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POLICY ANALYSIS:

# ASSESSING AGRICULTURAL NUTRIENT MANAGEMENT IN THE STATE OF DELAWARE: INTEGRATING REGULAR SOIL TESTING INTO EXISTING POLICY

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## I. Executive Summary

Fertilizer over-application in the agricultural realm poses a serious risk to the health of humans through contamination of drinking water and aquatic ecosystems. Nutrient surpluses in crop fields increase the potential for loss of nutrients to the environment via volatilization, storm runoff, and infiltration into groundwater.

Excessive nutrient loads derived from anthropogenic sources including domestic, municipal, industrial, and agricultural land uses continue to threaten the health of bays and estuaries along the eastern coast of the United States. In excess, specifically nitrogen and phosphorus can fuel algal growth to the point of altering the natural balance of an estuarine or marine system, driving it into a state of eutrophication (Volk et al. 2006). In Delaware, USA nutrient loads derived from agricultural land use provide a significant source of excess nutrients to the state's bays and estuaries, second only to sewage effluent ("Delaware Water Quality Assessment Report").

The Nutrient Management Law, passed by the state of Delaware in 1999, requires that every farmer acquire and maintain a nutrient certification and design and utilize a nutrient management plan with the help of a certified nutrient consultant. The plan must include a map of the property, soil and manure analyses, crop yield goals, and a nutrient budget. Additionally, farmers must maintain nutrient handling records and submit annual nutrient use reports. Renewal of both nutrient certifications and management plans is required every three years (Hughes et al. 1999).

The Delaware Department of Agriculture and the University of Delaware Cooperative Extension both emphasize the environmental and economic benefits of soil testing prior to fertilizer application. Soil testing determines the nutrient needs of soils at a specific point in time. This helps farmers to avoid over-application and under-application of fertilizers. At present, a soil test is only required once per three years with the renewal of a nutrient management plan. Because the nutrient content of soils – specifically nitrate-nitrogen – changes readily with fertilizer application and crop cultivation (Ritter et al. 1990), more frequent nitrate soil testing needs to be required in order to minimize environmental health impacts and financial loss via fertilizer over-application.

Integrating more frequent nitrate soil testing into existing policy will not be a simple transition. Agricultural land owners and farmers have different priorities than federal and state environmentally-focused organizations such as the Environmental Protection Agency (EPA) and the Delaware Department of Natural Resources and Environmental Control (DNREC); the majority of land owners and farmers prioritize efficiency and productivity regarding fertilizer use, while the EPA and DNREC are more concerned with nutrient regulation and environmental impact. Outreach and an integration of priorities across these pools of stakeholders is necessary in order for the policy modification to be successful.

This policy analysis examines Delaware's current agricultural nutrient management policies in the context of estuarine and marine health and suggests improvement on existing policies through the requirement of more frequent nitrate soil testing on agricultural land.

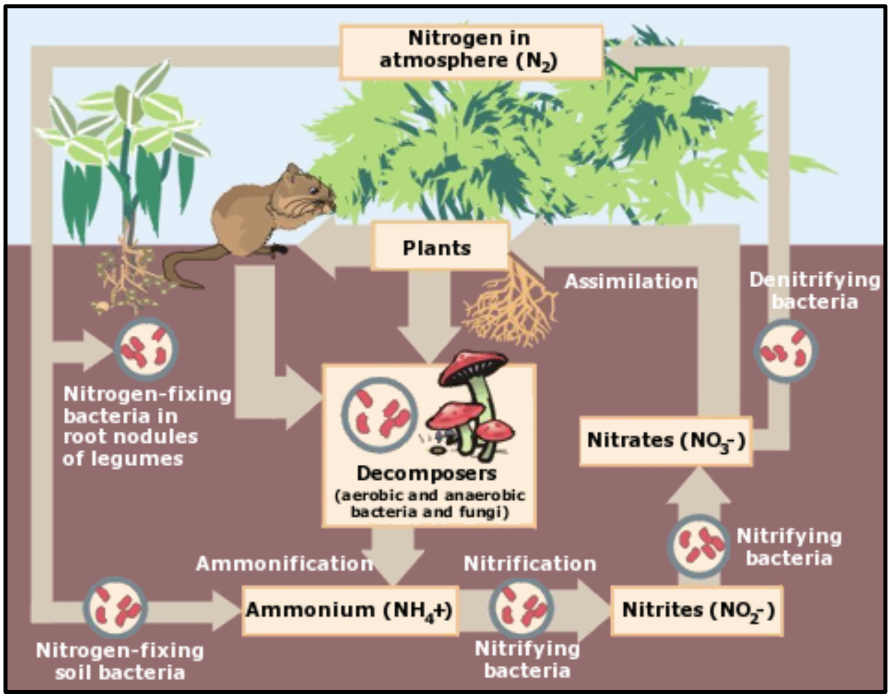
## II. Introduction

### *What is the relationship between agriculture and nutrient loading?*

Nitrogen and phosphorus are the principal nutrients responsible for limiting primary productivity in aquatic ecosystems. If available in excess, they can generate algal blooms, forcing an ecosystem into a eutrophic state (Volk et al. 2006). Both crucial elements for crop growth, they are common components of fertilizers, often applied in the forms of nitrate and phosphate respectively. Nitrate is a highly soluble form of nitrogen, easily incorporated into runoff and groundwater. Unlike nitrate, phosphate readily bonds to sediments, meaning that it often remains in soil until taken up by a crop ("Nitrates").

Nitrogen is by far more naturally abundant in the atmosphere, hydrosphere, and biosphere than phosphorus. Its abundance however, is not indicative of availability for direct use by crops. More than 99% of nitrogen on earth exists in the form of molecular nitrogen, unusable by most organisms. However, a small fraction of organisms – nitrogen-fixing bacteria – present in soils and on the roots of certain plants are capable of converting atmospheric nitrogen into biologically usable forms, namely ammonium. Nitrifying bacteria in the soil then convert the ammonium into nitrate which can be utilized by plants. If the plants die and decompose within the environment, that nitrate will be recycled within the system via re-mineralization of the organic plant material. However, if the plants are harvested as crops, this disrupts the nitrogen cycle (Figure 1) by removing nitrogen from the system. Nitrogen fertilizers must therefore be routinely applied to agricultural fields in order to promote crop growth and maximize yield (Galloway et al. 2003).

**Figure 1: The soil nitrogen cycle**

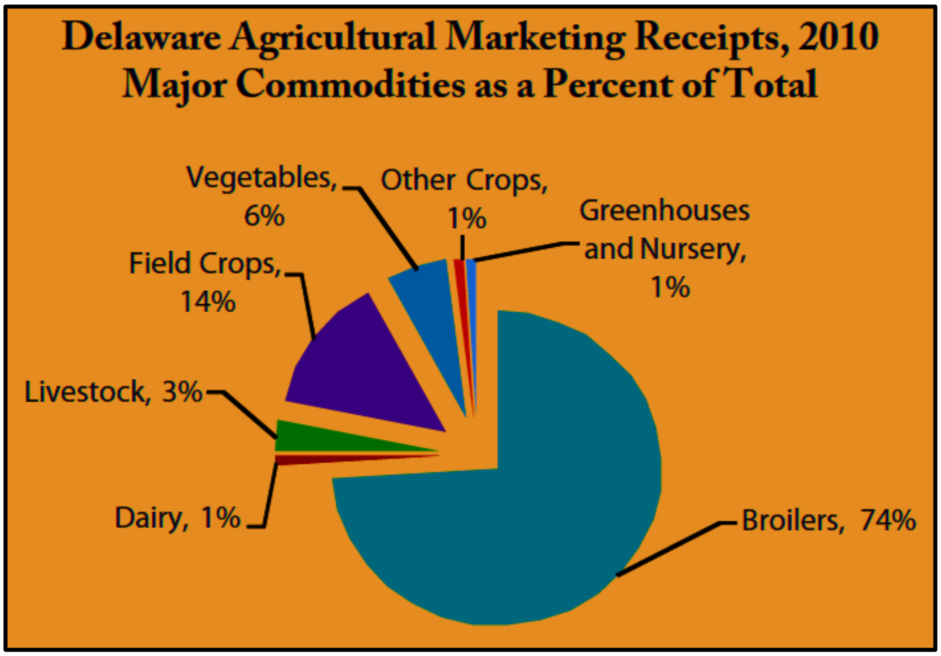



("The Nitrogen Cycle")

Prior to anthropogenic production and distribution of nitrogen fertilizers, the generation of biologically-usable nitrogen (via atmospheric fixation) was largely balanced by its removal to the atmosphere via denitrification (the conversion of nitrate to nitrogen gas by denitrifying bacteria). However, due to a worldwide overuse of fertilizer, nitrogen is presently accumulating in the environment on local, regional, and global scales (Seitzinger et al. 2006).

74% of Delaware's agricultural revenue comes from broiler (chicken) production, 14% from the cultivation of field crops, and the remaining 12% from vegetables, livestock, greenhouse and nursery, dairy, and other crops collectively (Figure 2) (Kee 2010). Poultry litter-manure, containing on average 57 and 44 pounds per ton of total nitrogen and phosphorus respectively, is used as a type of fertilizer on farmland with low soil-phosphate or as a means of complying with phosphorus-limited nutrient management regulations. In order to comply with best management practices, poultry litter-manure is ideally applied to cropland as quickly as possible after collection in an effort to prevent storage and leaching into the environment (Delaware Nutrient Management Commission, Annual Report).

**Figure 2: Distribution of Delaware's agricultural revenue in 2010**




(Kee 2010)

Litter-manure and synthetic fertilizers are the two most common types of fertilizer applied to agricultural fields in Delaware, with the use of synthetics slightly outcompeting manures. Varieties of synthetic nitrogen fertilizers include ammonium nitrate, ammonium sulfate, non-pressure nitrogen solutions, and various other blends. Some synthetic phosphorus fertilizers include ammonium phosphate, monoammonium phosphate, diammonium phosphate, and additional blends. It's important to note that synthetic fertilizers incorporate inorganic compounds of nitrogen and phosphorus, while manures are largely organic. How quickly a fertilizer acts on a particular crop varies with fertilizer composition – organics versus inorganics; depending on the phase of cultivation one fertilizer might be preferred over another (Binford 2006).

Fertilizer applied topically to a field can be taken up by crops to facilitate growth, volatize into the atmosphere, be transported off of the field as runoff, or leach into soils and groundwater. Because much of Delaware is underlain by sandy, unconsolidated sediments, leaching of fertilizer-derived nutrients – specifically nitrogen in the form of nitrate – into groundwater is a serious environmental concern. From fields, nitrates are transported via surface and groundwater to Delaware's bays and estuaries; this is known as nonpoint source (NPS) nutrient loading (Valiela et al. 2000).

## *What are the environmental impacts of nonpoint source nutrient loading?*

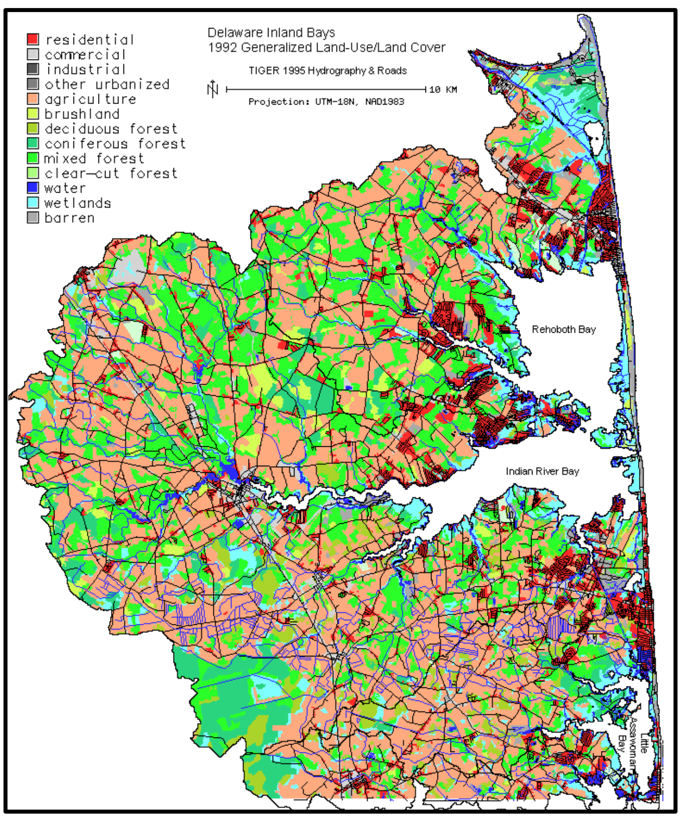
Eutrophication refers to the state of a water body in which a high influx of growth-limiting nutrients has resulted in rampant algal growth. It is an excursion from the natural oligotrophic or mesotrophic state of a system in which nutrients exist in low to moderate quantities respectively. Eutrophication of a water body results in highly turbid waters and low to nonexistent concentrations of dissolved oxygen. Such conditions make the environment less hospitable for aquatic life, potentially leading to loss in biodiversity, fish and shellfish kills, and the formation of dead zones – sections of an aquatic environment where no life exists (Volk et al. 2006). Some algal blooms are directly harmful to plants, animals, and humans that utilize an aquatic environment for commercial and recreational purposes. Commonly known as red tides, these events can lead to mass fish and shellfish kills, adversely impacting the ecosystem as well as the fishing industry. Furthermore, human exposure to the blooms either through consumption or direct contact can lead to serious illness and death (Anderson et al. 2002).

In addition to environmental and human health, eutrophication puts revenue from recreational tourism at risk of decline. Activities impacted include swimming and beach-going, boating, and recreational and commercial fishing. Algal blooms make coastal waters murkier, often tinting them green; this reduces the aesthetic value of an environment for tourists and residents alike (Anderson et al. 2002). The state of Delaware depends upon tourism as a vital driver of its economy. In 2010, the industry's contribution to the state's livelihood was right around 2.1 billion dollars; it is also the third largest private employer in the state ("Delaware Tourism Industry Study Results"). Delaware's economic dependence upon the success of its tourism industry is yet another incentive to keeps the state's primary attractions – its bays and beaches – in pristine condition.

Eutrophication was first recognized as an environmental concern in the 1950's with the emergence of large algal blooms and their impact on shellfish harvests in Moriches Bay – a lagoon along the shores of Long Island. The source of the problem, identified by marine ecologists at the Woods Hole Oceanographic Institution, was the expansion of duck farms along lagoon shores. Nitrogen and phosphorus-containing organic waste from the farms entered the Bay via several tributaries, prompting the onset of eutrophication. Analyses of water samples taken from affected sites in the bay revealed the presence of ample quantities of phosphorus, but an absence of all forms of nitrogen. It was thereby discerned that nitrogen is the principal limiting nutrient controlling primary production in temperate estuarine and marine environments (Ryther and Dunstan 1971). Today, the most common factor contributing to eutrophication in estuarine and marine ecosystems is increased inputs of nonpoint source (NPS) nutrient pollution, specifically nitrogen (Nixon 1995). Human activities including deforestation, agricultural land use, fertilizer use, and the treatment and expulsion of wastewater increase the quantity and rate of nitrogen delivery to coastal systems (D'Avanzo et al. 1996). Globally growing nitrogen loads and the accompanying adverse environmental effects have made temperate estuaries the most impaired of marine ecosystems worldwide (Jackson et al. 2001).

Locally, Delaware's Inland Bays are subjected to high NPS nitrogen loads and classified as eutrophic. Agricultural cropland makes up 40% of all land use within the basin (Figure 3), claiming approximately 72,000 acres. Consequently, agricultural practices are key contributors of nitrogen to the Inland Bays. Croplands are largely dedicated to the cultivation of row crops – corn and soybeans; the majority of the harvest is used as feed to support the state's poultry industry. Nitrogen – specifically in in the form of nitrate – is readily transported from fields to water bodies via storm runoff and groundwater ("Nitrates").

**Figure 3: Land use/cover distribution within the Inland Bays basin, DE**




("Delaware Inland Bays Watershed Nutrient Management Project")

## III. Current Policy

### *How is nonpoint source nutrient pollution managed in Delaware?*

State non-point source (NPS) nutrient management programs are funded by the Environmental Protection Agency (EPA) as authorized by the Clean Water Act of 1987. Prior to funding, a state must have a completed and approved NPS nutrient management plan. Delaware completed and submitted its management plan to the EPA in May of 1995, having since updated it to comply with current program guidelines (Hughes 1999).

The EPA further requires that a state submit an NPS assessment report to assure optimal delegation of federal funds. Delaware submitted its report in May of 1995, having prioritized watersheds on a countywide basis through assessment of surface and groundwater quality, use and susceptibility, and associated land use contributing to NPS nutrient loads. Federal funding is prioritized for management on a watershed or sub-watershed scale where management measures are thought to have the most impact (Hughes et al. 1999).

In accordance with the Clean Water Action Plan of 1997, Delaware created a Watershed Assessment Team in 1998, responsible for identifying the most quality impaired watersheds in the state. The team included representatives from federal, state, and local agencies as well as industry and advocacy groups; some members included the EPA, the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Department of Agriculture (DDA), and the Delmarva Poultry Industry, Inc. (Hughes et al. 1999).

The purpose of identifying severely impaired watersheds is to determine which are in need of the application of total maximum daily loads (TMDL). A TMDL refers to the maximum quantity of a pollutant a water body can receive annually while still complying with water quality standards. The objective in establishing TMDL's for a water body is to meet use goals including drinking water supply, swimming, fishing, and shellfish harvesting. As an example, an 85% reduction in nitrogen loads and a 65% reduction in in phosphorus loads is required for the tributaries of the upper Indian River, DE in order to meet EPA standards (Hughes et al. 1999).

Establishment and implementation of TMDL's is an ongoing process in the state. Because the development is time-consuming, requiring first identification of the pollutants responsible for the water quality impairment, determination of the pollutant sources, and assignment of load allocations, the most severely impaired water bodies are prioritized. Implementation of TMDL regulations is carried out through the development of Pollution Control Strategies (PCS's) and Watershed Restoration Action Strategies (WRAS's) developed by DNREC. Tributary Teams, ideally composed of representatives from multiple organizations including local, state, and federal agencies and the agricultural industry, drive the implementation effort and function as an outreach body to the public (Hughes et al. 1999).

## *What is the current policy on agricultural nutrient management in Delaware?*

The Nutrient Management Law, passed in 1999, is the primary piece of policy governing the management of nonpoint source (NPS) nutrient pollution in Delaware. It requires that all nutrient handlers – including farmers – create and implement nutrient management plans, keep precise records of nutrient use, acquire and maintain a nutrient certification, and submit annual reports (Hughes et al. 1999).

The Nutrient Management Law underwent a phase-in process over a five-year period, ending on January 1st, 2007. This process began with the identification of properties requiring nutrient management planning. Property owners or lessees were subsequently notified regarding their compliance ("Agriculture Regulatory Provisions, CHAPTER 22. NUTRIENT MANAGEMENT, Subchapter III. State Nutrient Management Program").

A nutrient management plan is a strategy for optimizing nutrient use. Its development is carried out with the help of a nutrient consultant; the consultant first requires information pertaining to the property in question including a property map, soil samples, crop yield goals, and a nutrient budget. Public and private consultants are available; up to a certain price, the state reimburses those who hire a private consultant. A nutrient management plan must be renewed every three years, requiring a current comprehensive soil test (Hughes et al. 1999).

A nutrient certification, acquired through the completion of certification classes, provides proof that an individual responsible for generating, applying, or handling nutrients understands and is capable of implementing nutrient-specific best management practices. There are four classes of nutrient certifications: nutrient generator, private nutrient handler, commercial nutrient handler, and nutrient consultant. A private nutrient handler – such as a farmer – applies nutrients to 10 or more acres of land that they own or lease; a private nutrient handler certification must be renewed every three years (Hughes et al. 1999).

Although current policy thoroughly addresses the need for agricultural nutrient management in the state, it does not utilize soil testing to its full potential in managing NPS nutrient pollution. Currently, a soil test is required of farmers once per three years with the renewal of a nutrient management plan. This testing regimen does not consider the potential for nitrate buildup in soils following nitrogen fertilizer application and crop cultivation. If nitrate accumulation goes unmonitored, fertilizers can be over-applied, leading to the release of harmful quantities of excess nitrate into the environment.

## IV. Proposed Modification

The nitrogen content of soils is highly susceptible to change through time with fertilizer application and crop cultivation. Over-application of nitrogen fertilizers can result in nitrate accumulation and leaching through soils. Ritter et al. (1990) conducted a study comparing nitrate concentrations in soil profiles beneath 16 agricultural plots throughout Delaware. Corn and soybeans were the major crops grown on all plots during the previous five years. The sites varied in quantity of fertilizers applied, which was found to be the most dominant factor controlling nitrate concentrations in soils within the root zone of crops (76 cm) and below. For example, during the fall, nitrate concentrations within the root zone of a field routinely fertilized with 185 Kg nitrogen per hectare over the period of a year were averaged at 134 Kg nitrogen per hectare, while nitrate concentrations beneath a field routinely fertilized with 224 Kg nitrogen per hectare and additional broiler manure were averaged at 241 Kg nitrogen per hectare.

I propose that Delaware's Nutrient Management Law be amended to require nitrate soil testing prior to every application of nitrogen fertilizer. By quantifying nitrate already present in soils within the crop root zone, fertilizer over-application can be avoided, reducing the chances of nitrate accumulation and leaching into groundwater.

### *What is agricultural soil testing?*

Agricultural soil testing is utilized to determine the current pH, quantity and quality of nutrients, and potential contaminants present within the soils of a crop field. These components directly influence a soil's fertility and its ability to support crop growth and yield ("Soil Testing"). Soil testing is a key component in effectively managing land used for crop cultivation. By knowing the current nutrient content of a soil, a farmer can determine the quantity of fertilizer that needs to be applied to maximize crop yield. Frequent testing helps farmers to avoid over and under-application of fertilizers, thus optimizing financial expenditure and minimizing environmental impacts ("UD Soil Testing Program").

The University of Delaware Soil Testing Program provides soil testing services to farmers throughout the state, offering five different tests: routine soil tests with lead for home gardeners, routine soil tests for agricultural operations, lawn care companies, and landscapers, soluble salts, pre-sidedress soil nitrate tests for corn, and soil lead screening (“What Soil Tests are Available”).

Required once per three years with the renewal of a nutrient management plan, a routine soil test for agricultural operations in Delaware measures pH, organic matter, and the following extractable nutrients: phosphorus, potassium, calcium, magnesium, zinc, copper, iron, boron, sulfur, and aluminum (“What Soil Tests are Available”). An analysis of nitrate concentrations is not included despite its potential for accumulation and leaching through soils if applied in excess (Ritter et al. 1990).

The University of Delaware Soil Testing Program advocates use of the pre-sidedress soil nitrate test (PSNT) for corn as part of a Best Management Practice (BPM) for crops. Conducted properly from sample collection through analysis, it yields accurate measurements of nitrate in soils, thereby providing a recommendation for any additional nitrogen fertilizer application. Samples must be collected from the top one foot of soil, placed into a cloth bag to dry, and shipped to the laboratory within three days of collection. Once received by the lab, nitrate is extracted from the soil sample using one of several suitable chemical extractants: calcium sulfate, potassium sulfate, ammonium sulfate, or calcium chloride. Following extraction, the sample is filtered to remove all particulate matter. Finally, the nitrate concentration of the sample is analyzed via colorimetric determination following cadmium reduction (the most common method). The pre-sidedress soil nitrate test has recently been adopted for use in cultivating various types of vegetables including pumpkins, peppers, cabbage, and broccoli (Griffin 2009).

It is important that the test be interpreted within the context of recent rainfall; due to the soluble nature of nitrate, rain events occurring after collection of analyzed samples have the potential to significantly reduce availability of nitrate within the root zone via leaching, thus increasing the quantity of nitrogen fertilizer required for optimum crop yield (Griffin 2009).

## *Why should frequent nitrate soil testing be required?*

The state requires that agricultural soils be tested once per three years with the renewal of a nutrient management plan (Hughes et al. 1990). A routine soil test for agricultural operations measures pH and quantifies organic matter, and the following major nutrients vital for crop growth: phosphorus, potassium, calcium, magnesium, zinc, copper, iron, boron, sulfur, and aluminum ("What Soil Tests are Available"). As previously noted, nitrate is not included. Prior to the 1980's soil nitrogen tests were not nearly as reliable as they are today, causing Delaware farmers to fall into the tradition of estimating the fertilizer-nitrogen needs of their crops; the common application rate for corn is one pound of nitrogen per bushel of anticipated yield ("Nitrogen Management for Corn in Delaware: The Pre-Sidedress Nitrate Test"). However, nitrogen removal per bushel of harvested corn is estimated at 0.69 pounds of nitrogen – less than the application rate; this disparity in the application versus removal rate implies that nitrogen is left behind in the soil following harvest either as crop residue or excess fertilizer ("Nitrogen Removal by Delaware Crops"). Modern soil nitrogen tests – specifically the pre-sidedress soil nitrate test is credited with reliability in estimating the contribution of soil nitrate to crop requirements; it serves to minimize the over-application of nitrogen fertilizers ("Nitrogen Management for Corn in Delaware: The Pre-Sidedress Nitrate Test").

Despite the ease with which nitrogen leaches through soils, it has the potential to build up in the crop root zone (Ritter et al. 1990). The assumption that a certain amount of nitrogen fertilizer need be applied to a crop field without soil testing can therefore lead to over-application. If soil nitrate testing were required prior to every application of nitrogen fertilizer, the minimum quantity of fertilizer required for optimal crop yield could be determined and applied.

Minimizing nitrate input to the environment is vital in maintaining the health of Delaware's estuarine and marine waters. If more nitrate is applied to agricultural fields than can be utilized by the crops, that excess nitrate is highly susceptible to transport via storm runoff and leaching into groundwater. Much of the nitrate contained in runoff and groundwater eventually makes its way into estuarine and marine water bodies where it heightens the risk of eutrophication (D'Avanzo et al. 1996).

The economic benefits of optimizing fertilizer application should not be ignored. The cost of ammonium nitrate fertilizer has increased from 194 dollars per ton in 2000 to 544 dollars per ton as of March 2013. Similarly, the price of urea has increased from 200 dollars per ton to 592 dollars per ton within the same time frame ("Table 9 – Average U.S. farm prices of selected fertilizers, 1960-2013"). With the worldwide demand for nitrogen fertilizers on the rise, prices will likely continue to trend upward ("Why Nitrogen Fertilizer Prices Have Increased So Much"). A pre-sidedress soil nitrate test costs eight dollars through the University of Delaware Soil Testing Program. By minimizing the quantity of nitrogen fertilizer applied to reach optimal crop yield, less money will be spent on extraneous nutrients.

***Table 1: A summary of barriers facing this policy modification including issues pertaining to planning and research, outreach, and soil testing logistics. The following are meant to be addressed prior to policy implementation.***

| Planning and Research |
| --- |
| What research will need to be undertaken to establish the feasibility of the proposed practices? |
| What monetary and labor capacity and from which sector will be needed to establish the practices and implement the policy? |
| **Outreach** |
| How will the agricultural community receive this policy modification? |
| Will the collection and transportation of soil samples prior to each instance of fertilizer application be seen as an inconvenience? |
| How will outreach to the agricultural community be facilitated? Through what organizations? |
| **Soil Testing** |
| How will the collection, transport, and analysis of samples be funded? Will the land owner or lessee be expected to pay the full expense? |
| What state facilities will be responsible for analyzing the increased volume of soil samples? |
| Will additional testing facilities need to be constructed in order to accommodate the increased volume of soil samples? Will additional employees need to be hired? |
| What will the turnover time for sample analysis be? How far in advance of applying fertilizing will a farmer need to collect and send off a sample? |

***Table 2: A summary of policy recommendations meant to address those barriers related to planning and research, outreach, and soil testing logistics. This is meant to be an outline of tasks to prioritize. Additional obstacles will need to be managed.***

| Planning and Research |
|---|
| Initial data will be collected regarding the agricultural nitrate contribution to groundwater under the current policy regime. Continual monitoring and data collection will take place after policy implementation to gauge the effectiveness of the modification; the University of Delaware is an ideal candidate to conduct this research. |
| In order to realize the proposed policy modification, federal, state, and local organizations will need to work in tandem. The EPA will be the primary funding source, and DNREC the principal state organization in charge of policy implementation. Locally-acting organizations such as the University of Delaware Cooperative Extension will head outreach to the farming community. What additional manpower and facilities needed to accommodate the increased volume of soil samples will be determined. The estimated annual cost of the increased volume of soil samples, and thereby what funding is required will be determined. |
| **Outreach** |
| Outreach will first be facilitated through nutrient certification classes. These classes will serve as a medium for introducing the modified policy to the agricultural community. |
| The University of Delaware Cooperative Extension office will be largely responsible for incorporating and presenting information on the new policy in their nutrient certification classes. |
| Discussion forums should be made a part of these classes or organized as separate events. The forums will facilitate open discussion of interests between federal, state, and local organizations. |
| **Soil Testing** |
| The transport and analysis of samples will be funded by the Environmental Protection Agency through the state non-point source nutrient management program as authorized by the Clean Water Act. |
| The University of Delaware Soil Testing Program will lead the charge in analyzing the increased volume of soil samples. Additional facilities will likely need to step forward to share the load. |
| The current turnover time for sample analysis is around 10 days. This will need to be decreased in order to accommodate time-dependent planting and fertilizer requirements of farmers. |

## V. Conclusions

Excessive application of nitrogen fertilizers to agricultural fields results in the transport of nitrate via groundwater and runoff into Delaware's estuarine and marine waters. Nitrate loading leads to algal blooms that increase turbidity and decrease dissolved oxygen levels, ultimately reducing biodiversity and adversely impacting fish and shellfish stocks.

Delaware's current policy on agricultural nutrient management requires soil testing every three years with the renewal of a nutrient management plan. The mandatory routine soil test for agricultural operations does not measure soil nitrate because of its assumed brief residence time in soils. In Delaware, the quantity of nitrogen fertilizer applied is typically determined by estimated crop yields.

Soil nitrogen tests – specifically the pre-sidedress soil nitrate test – measure current nitrate levels in soils. By quantifying nitrate already present in a soil, farmers can determine the minimum amount that needs to be applied in order to maximize crop yield. This practice minimizes nitrate release into aquatic environments.

This proposed policy modification requires that a soil nitrate test be carried out prior to every application of nitrogen fertilizer. Soil testing is one of many best management practices utilized in Delaware and neighboring states. Additional practices include the use of cover crops to minimize soil erosion and nitrogen leaching into groundwater and strategic timing of manure application and irrigation to prevent nitrogen loss via runoff and leaching. Comparably beneficial, soil testing is a straightforward, cost-effective practice. And with the prices of certain nitrogen fertilizers having nearly tripled in the past thirteen years and continuing to skyrocket, an eight dollar test seems a small price to pay for optimized fertilizer expenditure.

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Bio

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