Controlling agricultural nonpoint water pollution: costs of implementing the Maryland Water Quality Improvement Act of 1998 ✩

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Abstract

The Maryland Water Quality Improvement Act of 1998 (WQIA) seeks to create environmental and other benefits to the Chesapeake Bay through reductions in nonpoint source nutrient pollution. This paper analyzes the economic impacts of the WQIA on agricultural users of nutrients (commercial fertilizers or animal manures) and on poultry growers in the state of Maryland. The net economic impacts to each of these groups are estimated along with some discussion of the distribution of the impacts. Recognition of the distribution of the impacts allows for the assessment of potential policies to address negative impacts. Additional sections of the WQIA are discussed in terms of their ability to shift the distribution of the impacts or to provide partial compensation to those most affected. The WQIA is the most restrictive agricultural nonpoint pollution control law in the US. While the WQIA only regulates nutrient use in the state of Maryland, other states, as well as the federal government, are watching how this law is implemented. Many states are considering similar laws. At the national level, the United States Department of Agriculture and the United States Environmental Protection Agency have issued draft guidelines that will control nutrients from animal operations in much the same way as the WQIA. Therefore, analyses of the economic impacts of the WQIA may be important in shaping policies in other states and at the national level. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Runoff and leaching from agricultural fields are a major source of nonpoint source pollution (US Environmental Protection Agency, 1996). Contaminated groundwater can have a negative impact when con-

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sumed, or it can contribute to surface water degradation by moving laterally into streams, lakes or bays. Direct runoff from fields also contributes to surface water degradation. Excess nutrients (nitrogen and phosphorus) in surface waters cause algal blooms and eutrophication, which can lead to problems with odors, fish kills, and other environmental concerns.

Control of nitrogen as an agricultural input has been addressed for both commercial fertilizer and animal sources (Trachtenberg and Ogg, 1994). Methods of control that have been addressed include input reduction, improved irrigation management, and cover

cropping in winter months (Helfand and House, 1995; Wu and Segerson, 1995; Suppalla et al., 1995; Lichtenberg et al., 1994). Since most phosphorus from agricultural lands is transported with sediment, sediment control has been the major focus for phosphorus control. Furthermore, because phosphorus binds to the soil, phosphorus has not been a groundwater concern. Thus, the majority of research on phosphorus management has focused on the control of sediments. Sediment control measures that have been assessed include cover crops, buffer strips, no or low till, and the use of polymers (Wu and Babcock, 1998; Hanson et al., 1993; Yiridoe and Weersink, 1998; Parker and Caswell, 1999).

Increased densities in the geographic distribution of animal production have led to excess quantities of nutrients in animal producing regions (Letson et al., 1998). Since most animal waste is applied to the land as a source of nutrients, the intensification of the animal industry has created a situation of gross excesses of certain nutrients being land applied. Recent soil science research has shown that very high phosphorus levels can lead to soluble phosphorus runoff (Sims, 1998). Thus, phosphorus control in animal intense regions must go beyond sediment retention. Recent research on phosphorus management has focused on current and alternative uses of animal wastes (Jacobs and Casler, 1979; Govindasamy and Cochran, 1995; Bosch and Napit, 1992; Parker, 1998). This paper considers nitrogen and phosphorus as part of a regional nutrient management strategy.

2. Concerns for the Chesapeake Bay

In August of 1997, the Chesapeake Bay experienced several toxic outbreaks of the microbe *Pfiesteria piscicida*. The microbe was responsible for several fish kills (each killing thousands of fish) in rivers on the Lower Shore of the Bay. Local fishermen and residents complained of dizziness and memory loss after exposure to those waters. The State of Maryland responded by closing several rivers and issuing health warnings to local residents. *Pfiesteria* had been present in the Neuse River in North Carolina for several years and, thus, there was the beginning of a scientific understanding of the microbe. Maryland's rapid response to the microbe furthered scientific inquiry into the life

cycle of the microbe and the conditions under which it becomes a toxic hazard to the waters in which it exists.

A scientific panel of experts was convened to assess the state of knowledge concerning the microbe (Cambridge Consensus, 1997). This panel concluded that high levels of nutrients in the Bay's waters, especially phosphorus, had combined with warm waters, high salinity levels, and high fish densities to create an environment conducive to the *Pfiesteria* outbreak. Attention immediately focused on the large poultry industry in the region as the most probable source of phosphorus pollution in the waters.

The Chesapeake Bay Program is a federal, state, and local effort to coordinate clean up the Chesapeake Bay. This program has been working to improve water quality throughout the bay region. One focus of the program has been on agricultural nutrient management. In 1989, the Maryland Cooperative Extension began a voluntary program to get growers to adopt nutrient management plans for their land. Adoption of nutrient management guidelines ensures that growers will credit all nutrient sources (commercial and animal waste), when making application decisions. Combining source information with information from soil tests, growers only apply that level of nutrients necessary to reach their yield goals. If followed, this management strategy would lessen agricultural nonpoint source pollution from excess nutrient applications.

At the time the nutrient management program was being implemented, concerns over excess nitrogen applications were paramount. Common soil science wisdom was that phosphorus runoff could be controlled by controlling sediments. Thus, nutrient management plans were written to limit the amount of nitrogen applied (often resulting in over application of phosphorus from animal waste by as much as 100%). In the early 1990s, research began to suggest that in very high phosphorus situations sediment control was insufficient to contain phosphorus. When the phosphorus level in the soil reaches high levels, dissolved phosphorus could runoff fields, even when sediments were controlled. For certain soils, nutrient management plans needed to address both nitrogen and phosphorus loads. To the poultry industry, this meant that application of poultry litter as a nutrient source could be greatly curtailed. This could lead to excess quantities of poultry litter on some farms. Furthermore, many farms currently using poultry litter would have

to switch to commercial fertilizers to achieve the necessary nutrient balance. This would entail switching from an essentially free source of nutrients, to having to purchase commercial nitrogen. There was a great deal of opposition by many growers to voluntarily implementing phosphorus based nutrient management plans. The Maryland Water Quality Improvement Act of 1998 (WQIA) will require all growers to implement nutrient management plans that consider both nitrogen and phosphorus in their recommendations.

3. Agricultural impacts of water quality regulation

The WQIA seeks to create environmental and other benefits to the Chesapeake Bay through reductions in nonpoint source nutrient pollution. This paper analyzes the economic impacts of the WQIA on agricultural users of nutrients (commercial fertilizers or animal manures) for land application, and on Maryland's poultry growers. The WQIA requires all growers to obtain and follow a nutrient management plan. The plans will regulate the quantities of nutrients (nitrogen and phosphorus) that may be applied to cropland. Maryland's large poultry industry is concentrated in a small region on the Eastern Shore of the Chesapeake Bay. The high densities of the industry will force it to find alternatives to local land application for some share of the poultry litter. This paper considers three alternatives to local land application of poultry litter: compost for wholesale and retail markets, energy conversion, and transport to alternative agricultural lands out of the area. The net economic impacts for each of these alternatives are estimated along with some discussion of the distribution of the impacts. Recognition of the distribution of the impacts allows us to assess the potential for different policies to lessen the negative impacts. Additional sections of the WQIA are discussed in terms of their ability to shift the distribution of the impacts or to provide partial compensation to those most affected.

3.1. All crop growers

Virtually all crop growers in Maryland will be required to have and implement nutrient management plans. Nearly 1 million acres of Maryland cropland

already have nutrient management plans (Maryland Cooperative Extension Service, 1997). Thus, the WQIA will require that an additional 1.2 million acres implement plans. These plans can be written by private consultants, Maryland Cooperative Extension, or growers that have been certified. The expected cost to write these additional plans is approximately $6.62 million. The plans will need to be updated every few years. For some growers these additional costs may be offset by additional profits from improved management.

3.2. Poultry growers and users of poultry litter

High concentration in the poultry industry has lead to county level excesses of the quantities of available nutrients from animal waste. As a base case, assume that all poultry litter is currently applied as a crop nutrient source within the county of origin. Implementation of the WQIA will limit the amount of poultry litter that can be used in any given county and, thus, require that some poultry litter be put to alternative uses. The alternative uses to in-county land application that will be considered are: compost, energy production, and transportation for land application outside the county of origin.

The change in value of poultry litter resulting from the WQIA can thus be broken into two parts; the changes in value for in-county land applications, and the additional changes in value under each of the three alternative use scenarios. The changes in value for in-county land application will remain constant across the three alternative use scenarios.

3.2.1. Estimating quantities of excess poultry litter

Information on the total number of acres currently receiving poultry litter is combined with estimates of acreage restrictions under the WQIA to determine the amount of excess poultry litter (that amount which can no longer be used for in-county land application). Soil test data from the University of Maryland's Soil Testing Lab are used to estimate the number of acres of cropland with excessive levels of phosphorus. There is concern that the University of Maryland's Laboratory tests represent a proportionately high number of soils receiving animal manures and, therefore, this data may overestimate the percentage of acres in each county with high levels of phosphorus. Thus,

this analysis may overestimate the impacts of the WQIA.

Since final regulations are not yet available and sufficient information on the impacts of the proposed regulations are not available, some simplifying assumptions concerning soil phosphorus test levels and nutrient management recommendations are made. For this analysis, assume that nitrogen based nutrient management plans will be required for all land with soil phosphorus test values below some pre-set maximum. For land above this level, the addition of phosphorus will not be allowed. [1] The economic impacts at five regulated soil phosphorus levels are estimated: 50 (low), 100 (medium), 150 (optimal), 200 (high), 300 (excessive).

The first step in estimating the expected quantities of excess poultry litter is to estimate how many acres of in-county cropland will be eligible to receive poultry litter. This is combined with information on the amount of poultry litter produced in each county to estimate the amount of litter that could be used for in-county land application. This number is adjusted to account for the fact that not every crop grower will choose to use poultry litter over commercial fertilizers. For the Lower Shore (the major poultry production region), it is assumed that 20% of the eligible crop acreage will not use poultry litter. This number is increased to 40% for all other Maryland counties. Fig. 1 shows the quantities of poultry litter that will be used as an in-county crop nutrient source under each regulated soil phosphorus level. As the phosphorus restriction is relaxed (moving towards 300), the quantity of in-county litter use increases.

Land with excessive soil phosphorus levels will not be permitted to add any additional phosphorus. Thus, in the long run (15–30 years) land with excessive soil phosphorus levels will see phosphorus levels drop. Eventually all cropland will again be available for poultry litter application. The long run, in-county

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[1] It is expected that the final regulations will require the application of a phosphorus index on lands above the pre-set soil phosphorus test level. Application of the phosphorus index is expected to allow some unknown amount of land above this level to apply phosphorus. Thus, the assumptions used in this analysis lead to overestimates of the amount of land for which no phosphorus, and thus no poultry litter, will be allowed. Therefore, this analysis overestimates the economic impacts at any given soil phosphorus test level.
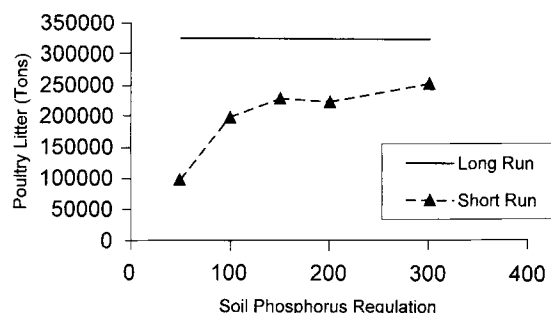

Fig. 1. In-county land application of poultry litter.

application of poultry litter under a phosphorus based nutrient management plan is also shown in Fig. 1. Notice that, in the long run, the regulated soil phosphorus level does not affect the outcome. The regulated soil phosphorus level does determine the amount of time it will take to reach this long-run equilibrium.

The amount of poultry litter that must find an alternative use is equal to the amount produced, less the amount that is land applied in-county. Fig. 2 shows that the amount of excess poultry litter decreases from a high of 270 000 t at a very restrictive level to just over 100 000 t as the regulated soil phosphorus level is relaxed. For the long-run equilibrium, there are still some counties with excess poultry litter and thus about 45 000 t would need to find an alternative use.

3.3. Changes in value of poultry litter

For each of the three alternative poultry litter use scenarios, the same estimate of net changes in poultry litter value for in-county land application is incorporated.
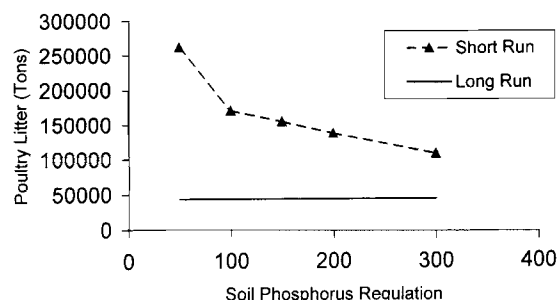

Fig. 2. Excess poultry litter.

3.4. Estimating the changes in value for in-county land application

The changes in value of poultry litter depend upon the current costs for land application of poultry litter. The current costs depend upon whether poultry growers use their own poultry litter or whether the poultry litter is transported to another crop grower for in-county land application. Currently, 36% of poultry growers use their own poultry litter on their own or on rented land, while 64% sell, give away, or pay to dispose of poultry litter (Michel et al., 1996).

Under the WQIA, the use of some amount of poultry litter for in-county land application will still be allowed. The change in value of the poultry litter that stays within the county of origin will be the gains in fertilizer savings from using the poultry litter as a nutrient source on the in-county farms (calculated at the rate recommended by a nutrient management plan), less the losses in fertilizer savings from no longer using poultry litter as a nutrient source (calculated at the current average rate of litter application in the base case), less the costs of marketing the poultry litter, less, for the share of poultry litter currently used on-farm, the costs of loading and transporting the poultry litter to another in-county farm

$$\Delta\pi_{IC} = [F_N - F_0 - M - 0.36(L + T_{IC})]Q_{MD}\beta \quad (1)$$

where $\Delta\pi_{IC}$ is the change in value for poultry litter to be land applied in-county, F_N the fertilizer savings under new law, F_0 the fertilizer savings before new law, M the marketing costs, L the loading costs, T_{IC} the transportation costs (in-county average), Q_{MD} the quantity of poultry litter produced in Maryland, and β the share of poultry litter used in-county after new law ($\beta = 1$ before law).

Note that for poultry litter that is not currently used on the farm of origin there is no change in loading and transportation costs. This is because the poultry litter is already being loaded and transported off-farm and we are assuming an even spatial distribution of poultry litter use within each county. The share of poultry litter that must find an alternative use can be represented as $(1 - \beta)$. As the restriction represented by the regulations gets tighter, $(1 - \beta)$ increases.

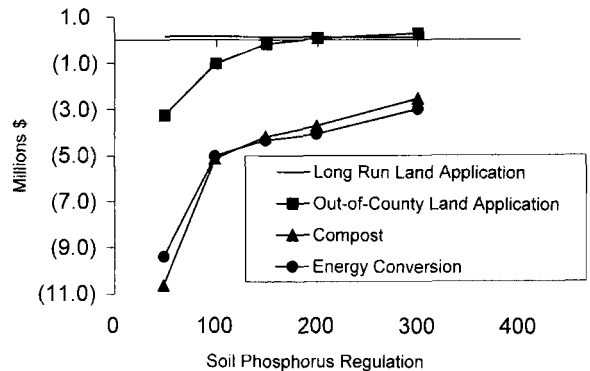The changes in value for the in-county land application are combined with the estimated net changes in

Fig. 3. Annual change in value of poultry litter from implementing the Maryland WQIA.

value from each of the three alternative use scenarios to get a series of net changes in value. The three alternatives are compost, energy production, and transport for land application out-of-county. The net changes in value for each scenario plus the net changes in value for the long-run equilibrium of land application in and out-of-county are all shown in Fig. 3. Each will be discussed separately below.

3.5. Compost

This scenario assumes a central compost facility is set up in each county and compost is sold in bulk form. The information for the analysis comes from variety of sources (Barker et al., 1990; Brodie et al., 1996; Composting News, 1998; Fritsch and Collins, 1993) and is adapted to Maryland conditions. The change in value for the compost option is the revenues generated from compost sales, less the costs to produce compost, less the losses in fertilizer savings associated with the litter that is no longer used as a crop nutrient source (calculated at the average rate of application), less, for the share of poultry litter currently used on-farm, the costs to load and transport the poultry litter to the compost facility

$$\Delta\pi_C = [R_C - C_C - F_0 - 0.36(L + T_{IC})]$$
$$\times Q_{MD}(1 - \beta)\alpha_C \quad (2)$$

where $\Delta\pi_C$ is the change in value for poultry litter to be composted, R_C the revenue from compost sales, C_C the costs to produce compost, and α_C the share of excess poultry litter going to composting.

The variable α_C represents the share of the excess poultry litter that is composted. If all excess poultry litter were composted, $\alpha_C = 1$. The net change in value for the industry if all excess poultry litter is composted is $\Delta\pi_{IC} + \Delta\pi_C$ (Fig. 3). As the strictness of the restriction on soil phosphorus is increased (β decreases), the net costs of this option ($\alpha_C = 1$) rises from about \$3 million to nearly \$11 million. As the restriction is increased, more poultry litter must be composted, more compost is produced, and local markets are saturated. This market saturation causes a decrease in the price of compost. Thus, the decrease in value of poultry litter results from the increase in quantities of poultry litter to be composted and from a decrease in the sale price of compost.

3.6. Energy conversion

This scenario assumes one central energy production facility is located in the center of the poultry producing region, Salisbury, MD. The facility burns poultry litter for electricity production and sells the phosphorus rich ash as an input to commercial fertilizer production. The information is taken from a study of poultry litter energy conversion in the United Kingdom (Dagnall, 1993), and adapted to US conditions with information from the Maryland Environmental Services study of energy conversion options at the Eastern Shore Correctional Facility (Maryland Environmental Service, 1998).

The change in value for the energy conversion option is the revenues generated from the sales of electricity and nutrient rich ash, less the costs to produce the electricity, less the losses in fertilizer savings associated with the litter that is no longer used as a crop nutrient source (calculated at the average rate of application), less, for the share of poultry litter currently used on-farm, the costs to load and transport the poultry litter to a centralized facility, less, for the poultry litter currently used off-farm, the difference in the transportation costs between in-county use and transportation to a centralized energy facility

$$\Delta\pi_E = [R_E - C_E - F_0 - 0.36(L + T_E) \\ -0.64(T_E - T_{IC})]Q_{MD}(1 - \beta)\alpha_E \qquad (3)$$

where $\Delta\pi_E$ is the change in value for poultry litter from energy conversion, R_E the revenue from energy and ash sales, C_E the cost to produce energy, T_E the

transportation costs to energy facility, and α_E the share of excess poultry litter going to energy.

The variable α_E represents the share of the excess poultry litter that is used for energy production. If all excess poultry litter were used for energy production, $\alpha_E = 1$. The net change in value for the industry if all excess poultry litter is used for energy conversion is $\Delta\pi_{IC} + \Delta\pi_E$ (Fig. 3). As the strictness of the restriction on soil phosphorus is increased (β decreases), the net costs of this option ($\alpha_E = 1$), rise from about \$3.5 million to over \$9 million. Because the price of electricity does not change (it only represents a very small part of the US electricity market), the energy conversion option is favorable to the compost option in the very restrictive cases.

If we were allow the share of poultry litter that goes to each option to vary ($\alpha_E \leq 1$, $\alpha_C \leq 1$), we would expect that poultry litter would be used for the production of compost until it drove down the price of compost such that the value of another unit of poultry litter composted is just equal to the value of poultry litter as an energy source.

3.7. Transport for out-of-county land application

This scenario uses a least cost travel model to distribute poultry litter to available lands in neighboring counties. It only looks at counties in Maryland. Thus, for the restrictive cases, poultry litter is shipped to Southern Maryland, Central Maryland, and, eventually, Western Maryland, and it is not considered possible to ship poultry litter to Delaware or Virginia.[2] As with the in-county land application, it is assumed that 40% of the available land not on the Lower Shore will choose not to use poultry litter.

The change in value for out-of-county land application is the gains in fertilizer savings from out-of-county land application (calculated at the nutrient management application rate), less the losses in fertilizer savings from the litter that is no longer used in-county (calculated at the average rate of application), less the costs to market the litter, less, for the share of poultry litter currently used on-farm, the costs to load and transport the litter for land application

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[2] Both Delaware and Virginia have high concentrations of poultry production in the region. Thus, shipment of any significant amount of poultry litter across state lines is unlikely.

out of the county, less, for the share of poultry litter currently used off-farm, the difference in the costs to transport the litter in-county versus out-of-county

$$\Delta\pi_L = [F_N - F_0 - M_L - 0.36(L + T_L)$$
$$-0.64(T_L - T_{IC})]Q_{MD}(1 - \beta)$$
$$\times (1 - \alpha_C - \alpha_E) \qquad (4)$$

where $\Delta\pi_L$ is the change in value for poultry litter land applied out-of-county, M_L the costs to market out-of-county, T_L the transportation costs to out-of-county sites.

If all excess poultry litter were used for land application out of the county of origin, $\alpha_C = 0$ and $\alpha_E = 0$. The net change in value for the industry if all excess poultry litter is used for out-of-county land application is $\Delta\pi_{IC} + \Delta\pi_L$ (Fig. 3). For very low restrictions (β close to 1), the net change in value from this option ($\alpha_C = 0$ and $\alpha_E = 0$), produces a net gain of approximately \$300 000. This gain results from two forces. First, at a low regulatory level very little poultry litter is transported further than is currently the case. Second, the law requires growers to adhere to nutrient management plans. Current rates of application are so high as to essentially waste nutrients in the litter. Under nutrient management plans, less poultry litter is applied per acre and more acres benefit. As the strictness of the restriction on soil phosphorus is increased (β decreases), the net costs of this option ($\alpha_C = 0$ and $\alpha_E = 0$) rises to over \$3 million.

The long-run equilibrium of poultry transport for out-of-county land application also produces a small net gain (Fig. 3). Again, this is because long-run application under phosphorus based nutrient management more efficiently utilizes the nutrients available in poultry litter.

The in-county use equation can be combined with the three alternative uses to create one decision model for the industry

$$\Delta\pi_{IN} = \Delta\pi_{IC} + \Delta\pi_C + \Delta\pi_E + \Delta\pi_L \qquad (5)$$

where $\Delta\pi_{IN}$ is the change in value of poultry litter for the poultry industry.

Given the dominance of the out-of-county land application option over the other two options (compost and energy conversion), we would expect a corner solution such that, $\alpha_C = 0$ and $\alpha_E = 0$. If land application restrictions became very tight, the marginal

cost of transporting another unit of poultry litter a very long distance may become so high that the compost option may be optimal for some share of the excess poultry litter. This does not seem likely under the set of regulations under consideration.

4. Distribution of impacts

The distribution of costs between groups of growers may vary significantly across the alternative use scenarios. In the cases of compost and energy production, the majority of the costs are almost certain to be borne by the poultry growers. A small number of growers may still be able to use poultry litter on their own fields and these growers may see little or no impact. Furthermore, some litter will be used on other fields within the county. This litter will produce fertilizer savings. It is unclear who will benefit from those fertilizer savings. If a strong market for poultry litter were to arise, the poultry growers could capture the fertilizer savings from the in-county use. If a weak market exists, the benefits from the fertilizer savings may go to the crop grower.

For the transport of litter for land application outside the county option, it is less clear who will bear the costs and who will receive the benefits (of fertilizer savings). If a strong market arises, then poultry growers will capture much of the fertilizer savings. Under these market conditions, poultry growers would bear the net costs shown in Fig. 3 (i.e. \$50 000 for a phosphorus soil test restriction at 150), and crop growers will essentially break-even. If there is a weak market for poultry litter, poultry growers could bear significantly higher costs, while crop growers could make significant profits. With a weak market for poultry litter, at the phosphorus soil test restriction of 150 scenario, poultry growers could face costs of up to \$4.7 million while crop growers would receive benefits of \$3.8 million. This uncertainty suggests a need to provide poultry growers either monetary aide or assistance in developing a competitive market for poultry litter as a fertilizer source outside its county of origin.

5. Actions to mitigate WQIA impacts

The WQIA has several sections that partially mitigate the economic impacts of requiring nutrient

management. To offset the costs of having nutrient management plans written, growers can apply for a cost share of 50%, up to $3 per acre. Furthermore, there are funds to increase the number of Maryland Cooperative Extension personnel who assist in writing plans.

The major expense to poultry growers will be purchasing additional commercial fertilizer for producing their crops (almost 75% of the net costs shown earlier). The WQIA provides for a 50% tax credit, up to $4500 per grower per year for up to 3 years, to help offset the costs of switching from poultry litter to commercial fertilizer.

The WQIA also does three things that attempt to assist in the creation of a strong market for poultry litter. (1) To facilitate the flow of information in the market (help willing buyers find willing sellers), an animal manure matching service will be set up at the Maryland Department of Agriculture. This service will allow buyers and sellers to call a toll free telephone number and be matched with others in their area who are looking to sell or buy poultry litter. (2) To help offset the costs of converting from commercial fertilizer to poultry litter, the WQIA provides a 100% tax deduction for the costs of manure spreading equipment in their year of purchase. This should help reduce the high entry cost barrier to use of animal manures. (3) The WQIA provides funds to match a voluntary industry contribution to promote poultry litter movement. The Poultry Litter Transport Pilot Project will use these funds to cost share, up to $20 t^{-1}, the costs of transporting poultry litter from poultry growing sites to alternative uses. These funds should provide an extra measure of profit to the poultry litter market that may help to compensate crop growers for some of the uncertainty involved in changing fertilizer sources.

6. Conclusions

Overall, the WQIA does a good job of balancing the need for improvements in environmental quality with the need for Maryland to maintain a healthy agricultural economy. While the Act attempts to mitigate some of its impacts on poultry growers with cost share programs and market stimulation, there is still the potential for some relatively large economic impacts on some growers. Some impacts not yet con-

sidered include; the possibility of changes in cropping patterns that may arise as a result of a shift in the relative costs of different nutrients, the impacts on other animal operations (specifically dairy) in other parts of the state, the impacts on organic producers, and the impacts on the horticultural industry.

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