assistance programs (such as Maryland's Poultry Litter Transport

Pilot Project, which offers a fixed loading cost-share and a per ton per mile cost-share) while utilizing existing equipment to begin marketing manure. One such case in Maryland involves Bowles Farms. The proprietor has taken advantage of the Maryland Poultry Litter Transport Pilot Project to cost share much of the variable transportation costs of hauling poultry litter across the state. The grower's start-up costs were low as he already owned a fleet of trucks that were used to haul grain from the southern portion of the state to the Eastern Shore, where it was sold to the poultry integrators as feed. These trucks were then used to backhaul poultry litter to the fields in the southern part of the state. The existing equipment allowed this grower to experiment with manure marketing at a very low cost.

Another case of manure brokering is evident in the AgriRecycle pelletizing plant, built in the heart of the poultry region on the Delmarva Peninsula. AgriRecycle processes raw poultry litter into pellets that are hauled via railcars to markets in the Midwest. AgriRecycle contracts for approximately 60,000 tons of poultry litter annually. This has created a credible long-term market for about one-eighth of the area's poultry litter.

Manure storage, clean-out, and spreading are all issues whose timing will impact manure marketing. Three storage possibilities that a manure brokerage system might consider are no storage, centralized storage, and on-farm (decentralized) storage. A brokerage system utilizing the no-storage option would require large amounts of information to time clean-outs with the transportation system and with crop needs. While this option is not feasible for the entire market, it may work for some segment.

A brokerage system utilizing centralized storage would lessen information and timing issues by creating a central facility that would smooth out fluctuations in supply and demand. Centralized storage may allow for economies of scale in storage (when compared to decentralized storage) and transportation (through more full truckloads and possibly larger trucks). Centralized storage may increase transportation costs, as trucks use a hub and spoke system similar to the airlines, and increase loading costs, as manure is put into and taken out of storage. Centralized storage may also face greater local resistance due to concerns over traffic, noise and odor at the storage facility.

A brokerage system utilizing decentralized (on-farm) storage may lessen transportation and loading costs, as manure is shipped directly from the animal producer to its end destination, but would require greater information and may face increased scheduling constraints. The transportation savings may be lost if this system is unable to maintain trucks with full loads. Computerized data bases of buyers and sellers may alleviate this problem. It may be more costly to build many on-farm storage structures, although cost share and other government programs may be more readily available.

Involving Integrators

In some industries, animal manure is not completely under the control of the animal grower. For example, poultry integrators own and place broiler chicks, provide feed and veterinary services, and determine the timing of clean-outs. This may limit the ability of growers to sign long-term contracts to provide manure to a manure broker. Furthermore, growers may not be in control of the nutrient content of the manure (because they don’t control the feed) or the timing at which the manure is available. Thus, the integrator’s involvement may be essential to a manure market.

For example, the AgriRecycle facility on the Delmarva Peninsula is a joint project with Perdue farmers. This relationship has helped provide AgriRecycle with a stable, predictable supply of poultry litter.

Integrators possess, in a centralized location, much of the information needed to operate a manure brokerage service (quantities of manure, quality of manure, location and time it will be available). Thus, setting up the integrator as the broker would have several advantages. Integrators can control the quality of the manure and the time it is available. As mentioned previously, integrator involvement may promote the idea of on-farm (or decentralized) storage and handling systems because they have control over the time at which manure becomes available. Furthermore, the supply-side data needed to run a decentralized storage system are already centralized with the integrator. Integrators also have access to large amounts of capital and the long-term commitment necessary to obtain credit for equipment needed to run a brokerage. Integrators could modify their contract structure to take ownership of the manure, and thus further guarantee a long-term supply.

Alternatively, integrator involvement with private manure brokers could take several forms. The integrator could work with a broker to supply lists of growers with excess manure. Integrators could also be involved in coordinating clean-outs to coincide with the manure broker’s needs. To provide the greatest level of synergy between the integrator and the broker, integrators could take control of the litter and, thus, reduce the broker’s transaction costs by becoming a large supplier to a private broker.

Conclusions

The potential exists for manure markets to emerge. Constraints to such a market emerging include high start-up costs, uncertainty in obtaining a long-term supply and limited access to credit markets. Educating crop growers as to the value of manure is also critical. Nutrient management planning is a potential remedy to the educational needs.

Nutrient budgets can be used to predict transportation patterns for manure markets. Assessing regional nutrient needs and nutrient supplies illustrates potential market transactions. Nutrient budgets can also be used to predict future constraints that may arise from new regulations and past usage patterns that may give insights into historic nonpoint source pollutant flows.

Regulation of manure use has the potential to create a supply of manure to be marketed. The net value of manure to the seller is the price they can receive less the disposal costs if the manure is kept on the farm. Without regulation, that disposal cost is zero. If on-farm disposal cost rises (through regulation), the net value of moving manure off-farm will increase.

The small individual gains from marketing manure suggest that a manure brokerage service may be necessary to overcome the large start-up and transaction costs. Setting up the integrators themselves as brokers, or creating a high degree of coordination between integrators and brokers, may be necessary to reduce transaction costs to acceptable levels.

References

Boesch, D., and K. Napit. 1992. "Economics of Transporting Poultry Litter to Achieve More Effective Use as Fertilizer," Journal of Soil and Water Conservation, V(47):4, July-August 1992.

Glewen, K., and R. Koelsch. 2001. "Marketing Manure-Part 1." University of Nebraska, Lincoln, Manure Matters, V(7):5.

Goan, H., W. Park, R. Roberts, and L. Warren. 2002, "Poultry Litter Production and Utilization in Tennessee and the Potential Impact of EPA's Proposed CAFO Regulations," University of Tennessee, mimeo.

Govindasamy, R., and M. Cochran. 1995. "The Feasibility of Poultry Litter Transportation from Environmentally Sensitive Areas to Delta Row Crop Production," Agricultural and Resource Economics Review, V(24):1.

Jones, K., and G. D'Souza, 2001. "Trading Poultry Litter at the Watershed Level: A Goal Focusing Application," Agricultural and Resource Economics Review, V(30):1, April 2001.

Lazarus, W., and R. Koehler. 2002. "The Economics of Applying Nutrient-Dense Livestock Water at Low Rates," Review of Agricultural Economics, V(24):1, Spring-Summer 2002.

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

Michel, K., J. Bacon, C. Gempesaw, and J. Martin. 1996. "Nutrient Management by Delmarva Poultry Growers: A Survey of Attitudes and Practices," FREC RR96-01. Department of Food and Resource Economics, College of Agricultural Sciences, University of Delaware, Newark, DE.

Moore, P., T. Daniel, A. Sharpley, and C. Wood. 1995. "Poultry Manure Management: Environmentally Sound Options," Journal of Soil and Water Conservation, V(50):3, May-June 1995.

Parker, D., 2000. "Controlling Agricultural Nonpoint Water Pollution: Costs of Implementing the Maryland Water Quality Improvement Act of 1998," Agricultural Economics, V(24):1.

Pennings, J., M. Meulenberg, and W. Heijman. 1996. "Environmental Rights on the Futures Markets: An Application to the Dutch Manure Market," Environmental and Resource Economics: 7.

Table 1. Manure Phosphorus by Animal Type

Animal	Category	Manure P
		(lbs/1000 lb animal wt.)
HOGS & PIGS		
	Breeding	0.0695
	Other	0.1325
CATTLE & CALVES		
	Cows & heifers- milk	0.080333
	Cows & heifers- beef	0.1195
	All other cattle & calves	0.097667
POULTRY		
	Layers	0.3125
	Pullets**	0.32
	Broilers	0.32
	Turkeys	0.265

Source: www.mawaterquality.org

Table 2. Nutrient Value of Poultry Litter

	Nutrients Used by Crops (pounds per acre) in Year			Total Value	
	1	2	3	per Acre	per Ton
Continuous Corn					
Phosphorus-Based Nutrient Management Plan					
Application Rate	1 ton per acre				
Nitrogen	35.22	14.088	3.522	$12.73	$12.73
Phosphorus	50	0	0	$12.50	$12.50
Potassium	46.86	0	0	$7.03	$7.03
Total				$32.26	$32.26
Nitrogen-Based Nutrient Management Plan					
Application Rate	3 tons per acre				
Nitrogen	105.66	42.264	10.566	$38.20	$12.73
Phosphorus	50	0	0	$12.50	$4.17
Potassium	46.86	0	0	$7.03	$2.34
Total				$57.73	$19.24
Corn-Soybean Rotation					
Phosphorus-Based Nutrient Management Plan					
Application Rate	1 ton per acre				
Nitrogen	35.22	0	3.522	$9.53	$9.53
Phosphorus	50	9.42	0	$14.64	$14.64
Potassium	46.86	0	0	$7.03	$7.03
Total				$31.20	$31.20
Nitrogen-Based Nutrient Management Plan					
Application Rate	3 tons per acre				
Nitrogen	105.66	0	10.566	$28.60	$9.53
Phosphorus	50	60	0	$26.14	$8.71
Potassium	70	50	0	$17.32	$5.77
Total				$72.05	$24.02
Corn-Wheat-Soybean Rotation					
Phosphorus-Based Nutrient Management Plan					
Application Rate	1 ton per acre				
Nitrogen	35.22	14.088	3.522	$12.73	$12.73
Phosphorus	50	9.42	0	$14.64	$14.64
Potassium	46.86	0	0	$7.03	$7.03
Total				$34.40	$34.40
Nitrogen-Based Nutrient Management Plan					
Application Rate	3 tons per acre	1 ton per acre			
Nitrogen	105.66	42.264	25.654	$49.12	$12.28
Phosphorus	50	120	0	$39.77	$9.94
Potassium	70	110	0	$25.50	$6.38
Total				$114.39	$28.60

Source: Lichtenberg, Parker and Lynch; 2002

Figure 1. Maryland's Eastern Shore Phosphorous Supply from Animal Manures

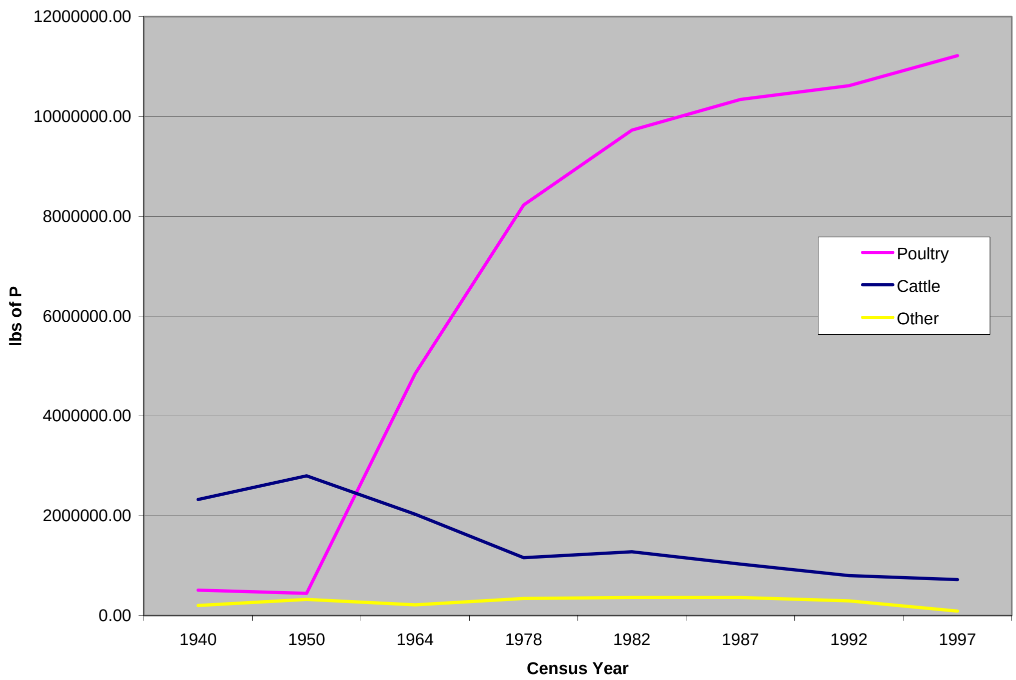

Figure 2. Maryland's (Minus the Eastern Shore) Phosphorus Supply from Animal Manures

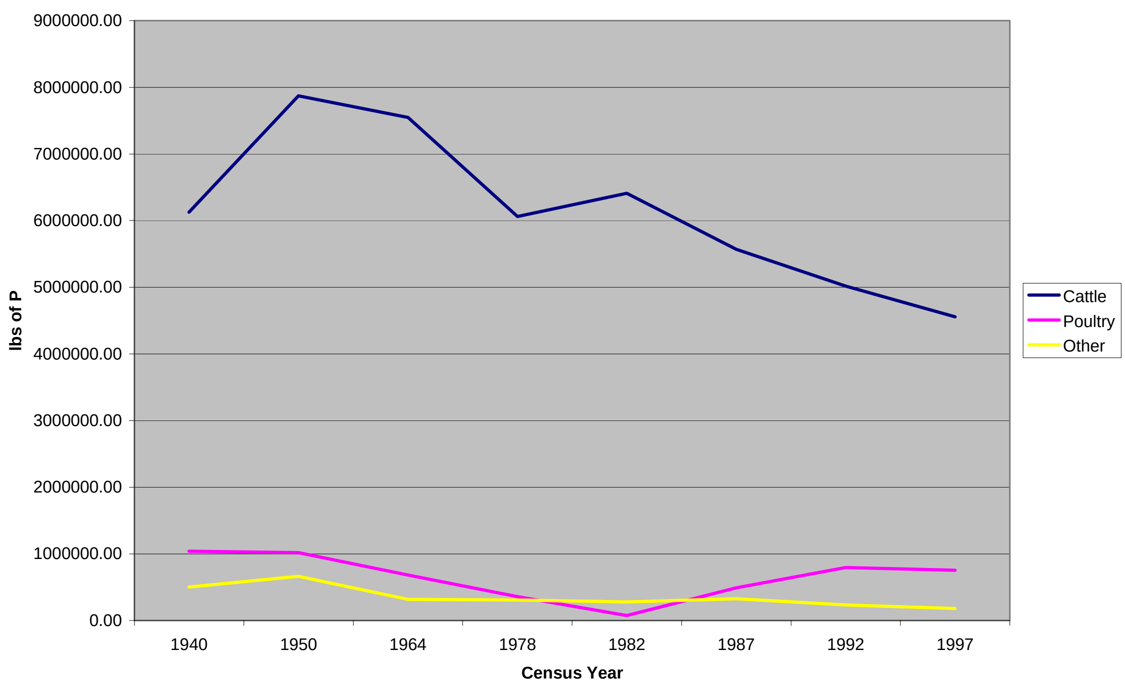

Figure 3. Maryland's Crop Phosphorus Removal By Region

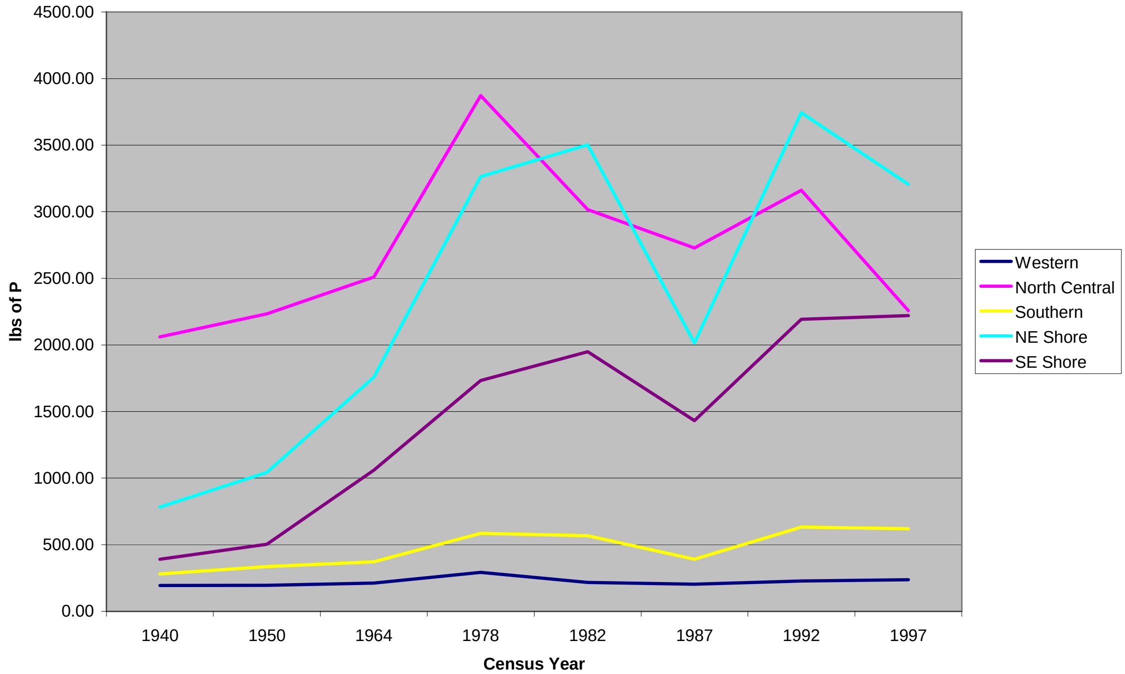

Figure 4. Maryland's Supplies of Phosphorus from Commercial Fertilizer by Region

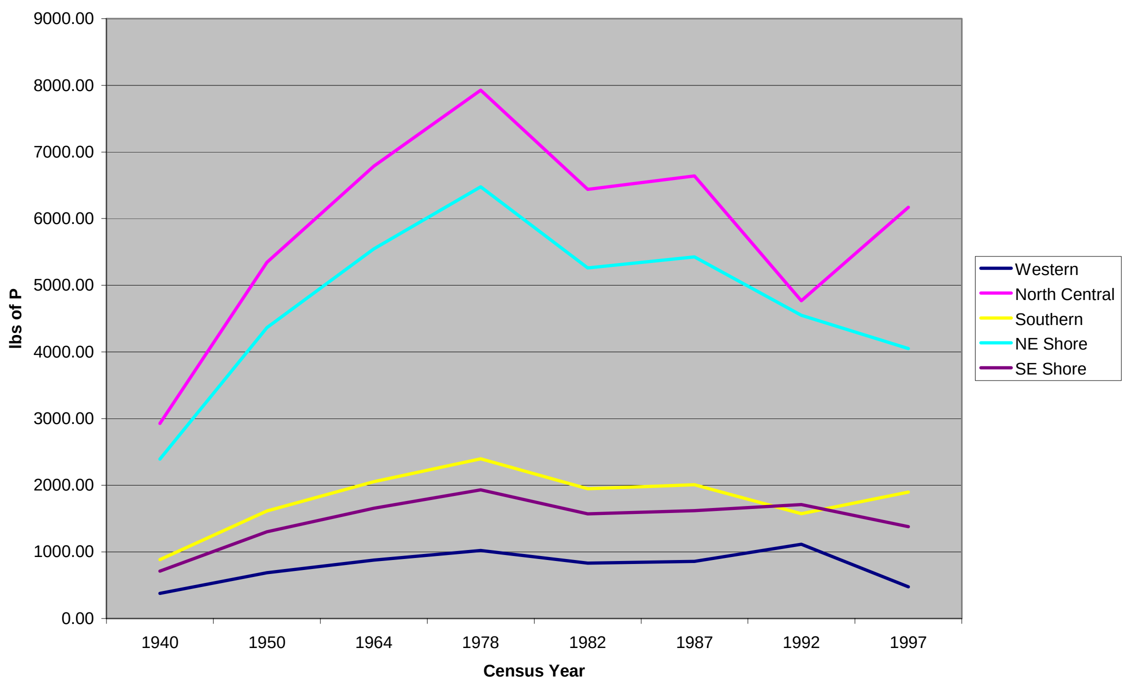

Figure 5. Maryland's Supplies of Phosphorus from Animal Manures By Region

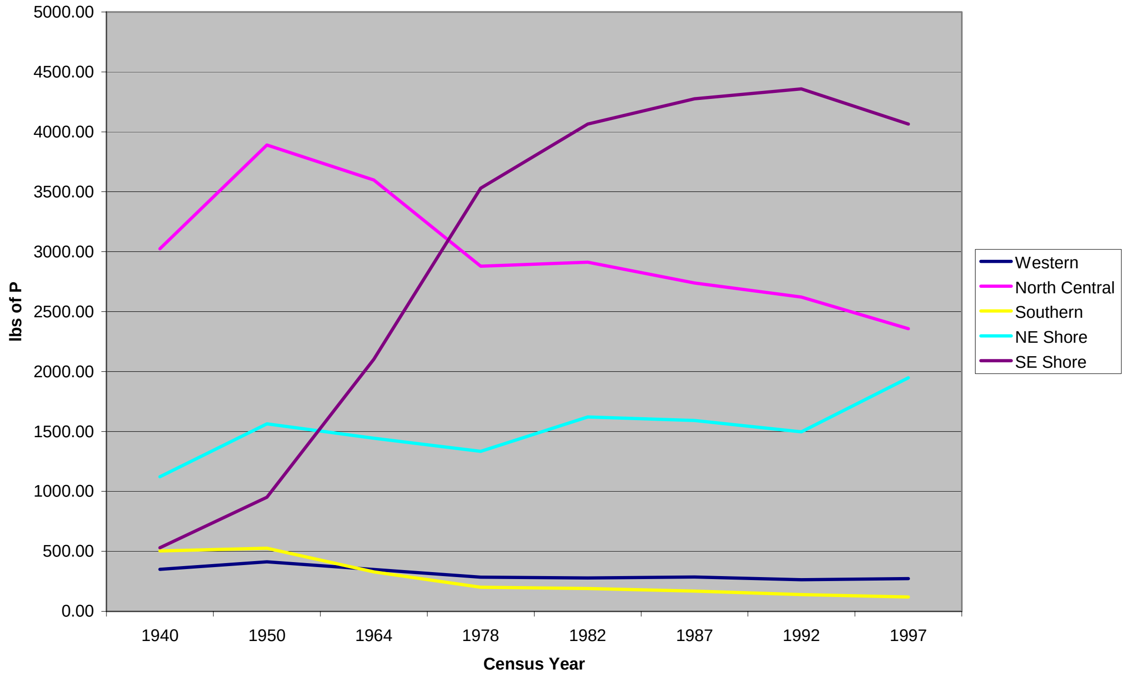

Figure 6. Maryland's Excess Phosphorus Balance by Region
(Commercial Fertilizer plus Manure minus Crop Removal)

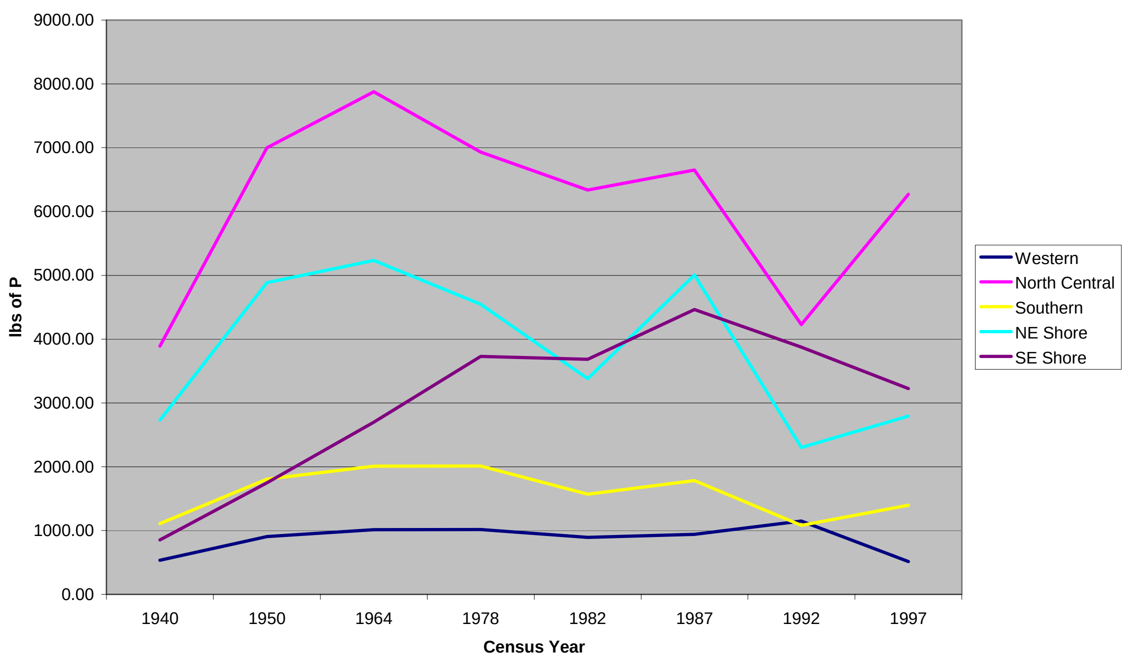

Figure 7. Maryland's Excess Organic Phosphorus Balance by Region
(Manure minus Crop Removal)