Small Farms in Maryland:

Big Challenges for a Shrinking Community

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Preface

All students who enroll in the Environmental Science and Studies Senior Seminar, are completing their academic program as an ESS major. As in years past, this class has completed a semester long project. The idea is for the students to bring to the project the knowledge, skills and abilities they have developed through their academic study and use them within a specific arena. This year the class took on a regional issue that impacts all citizens of the state. The focus was on farms and farming, especially on small farms.

The class took a broad view of farming although their primary concern was Maryland. They looked at different farming practices, the economics behind different practices and their potential environmental impact. They looked at the importance of farmland as a land use and considered the environmental impact of farms, but also considered the potential environmental impact if this land were to be developed into residential, commercial or industrial uses. They carefully considered the nutrients (mainly nitrogen) that farmers apply and tried to determine its importance to production and its role in pollution. The class looked at how farmers and farming practices have been altered to address nutrient runoff and the role of governmental programs that both regulate and support farming. We were aided in our investigation by a local farmer who thought this academic project worthwhile and who very generously shared his knowledge and experiences with us.

The students have worked on their own. I provided limited guidance and helped as requested. They deserve the credit for their success.

I. Challenges Maryland Farmers Face

Economics

Agriculture is an essential element in our economy; it provides jobs for people, helps develop communities, and supplies the food for our nation as well as other nations around the world. U.S. agricultural exports exceed $50 billion a year (U.S. Department of State 2005). Conversely, the economy is important to agriculture because the demand for agricultural commodities fluctuates with the economy.

Even though agriculture in Maryland has declined over the years, it is still a major part of Maryland's economy (Gardner 2002). In some parts of the state, agriculture is the largest industry of these regional economies (Gardner 2002). In 1999, farming was responsible for about five billion dollars of Maryland's gross state product and employed up to 62,700 workers (Gardner 2002). Even though farming is responsible for a large portion of Maryland's gross state product, Maryland Farmers are still facing the economic realities of ongoing challenges such as environmental polices, unpredictable weather, and decreasing farm sizes. Table I-1 provides data on the costs of farm inputs and outputs, and the capital consumption for Maryland farms in 1999 and 2000 (CANRP 2002).

Farmers must generate enough income to avoid renting or selling their land (CANRP 2002). If Maryland agriculture is to flourish in the future, the returns of farming must be sufficient to repay investment costs to maintain the capital stock (CANRP 2002).

Table I-1: The following table reports data on the value of farm output, the estimated costs of major inputs, and capital consumption for Maryland Farms in the years 1990 and 2000 (CANRP 2002).

Revenue Sources:	**1990 ($)**	**2000 ($)**
Final crop output	550,015	659,843
Final animal output	825,192	841,101
Services and forestry	173,518	250,057
Machine hire and custom work	12,321	12,606
Forest products sold	23,000	33,080
Other farm income	59,883	108,074
Gross imputed rental value of farm dwellings	78,314	96,297
Inventory and other adjustments	-178,518	-250,057
Direct government payments	17,386	88,470
Costs:		
Manufactured inputs and services bought	228,601	283,729
Fertilizers and lime	63,256	63,020
Pesticides	30,624	43,453
Petroleum fuel and oils	34,181	41,350
Electricity	17,299	21,508
Repair and maintenance of capital items	67,334	87,134
Machine hire and custom work	15,907	27,264
Marketing, storage, and transportation expenses	70,003	59,793
Contract labor	4,162	4,775
Miscellaneous expenses	139,106	197,525
Motor vehicle registration and licensing fees	2,390	2,512
Property taxes	34,307	37,184
Capital consumption	145,513	139,451
Hired labor	93,093	122,701
Net rent paid for leased land	29,021	30,377
Interest payments	84,851	82,963
Total of Costs:	976,406	1,130,341

It is important to recognize the major costs of farming, and whether these costs will pay off. Variable costs include expenses such as fertilizer, pesticides, labor and marketing. Other expenses include capital costs such as new buildings, equipment, and machinery (Hanson et al.1988). It is important to consider what price to use in valuing resources that are used in production. Resources such as fertilizer and pesticides are easier to price than other resources, and they may be valued using market prices (Hanson et al. 1988). Other resources such as soil quality and labor are not as easily given a price because they rely on opportunity costs, which consist of placing a value on a product that is not being produced (Hanson et al. 1988). For example, if a farmer produces only corn, the lost income from not producing any other type of crop is considered the opportunity cost.

Farmers must also take fixed costs into consideration (Hanson et al.1988). Fix costs are costs incurred even if there is no output being produced, and they include such components as depreciation, interest, rent and repairs, taxes and insurance (Hanson et al. 1988). For example, if a farmer paid an annual interest charge for their farm, this would be considered a fixed cost because the payment would have to be made regardless of the amount produced that year (Hanson et al.1988). Taking into consideration all possible costs is extremely important to the future success of a farm. Whether these expenses pay off, depends on the farmer's techniques and the environmental characteristics of the farm.

Modern farmers attempt to maximize their profit by finding specific market niches in their local communities. Farmers in Maryland have specialized in growing a number of different crops. As estimated by the Economic Research Service, greenhouses/nurseries provided the greatest return in Maryland crops with over $325,000,000 in 2003. The next greatest returns were from corn for grain and soybeans, at over $87,000,000 and $86,000,000 respectively (Maryland Highlights for 2003 2005). Vegetable crops in order of value of production in Maryland are as follows: sweet corn, tomatoes, watermelons, pumpkins, snaps, squash, strawberries, other greens, cantaloupes, cucumbers, peas, kale, cabbage, and finally lima beans (Maryland Highlights for 2003 2005). Vegetable crops accumulate a return of $44.5 million for Maryland farmers

(Maryland Highlights for 2003 2005). Other crops worth noting are hay ($23.4 million) and wheat ($16.9 million) (Maryland Highlights for 2003 2005). Potatoes, apples, tobacco, peaches, and barley contribute about another $24 million (Maryland Highlights for 2003 2005).

Livestock can be another important part of a farmer's income. Broilers were responsible for producing almost 1.4 billion pounds, which had cash receipts of almost $495,000,000 (Maryland Highlights for 2003 2005). Milk brought Maryland farmers $163,000,000 (Maryland Highlights for 2003 2005). Farmers earned around $79.4 million for cattle and calves in cash receipts, eggs were $46.2 million, and hogs were $6.9 million (Maryland Highlights for 2003 2005). Livestock may also serve as a good secondary project on farms to save money (Guidelines for Estimating Cost of Raising Dairy Steers For Weight Range of 100 - 530 lbs 2002). Livestock can be highly beneficial when used to feed ones family (Guidelines for Estimating Cost of Raising Dairy Steers For Weight Range of 100 - 530 lbs 2002). Based on Manitoba's *2002 Guidelines for Estimating Cost of Raising Dairy Steers For Weight Range of 100 - 530 lbs*, the total cost for raising a steer may be estimated at $657. Since beef can easily cost around $4-$15 per pound in stores, there is an opportunity to save a considerable amount of money if you rear your own. Such supplemental farming practices can be beneficial to sustain a practical budget on the farm.

One primary advantage of Maryland agriculture is its location to markets. Grain farmers benefit directly from the close proximity to the poultry industry (University of Maryland 1999). Products, such as fruit, vegetables, dairy, beef, swine, and other specialty crops are sold to approximately five million people in the Washington-Baltimore region (University of Maryland 1999). Products exported out of state are shipped out from either the Port of Baltimore or the Baltimore-Washington International Airport (University of Maryland 1999).

Modern farming brings forth new alternatives for increasing a farmer's income. Finding specific niches for recyclable material can save farmers a significant amount of money. For example, farming with a niche for mulching gives farmers an opportunity to save money. Some farmers may use 5-6 tons of wood chips per acre to prevent serious erosion (Mulching Undated), and that much mulch could cost up to $4,000 every 3-4 months per acre (Wood Mulching 2003).

Farmers can also fill the niche of raising horses for Maryland Races. Horses can be an extraordinary though risky investment with the potential of a greater return than nearly any other avenue of investment for farmers (Buy a Horse: Racing Buyers Guide Undated). For example, the 1999 three-year-old Champion Old Habits was purchased as a yearling for $18,500 and by the completion of his second year of racing he had earned more than $672,000 (Buy a Horse: Racing Buyers Guide Undated). Perhaps the greatest return on an investment was the mere $3,800 purchase price for Refrigerator, who retired with earnings in excess of $2.1 million (Buy a Horse: Racing Buyers Guide Undated). The website Ehow.com has a lot of information on buying horses. Raising a horse costs approximately $25,000 to $30,000 annually for horse training, $150 to $500 per month for vet charges, and $100 for monthly shoeing expenses (How To Buy a Thoroughbred Racehorse 2005). These prices do not even include food and dietary supplements, which are paid for separately (How To Buy a Thoroughbred Racehorse 2005).

Even with the predicted costs and benefits of agriculture, there still remain risks that could have a negative impact on a farm. Therefore it is important for farmers to identify the risks on their farm. Some crops are affected by weather (Comis 2004). For instance, studies show that oats and soybeans may have vastly different yields depending on the weather (Comis 2004). In addition, some crops such as tobacco and strawberries are very susceptible to insects and mold (Webber 1995). Identifying potential problems on the farm may be vital to producing maximum crop yields. For struggling farms, farm managers may help to recognize strengths and weaknesses of farms, as well as coordinate the workers (Dobbins and Robbins 1983). Usually farm managers work for a firm that receives a percentage of the profits. Locally, the University of Maryland offers help to local farmers in need of assistance and expert advice (A Welcome Message From the Coordinator 2005).

The survival and prosperity of small farms is important to development of rural communities. Since the 1960's Baltimore County has developed and adopted master planning in order to direct the development of the county (Baltimore County Council 2005). In 1967 the county differentiated between two distinct land management areas with its urban rural demarcation line (URDL) (Baltimore County Council 2005). This was created to efficiently spend the county's revenue on a centralized infrastructure for urban development while preserving the natural and agricultural benefits of rural areas (Baltimore County Council 2005). Although the 1967 agreement was not officially a master plan, it paved the way for the five master plans Baltimore County adopted in 1972, 1975, 1979, 1989 and 2000 (Baltimore County Council 2005).

The URDL is reinforced by land use and zoning, therefore, rural areas do not receive public water or sewer services, in turn, limiting the land use activities and concentrations of people supported by well water and septic systems (Master Plan 2000). Due to the dispersed nature of the population in rural areas, it is not cost effective to provide the same quantity of public services to the rural communities; however they are guaranteed the basic education and public safety services (Master Plan 2000). Twenty-five percent, about 100,000 acres, of Baltimore County are classified as agricultural

(Master Plan 2000). The county's agricultural sector contributes $400 million to its economy; 78,000 acres of this sector is used for large-scale farming, equine operations, dairies, beef cattle, other livestock, vegetables, horticulture, and specialty farms (Master Plan 2000). The remaining acres are in commercial forest, hobby farms, and natural lands (Master Plan 2000).

In order to protect agricultural areas within the county, the URDL must be enforced, permanent protection of productive lands must be provided, and agricultural zoning and development controls must be refined in order to allow for economic stimulation while protecting the land (Master Plan 2000). The reinforcement of property tax incentives will also encourage land owners to keep their land in agricultural use (Master Plan 2000). Other methods land owners can use to protect Baltimore County's agricultural area include the Agricultural Preservation District, which is a five year agreement among the state, county, and owner of the land. This agreement means that the land will only be used for farming during that time period; it is also a prerequisite for the Land Preservation Easement, which makes the agreement permanent (Master Plan 2000). Land Trust, Purchase of Development Rights (PDR), and Transfer of Development Rights are other options owners can explore (Master Plan 2000).

Housing developments and agriculture are not very compatible because increased traffic associated with development interferes with large agricultural equipment and the residents complain about dust, odors, and loud equipment operated in the early morning and late at night (Master Plan 2000). As Baltimore County ages, its infrastructure focus has shifted from building to maintaining and upgrading transportation networks, sewage systems, storm drain systems, solid waste treatment, and providing adequate water supply (Master Plan 2000). As farmers face economic pressure to sell their land for development, these new developments will also require greater infrastructures and infrastructure maintenance.

Policy and Science

Maryland farmers feel increasing pressure from the scientific community, government, as well as the public due to environmental issues, such as the deterioration of the Chesapeake Bay. Nutrients, such as nitrogen and phosphorus, from farms are considered pollutants that affect the health of the Chesapeake Bay ecosystem (EPA 2005a). Therefore, farming practices, among other sources of pollutants, have been increasingly scrutinized by scientists and policy makers in an effort to reduce the nutrient loading of our waterways (EPA 2003). In an effort to reduce nutrient loading, policy makers have passed legislation requiring farmers to manage the amount of nutrients applied on their farms. Should Maryland farmers accept the base of research from the scientific community, and if so, how should they change farming practices in order to reduce nutrient overloading? Is it a good idea to require mandatory regulations where farmers pay out of the pocket for developing management plans? Farmers have credible concerns when thinking about altering their farming practices, and they tend to initiate change with caution because they may be risking a reduction to crop yields or adding expense. Changes in production methods require a considerable amount of planning and effort to achieve. They may also require purchase of additional equipment and can have risky economic outcomes.

For example, best management practices (BMPs) are intended to minimize nutrient pollution to waterways by determining cost effective ways to reduce the application of fertilizers and to minimize runoff from cultivated land. A key issue here is designing BMPs that do little to inhibit the viability of a farmer’s practice. It is important for farmers, especially on small farms, that any mandated changes in their farming practices do not reduce crop yield or create an excessive work burden. In the case of a small farm in Baltimore County, the farmer already plants across the contours of his land to prevent the loss of nutrient he applies and to control erosion. But, he says it is too difficult to strictly follow BMP standards of contour farming. He would have to take some land out of production, which would affect the profitability of his crop yield, and it would be very difficult to maneuver his farm equipment along advised contours (Reynolds 2005). Therefore, he chooses to not follow all BMP recommendations, but does what he can to capture runoff. It is in the farmer's best interest to reduce the amount of nutrient runoff and to conserve soil nutrients (Reynolds 2005). The purchase of supplemental fertilizer is expensive, and its application is time consuming. Should farmers sacrifice their income and work harder for environmental change? Can some small change in practice bring an improvement in environmental impact? For reasons such as these, the best intentions of scientific findings, i.e. best management practices, may not be appropriate for all farmers in all situations. Each farming operation has a unique set of environmental (land topography, soil, etc.), physical (labor) and economic considerations and constraints.

Along these same lines, some politically produced measures, such as strict contour farming, may be conceptually simple, but their implementation is difficult for farmers. Politicians may be concerned with environmental issues, but at the same time, they have to take into account economic realities as well. Is it good for farmers to be forced to comply with government regulations at the cost of the farmer's livelihood? According to interviews with over 300 farmers in Maryland concerning the Nutrient Management Program, no farmer said it would be good to implement mandatory laws or licensing to achieve environmental goals (Smith 1999). It seems that farmers are willing to implement many of the ideas from the scientific community, but only on their own terms and of their own volition.

Since the 1960s, the position of the environment in the public's major 'issues of concern' list has changed over time (Kraft 2004). These shifts, in the majority's opinion, are voiced by elected officials and, in effect, influence policy. Differing priorities, commonly economy vs. environment, are set into the agendas of the administration and guide policy formulation. The most powerful and influential political institutions, who acquire most of the control throughout a decision making progress, often lack the wisdom of doing so in an environmentally friendly manner (Smith 2004).

The opposing ideas, therefore, create the policy paradox (Smith 2004). As stated by Smith, the environmental policy paradox is caused by dramatic differences between the sciences and policy—"the scientifically correct answer to a problem may not be politically viable" (Smith 2004). The process of switching to new ways of thinking in regard to farm policy formulation has proven to be very difficult. Some of this difficulty is due to the influence of manufacturers whose products are designed to serve farming but which are potentially hazardous to the environment (Smith 2004). Frequently, we are aware of certain changes that should (and could) be made to improve and conserve the environment, however, initiating the process to address these environmental problems is very difficult. Often, ideas are not put into effect or are initiated after an extended delay—usually after it is too late (Smith 2004). Consequently, scientists, policymakers, and farmers face many challenges in the environmental arena, in which all sides are trying to agree on appropriate courses of action to help protect Maryland resources.

Public's Perception of Farming and Farmers

Agriculture is often blamed for many of the Chesapeake Bay's environmental issues affecting the public's perception of farming. Although in the last few years, some environmental organizations such, as the Chesapeake Bay Foundation, have focused on conserving farmland and supporting farmers with the purpose of improving the Bay's water quality. This support suggests that farming is important to the long-term improvement of the Bay.

Recent surveys indicate that the general U.S. public has a high opinion of farmers. According to a 2004 survey from the National Corn Growers Association, the public strongly believes farmers and ranchers are concerned about the quality of their food produced and the well being of their animals and the public (CSD 2004). This survey polled over 1,000 U.S. adult consumers who were asked a number of questions relating to agriculture. The response to the poll was generally positive. Most respondents were open to the idea of genetically enhanced food with nearly half claiming that scientists should be free to use science and genetics to breed farm animals to be resistant to harmful bacteria (CSD 2004). A significant number of respondents stated that they are willing to pay higher prices for food certified and labeled "humanely raised." That being said, the survey also showed that animal rights activist groups do not have much influence on consumer decisions to buy humanely raised products. Only 7% of people surveyed said that animal rights groups had a profound effect on their purchasing decisions, so most people are formulating opinions on their own about how farm animals should be treated (CSD 2004).

Another poll taken by the Eastern Shore Land Conservancy surveyed 1,202 registered voters about their attitudes and perceptions regarding land use on the Eastern Shore. Voters indicate that they want the government to play a bigger role in preserving farmland and habitat areas. Residents support the funding of farmland preservation and encourage that new funding programs be created (ESLC 2004). Most voters also support urban growth boundaries, citing that controlling growth, development, and sprawl is one of the most important problems facing the Eastern Shore today (ESLC 2004). The majority (89%) of those polled support conservation easements and other incentives provided for farmland owners (ESLC 2004). In addition, 91% of voters feel that it is important to promote agriculture, forestry, fisheries, and other natural resource-based industries as a way to improve the environment and the economy (ESLC 2004).

On the other hand a Maryland farmer, Tom Reynolds, said during an interview that he thinks the public holds the opinion that farmers are uneducated, and provide cheap labor (2005). The idea that farmers are uneducated is not true; modern farmers must be intelligent and must keep current with technology and science, in order to be competitive in today's market (Reynolds 2005). Farming is difficult and complicated, and has been known to produce undesirable environmental effects. As a consequence, farmers face tough criticism, and perhaps undeservedly, from residents who build in or move to rural farmland areas. There have been some cases where people who move next to existing farms complain about the fertilizer smell, pesticide application, and farm equipment moving slowly on roads (Apperson 1999).

Often the public's lack of knowledge regarding the nutrient pollution in the waterways causes blame to be placed on agriculture. This view is evident in the intensifying number of regulations placed on farmers (Gardner 2002). Some people are concerned that the average citizen does not realize the economic and environmental value of farming and farmland, which is also demonstrated through the rapid disappearance of farmland (Gardner 2002). Due to the finite size of the farming community, and only 2% of the population working in the agriculture industry, farmers' voices are not very loud (Juday 2003). This makes it much easier to regulate the fertilizer application, thereby the runoff from agriculture, than it is to regulate on golf courses and residential lawns (Juday 2003). Although the public may assume that farmers can easily reduce the use of fertilizers to improve water quality, this opinion reflects a lack of understanding of the issues farmers face. A reduction in fertilizer results in a lower yield, and therefore less income for the farmer in an already tight produce market (Dewar and Horton 2000). The same person who says 'reduce fertilizer use' may refuse to purchase produce that isn't as 'pretty' as they would like because it was grown with less fertilizer. The economics of farming is involved and dependent on many factors; however, this is also greatly misunderstood by the public (Gardner 2002). Since the majority of the American population resides in cities, they do not have much interaction with farmers and farmland (Farm Foundation 2004). The disconnect between the farming community and public is a major obstacle to overcome in efforts to clean up the Chesapeake Bay.

Pfiesteria piscicida is a toxic organism that can kill fish and cause illness in humans (Dewar 1999). *Pfiesteria* is found in many of the Chesapeake Bay's tributaries, and may lay dormant for some time, becoming toxic only under certain conditions (Dewar 1999). What exactly spurs the growth of the harmful algae blooms is still not clearly understood. In 1997, the Eastern Shore experienced a *Pfiesteria* outbreak resulting in massive fish kills and the illness of thirteen citizens (Dewar 1999). The culprit was thought to be runoff from poultry farms, although this is still being debated (Horton 2001). While there is a link between nutrient runoff and *Pfiesteria*, there is alternative evidence that toxic levels of *Pfiesteria* can occur even when nutrient levels are low (Juday 2003). Despite the unclear circumstances, Maryland's seafood industry sustained about a $43 million loss due to the public's reaction to the outbreak, even though crabs, oysters, and shellfish were not affected (McCord 2000).

Nutrient management plans, regulating poultry and other farmers' nutrient application in order to reduce nutrient runoff entering the watershed, were created due to the 1997 *Pfiesteria* incident (Horton 2001). Some farmers feel these plans are doing more harm than good, increasing paperwork and costs, while reducing crop yields for their already fragile businesses (Dewar 2000). It was feared that these new regulations would push poultry farms out of business, but so far this has not been the case, says Heather Dewar, of *The Baltimore Sun* (2000). Influenced by the media, the public was quick to blame agriculture for the *Pfiesteria* incident; however, other factors may be at fault (Horton 2001). Other sources of pollution such as chemically-treated lawns, impervious surfaces, and sewage treatment plants need to be brought to the public's attention (Horton 2004).

Most citizens blame agriculture as the major contributor of nitrogen pollution. Dave Juday, of the Hudson Institute's Center for Global Food Issues, believes that the dumping of raw sewage from urban sewage treatment plants nationwide is the number one contribution to nitrogen pollution (Juday 2003). Septic systems contribute about 4 percent of nitrogen to the Chesapeake Bay, and sewage treatment plants are an even larger contributor (Marx 2005). Recently passed legislation, the 'flush tax', imposes a modest monthly fee for Maryland citizens connected to the sewer system, as well as those with septic systems. The money collected from this new tax is used for Bay restoration efforts, in the form of upgrading sewage treatment plants (Marx 2005). Before this law was passed, the Chesapeake Bay Foundation conducted an opinion poll which demonstrated a 72 percent approval rate for the sewer tax, indicating the public is willing to pay a small fee to help fund the Bay's restoration (Marx 2005).

While the costs associated with operating and owning farmland have risen drastically over the recent decades, the price of food has remained constant (Dewar 2000). This means that consumers are spending a smaller percentage of their income on food than prior years, even though the cost of food production has steadily increased (Dewar 2000). Another public perception regarding local farmers is that they receive subsidies to either grow, or not grow, crops. In reality, the recipients of 72 percent of subsidies are agribusinesses (*The Baltimore Sun* 2005). Nearly two-thirds of Maryland farms are too small to qualify for subsidies (*The Baltimore Sun* 2005).

As the population in Maryland increases, there is more suburban sprawl due to the demand for additional housing (Rodricks 2005). While there has been progress made in the Bay's water quality by reducing agricultural pollution, the exponential population growth shadows these gains in the Bay's water quality (Horton 2004). Additionally, the EPA reports that it is cheaper by the acre to regulate agriculture runoff than urban runoff (Horton 2004). The general consensus is that agriculture is the biggest nutrient polluter, but there also needs to be focus on the smaller sources of pollution. After all, agriculture is producing our food while the other sources of pollution might not be associated with a similar benefit.

Informing the public about agricultural practices may be the best way for individuals to formulate educated opinions. Some individuals, for example, are opposed to the use of pesticides on crops; however, they only want to buy blemish-free produce (Reynolds 2005). This places the farmer in a predicament, because without the use of pesticides, blemish-free produce cannot be produced in large enough quantities to fill demand. In order to fill grocery stores with aesthetically pleasing produce without the use of pesticides, the farmer would have to grow a considerable amount of additional produce than can be sold to particular consumers. This would increase the cost of food production therefore increasing food prices. Many individuals may not be willing or able to pay the higher cost of produce to support blemish-free demand. If consumers fully understood the process of food production they may realize although a tomato may not look perfect, it is still healthy and full of flavor.

Perhaps most importantly – education is what is most needed to reduce the disconnect between the public and farmers. Uniting the public, farmers, businesses, and government is the way to achieve success in pollution reduction. Often it takes an incident like *Pfiesteria* to cause change in opinions and in laws (Dewar and Horton 2000). These types of events are helping to educate people that worldwide, nitrogen is the biggest contributor to water pollution (Dewar and Horton 2000). In addition to providing more agricultural supports for farmers, reducing driving, buying fuel-efficient cars, reducing meat intake, and consuming locally produced foods are all practices that individuals must adopt to help curb nitrogen pollution (Dewar and Horton 2000). Farmers need greater support from the community to prevent the continual disappearance of farmland. Through economic support and education, the government can work alongside farmers to achieve the best policies and regulations that are both economically and environmentally less costly.

How Farmers Obtain Information

Information on agricultural production methods and practices are available from a wide range of sources although some sources of information might be associated with particular types of motives. By far, the most common method a farmer might use to obtain useful information is from direct communication with another farmer. Research has shown that farmer networking is a crucial factor in transitioning to sustainable agriculture methods (Badgley 2003, Gregory 2004). If a farmer incorporates a new conservation practice on his farm and he has witnessed both financial success and environmental sustainability as a result of its incorporation, other farmers will be more likely to give this new practice a try (Gregory 2004). In Minnesota, a project promoting rotational grazing was successful because farmer-to-farmer information exchange increased farmer confidence in the economic viability of the new practice (Badgley 2003). Farmers may offer both the support and expertise after implementing new methods with success on their farms (Gregory 2004).

Extension services play a major role in supplying farmers with the resources that are needed to ensure their farm is an economically and environmentally viable operation. Extension education is important in assisting farmers in adopting conservation practices. A variety of services are available, and research has shown that farmers rely upon the technical assistance available from extension resources to develop conservation structures and practices on their farms (Gregory 2004). Maryland Cooperative Extension, which is a part of the College of Agriculture and Natural Resources at the University of Maryland, offers a large amount of information that may be helpful to farmers (MCE 2005b). They provide academic extension programs, seminars, and publications concerning agriculture (MCE 2005b). Many of the publications are free and can be downloaded online (MCE 2005b). Their website contains information about growing crops, raising livestock, and starting a nursery/greenhouse business (MCE 2005b). Pamphlets that provide guidance on pesticide application, raising beef cattle, growing all types of crops, nitrogen management, life insurance for farmers, and no-till corn production, just to name a few, may be downloaded free or purchased from this site (MCE 2005b). Links are also provided on the Maryland Cooperative Extension site to the Small Farm Institute, Nutrient Management for Maryland, and Commodity Marketing which all provide additional information for farmers (MCE 2005b).

In addition to extension services, governmental and non-profit programs make available a wealth of information on agriculture. Websites are often an easy and effective way for these organizations to spread their objectives. The main purpose of the United States Department of Agriculture (USDA) website is to assist farmers in the production of high quality products (USDA 2005a). They offer information about eradicating diseases in livestock and poultry and controlling insects and weeds (USDA 2005a). To ensure maximum yields for the farmer, the USDA routinely inspects seeds and fertilizers before distribution (USDA 2005a). They also study market reports and statistics so they may assist farmers in planning their farm management practices (USDA 2005a). The USDA has links connecting to information about education, outreach, laws and regulations (USDA 2005a). The Maryland Department of Agriculture website lists many links that may assist farmers such as County Agriculture and Land Use Information, Maryland Cooperative Extension, Maryland Agriculture Organizations, US Agriculture Links, and Rural Maryland Council (MDA 2005a).

The Maryland Agriculture Web Links site is maintained by the Maryland Cooperative Extension and contains a lot of agricultural links. These links provide farmers with helpful agricultural, educational and government web sites, agricultural associations and organizations, agricultural suppliers and equipment dealers, financial institutions, and publications and software (Maryland Agricultural Web Links Undated).

Information about the Small Farm Success Project may also be found online. This site is managed by a coalition of land grant universities, the USDA, and many non-profit organizations in the Mid-Atlantic region (Small Farm Success Project 2005). The coalition's goal is to help small and/or new farmers achieve financial success (Small Farm Success Project 2005). The funding for this project is provided by the USDA's Initiative for Future Agricultural Food Systems and its intention is to help farmers use research effectively and offer them direct marketing strategies (Small Farm Success Project 2005). They also assist farmers in implementing sustainable farming practices like crop rotation (Small Farm Success Project 2005).

The Natural Resource Conservation Service (NRCS) also offers links to various helpful agricultural sites. They provide conservation programs that assist farmers in adopting conservation practices (Natural Resource Conservation Services 2005a). The NRCS also offers technical information to farmers on the best methods of farming to adopt that also protect the natural resources (Natural Resource Conservation Service 2005a). They provide a link to the farmer's local USDA Service Center (Service Center Locator 2005). This site contains the address and directions to USDA Service Centers in specific Maryland counties (Service Center Locator 2005). These service centers allow farmers to access all information available from the Farm Service Agency, Natural Resource Conservation Service, and the Rural Development agencies (Service Center Locator 2005). Part-time farmers have stated that they would really benefit from an on farm one-on-one personal consultation on conservation planning from an NRCS staff member (Gregory 2004). This is because part-time farmers work during the day and are unable to visit the NRCS during office hours preventing them from obtaining the forms and guidance needed to participate in governmental cost-share and incentive programs (Gregory 2004).

The Sustainable Agriculture Research and Education (SARE) program, which is part of the USDA's Cooperative State Research, Education, and Extension Service, may also be accessed online (SARE 2005). The program provides funding for projects and employs coordinators who hold statewide seminars to inform farmers about sustainable agriculture methods (SARE 2005). These coordinators also act as points of contact for activities and sustainable agricultural information specific to each state (SARE 2005).

However, farmers must often rely on agricultural supply and consulting companies for recommendations on practices such as applying fertilizers. Southern states and similar cooperatives and corporations provide soil tests for farmers to help them decide the nutrient needs of each of their fields. These soil tests are sent to analytical laboratories where the basic soil chemistry is determined and recommendations for nutrient application are made. A & L Eastern Laboratories is a local firm that provides such soil tests for Southern States and other agriculture consulting agencies. Their basic test involves analysis for organic matter, available phosphorus, exchangeable potassium, magnesium, calcium, hydrogen, pH, and cation exchange capacity (A&L Labs Undated). A primary source of nutrient pollution, nitrogen, is never directly tested. The estimated nitrogen release is extrapolated from organic matter data, but the lab admits that this is only an approximation of the total amount of nitrogen available for plants (A&L Labs Undated). Therefore, recommendations are being made by the laboratory and by the consulting firm to the farmers that are not based upon actual data. In a time when nitrogen input by farmers is subject to high levels of governmental regulation (via detailed nutrient management plans), it seems very odd to require and permit soil tests that do not even test for the nutrients being regulated. It seems very unfortunate that the testing agencies can provide no information about the nutrient that causes most of the problems and that farmers are called upon to most drastically reduce. As a crucial source of information for farmers, this failure on the part of testing agencies severely impairs a farmer's ability to reduce nutrient input effectively.

Overall, farmers are becoming increasingly aware of agricultural methods that both harm and help the environment. Fairly new regulations, such as nutrient management plans, ensure that all practicing farmers are aware of the problems created by nutrient pollution and the practices that cause this to occur 'or' can prevent pollution. Other state and federal programs that offer monetary incentives for instilling best management practices and conservation methods into agricultural operations spread the environmental messages to farmers. In the Chesapeake Bay Watershed, runoff from farms has been declining, in no small part due to nutrient management and runoff control techniques adopted by farmers (Chesapeake Bay Program 2005). It is vital that farmers can easily access information on sustainable agricultural practices, both for their economic success and for the protection of our natural resources. Farmer to farmer communications will likely be the most useful technique in spreading conservation practices, but these communications must be supplemented by technical support from extension services. Non-profit and governmental agencies must be willing to share information with farmers in a way that does not place additional burdens on farmers' valuable time and economic constraints. The web sites are wonderful but they require computers, high speed Internet access, and time. Finally, those corporations in a position to make recommendations to farmers must do so in an environmentally responsible way, which includes testing soil not only for a product's potential uses but also its potential damage. By improving both the quality of information that is available to farms and the networks through which this information is disseminated, the ability of farmers to adopt responsible farming practices will increase.

Urban sprawl and Development Pressures

The EPA acknowledges that managing population growth with proper development is one of the biggest problems for the Chesapeake Bay both today and for the future (Blankenship 1995a). Maryland has the 19th largest population in the country with a density of 529 people per square mile (6th most densely populated) (Knapp et al. 2003, Goldstein 2004). In 1950, the Maryland population was 2.3 million people and has increased to a population of 5.5 million people in 2003 (Goldstein 2004, Hanson 1998). The Maryland Department of Planning expects the population to rise to 6.1 million by 2020 (Goldstein 2004). The problem is that development is diffusing out of the city and other urban areas and is moving into open spaces of the countryside (Knapp et al. 2003). The increase in population can be attributed to the prospering economy that supports a large job market for many commercial industries. With a good job market, nearby industries encourage internal immigration of people from surrounding states (Knapp et al. 2003). The population growth is also due to a low death rate and a steady birth rate, resulting in a population consisting of more people who live for longer periods of time (Knapp et al. 2003). We are faced with a growing population some of which is urban but much of which is suburban.

Another factor that contributes to sprawl in Maryland is that individuals can have the picturesque American dream of nice green lawns and all the creature comforts of the country within a short commute to a large metropolis that holds many opportunities for employment. For many years the relatively low cost of gas and more fuel efficient vehicles paired with “better” schools and safer neighborhoods made the commute from surrounding suburban and rural areas worth the expense, encouraging many people to disperse out of the city (Blankenship 1995b). Between 1949 and 2001 Maryland lost 48% of its farmland, while in contrast, the U.S. only lost 19% of its farmland (CANRP 2004). However, the rate of lost of farmland in Maryland is slowing despite the increase in development (CANRP 2004). This trend is due to the slow rate of development in the most rural counties and the increased rate of development in more suburban counties (Knapp et al. 2003). The farms that have the highest risk of development are in the more urban areas where most of the development is occurring (CANRP 2004). To protect the highest risk farms, policies such as Smart Growth were developed.

Smart Growth policies are designed to encourage growth in current urban areas in order to preserve rural land and prevent the development of these rural lands (Knapp et al. 2003). Some of the Smart Growth policies that encourage environmentally conscious decisions are Live Near your Work, Rural Legacy Program, Priority Funding Areas Act, and Job Creation Tax Credit Program (Knapp et al. 2003). Although Maryland is one of the leading states with respect to Smart Growth policy and advocacy, these Smart Growth programs are not as effective in preserving open spaces and natural habitats including farmland as policymakers had hoped (Knapp et al. 2003). Policy for guiding urban development and the preservation of rural land (forest, farm, and open space) began in the 1970's with the State Planning Act, which gave the state the authority to act in land disputes (Knapp et al. 2003). Since the 1970's there have been many policies developed in Maryland and in some parts of the U.S. that lay out provisions for development, such as the Smart Growth and Neighborhood Conservation Initiative in 1997 (Knapp et al. 2003). The main goal of these policies is to encourage growth in the Priority Funding Areas of current urban areas and restrict growth in outlying suburban and rural areas (Boesch and Greer 2003). All of these policies designate zoning and urban growth boundaries that prevent intensive land use development beyond designated areas, therefore preserving more rural areas from development (Knapp et al. 2003). Through the purchase of easements for more than 51,000 acres of farmland in the first five years, the Smart Growth Rural Legacy Program has protected some of our natural land, but this is not preventing the development of existing farmland (Knapp et al. 2003). The government is unable to give farmers the market value for their land due to the lack of funding; therefore the best alternative is to sell the land to developers who can pay the current market value (Greer 2005a). There is a disconnect between the state growth management program and the local growth management programs (Knapp et al. 2003). The state government should require more detailed growth management plans from local governments that include housing capacities and municipal service accommodations and require local governments fill the existing priority funding areas rather than expanding them or creating new zoning regulations (Knapp et al. 2003).

The high value of land in Maryland paradoxically contributes to the decline in farmland. The value of land in Maryland is among the 5^{th} most expensive in the nation (MCE 1997). The increase in land value makes the asset value of farmland increase therefore making financing loans much less difficult, but this increase in value also makes the alternative of selling the land more enticing for the farmer (CANRP 2004). The average value of a farm in Maryland in 2000 was $501,000 compared to the U.S. average value of $429,000 (CANRP 2004). This shows that there is an increase in demand for land outside of the Priority Funding Areas which supports sprawl. Most development in Maryland has occurred in areas surrounding metropolitan areas, where the market value of housing rose 54% between 1991 and 2002 (Knapp et al. 2003). The majority of land being developed (75%) today is low-density housing (Knapp et al. 2003). From 1985 to 1993 there was a 36% increase in the lot size per household and fewer people per household (in 1970 ~3.2 people per household and in 1990 ~ 2.4 people per household) (Blankenship 1995b). According to the Maryland Department of Planning, the prices of housing in Baltimore City are depressed, and both the vacancy and ownership rates of the city are declining due to the decrease in demand for homes in the city (Knapp et al. 2003).

Selling farms and other natural land areas have impacts on the environment, society, and the economy. For the farmer, the increase in the value of the land has made selling their farmland more attractive than their current labor of love, farming, which typically has low cash returns relative to other sources of income (CANRP 2004). The decreased number of farms and the physical separation between existing farms causes hiring labor, supplying materials, and marketing products to be more difficult and more expensive (CANRP 2004). If the loss of farms continues it may reach a point where the agricultural industry of Maryland could collapse and become no longer commercially viable (CANRP 2004). Environmental impacts of the increase in development outside of urban areas include creating more impervious surfaces, more travel time in cars, a decrease in natural habitat, and an increase in demand for municipal services (sewers, schools, infrastructure, etc.) (Blankenship 1995b). The increase in travel time in cars increases air pollution. Cars produce one third of the nitrogen oxides emitted into the atmosphere, and they leak other harmful toxins that eventually run in storm water (Blankenship 1995a). Atmospheric nitrogen oxides are deposited onto the land and water contributing to nitrogen pollution. An increase in cars also creates a demand for more roads and other infrastructures that can alter the hydrology of surrounding habitats such as wetlands, forests and streams (Blankenship 1995a). The altered hydrology can cause flash flooding of streams (increasing sediment in streams and eroding stream banks), change in the position and quality of water tables, and overwhelm sewers and septic systems by increased storm water runoff from increased impervious surfaces (Blankenship 1995a). The growth of suburban development in districts that are not designed for such an increase in population can also overwhelm public services such as schools and wastewater treatment facilities (Boesch and Greer 2003). Many of the new developments outside of Priority Funding Areas have septic systems, which are less efficient at nutrient removal than sewers (Blankenship 1995a). The typical homebuyer of new homes in suburban developments desires open space and the more populated the suburban development becomes the further out individuals must move to acquire the desired open space (Boesch and Greer 2003). Consequently, this creates a perpetual cycle of moving further and further from metropolitan areas (Boesch and Greer 2003).

Maryland is not losing resource based land areas just because of population growth; the State is losing land because of where people are moving. People are migrating out of the metropolitan areas in what was the country (CANRP 2004). Many people work in urban areas, therefore sustaining the economy; however, as more individuals move out of these urban areas there is a decrease in the amount of money that is able to be recycled within these local urban economies (Boesch and Greer 2003). This migration makes it much harder for these urban areas to rejuvenate their public service facilities such as schools, roads, and sewage treatment plants (Boesch and Greer 2003). Many people move out of urban areas seeking better schools. With time, this produces a larger number of students within the non-urban area thereby reducing the quality of schools. This defeats the initial purpose of moving to a different district (Boesch and Greer 2003). The population growth in rural areas creates many problems for the infrastructure of these communities and for the farming community's economic viability in these areas. This makes it more difficult for businesses to acquire the basic necessities for farming (supplies, labor, community support, and marketing) (CANRP 2004).

Loss of Farms and Farmers

The number of farms and land in farms has decreased by 63% and 48% respectively since the 1950's (MCE 1997). This decrease is due to the increase in property value, the increase in the age of a typical farmer, a decrease in new farmers, and the increased cost of farming (CANRP 2004). Although the increase in property value makes farm asset values increase, it also makes the purchase of more land more difficult and the selling of current farmland more appealing to farmers (Boesch and Greer 2003). When the selling of farmland becomes the best alternative for economic viability, current farm communities become fragmented. The more fragmented the farm community becomes the more difficult and costly it is for farmers to purchase supplies, market their products, and find quality employees (CANRP 2004). Because farmers seem to be blamed for many of the current environmental problems and because the cost of farming is increasing due to regulations, farmers are not very supportive of big government (Greer 2005b). Although, many farmers are dependent on subsidies, because of weak local and international markets, they do not like to be dependent on the government for financial stability (CANRP 2004, Greer 2005a). Farmers are not very active in the development of policy and they are not commended for their efforts as a community to control their impact of the environment (Greer 2005a). As a result of new regulation, there is an increase in the burden of management (financial and executive) for farmers and pessimism from new homeowners toward accommodating the needs of the local farming lifestyle (traffic, odors, equipment) (CANRP 2004). Due to the influence of the media, many of the new homeowners are inhospitable to the needs of farmers (Knapp et al. 2003, CANRP 2004). These resulting impacts make entering the agriculture industry less appealing to younger generations (CANRP 2004).

One of the biggest concerns for farmers today is the succession of their farms to younger generation farmers since fewer people under the age of 35 want to enter the industry (Greer 2005b). The average age of farmers today is 55 years old and only 3.2 percent of farmers in 1997 were under the age of 35 (CANRP 2004). Today's generation can find off-farm employment with higher wages and fewer labor demands in the surrounding urban areas (CANRP 2004). The high demand for cheap goods is creating a weak market for high production cost agricultural goods and therefore causing low returns for farmers (CANRP 2004). Also, the high demand for suburban housing is creating a strong market for the development of land, which is inflating the cost of land (Knapp et al. 2003). As the farm community diminishes, the voice of the farmer becomes weaker and the market demands of the greater population drown out the needs of the farmer (Greer 2005a). If the number of farms and farmers continue in a downward trend, the agriculture industry may reach a point where the industry would no longer be economically sound and the industry in Maryland could collapse (CANRP 2004). This would be a terrible loss to the citizens of Maryland.

Why Farmers are Important

Agriculture is important socially, economically, and environmentally. Farming communities exemplify core family values, create a sense of community, and demonstrate a work ethic upon which many individuals base their ideals. The idea of a farmer comes with the sense of unity and passion for what they do. Farmers are stewards of the land—reducing the disconnect between society and the environment. As a result of their passion for farming, they fight to maintain their position in society. Preserving farmland is a struggle today; the nation needs a louder unified voice for its protection. The open spaces of undeveloped land are important simply for aesthetic purposes, maintaining natural places in all communities. Although farmland is not a non-impact land use, it does reduce impervious surfaces, cycles nutrients, and conserves natural landscapes and habitat. Farming is a keystone industry in rural economies; the disappearance of this industry may result in the collapse of many local Maryland economies (CANRP 2004). One eighth of the state's employment is in agriculture related industries such as cultivation, processing, packaging, and exporting food (EPA-MAIA 2001). Despite these many beneficial functions of farms, they are not without some cost. The question is what role do they truly play in the degradation of the environment?

II. History of Conventional Farming

Changes in Farming Methods and Technology

Farming has seen many changes over time, but the plow has always been considered the most important tool for tillage (Beyer 2001). During the 19th century, oxen were replaced with American horses, which were used for pulling plows until tractors were invented (Culpin 1992, Beyer 2001). The moldboard plow was developed in England during the 1800's (Beyer 2001). Thomas Jefferson brought his sketches of the moldboard plow back to Virginia when he returned from France at the end of the 18th century (Mountford 2004). Jefferson wanted to make improvements to the European plow that would make it lift and turn more efficiently and with the least amount of force necessary so fewer animals would be needed to pull it (Martin and Stanton 1988). His improved plow was known as the "moldboard of least resistance" (Martin and Stanton 1988). The design of Jefferson's plow was simple enough for the most inexperienced craftsman to duplicate (Martin and Stanton 1988).

Figure II-1: A model of Jefferson's moldboard plow, photo by Skip Johns (http://www.monticello.org/reports/interests/moldboard.html)

The modern moldboard plow was standardized by 1870 and improved with various attachments such as the colter, which is a sharp blade or disk that cuts into the ground in advance of the share (Plowshare 2003). The share is a sharp steel wedge on the plow that cuts topsoil loose (Culpin 1992). The moldboard plow was the first plow to invert soil, which resulted in covering crop debris (Beyer 2001). Covering crop debris allows the nutrient value of the debris to become incorporated in the soil (Beyer 2001). However, critics argue that the crop residue gets buried too deep, thus preventing the decay which is required for nutrients to be released to the soil (Sullivan 2003a). The moldboard inverts the soil by creating a furrow and a furrow slice (Beyer 2001). The first slice is inverted to the right of the furrow and the next is inverted into the previously-formed furrow (Beyer 2001). The furrows are usually six to twelve inches deep and ten to eighteen inches wide (Beyer 2001). Almost none of the topsoil is left on the surface, which exposes the soil to erosion and results in an impairment of the water and mineral cycles in the soil (Sullivan 2003a). The moldboard plow was considered the most significant contributor to soil erosion before the invention of the bulldozer (Mountford 2004).

Even in the 18th century, Thomas Jefferson stated seeing "our soil running into the rivers" and advised his friend to plow horizontally on sloped surfaces to prevent this from happening (Mountford 2004). Before 1776, only 21% of the landowners in Charles County, Maryland, owned plows and only 2% of the land had been cleared. However, after 1776 this number rose to 73% of landowners owning plows and 40% cleared land (Chesapeake Bay History 1999). The deforestation and plowing of coastal land resulted in a significant amount of soil erosion (Chesapeake Bay History 1999). Widespread plowing marked the beginning of sediment and nutrient leakage into the Chesapeake Bay (Chesapeake Bay History 1999). At first, fish and shellfish flourished from the input of nutrients, but nutrients became a big pollution problem for the Bay after 150 years of nutrient leaching (Chesapeake Bay History 1999). A rapid increase in the region's population resulted in a movement of people into the Piedmont, and by the late 1700's into the Appalachian valley (Chesapeake Bay History 1999). Heavy plowing in the piedmonts was disastrous because of the region's steep slopes and highly erodible soil (Chesapeake Bay History 1999). Ports around the Bay filled up with sediment and became too shallow for navigation (Chesapeake Bay History 1999).

The 1930's were hard for the American farmer (Ganzel 2005). The world suffered a global economic slowdown, which became know as the "Great Depression" (Ganzel 2005). People did not have enough money to buy the crops and/or animals that farms produced, thereby greatly reducing the farmers' incomes (Ganzel 2005). The Great Plains suffered its worst drought in history, which made it impossible to plant or harvest crops (Ganzel 2005). This resulted in many farmers losing their farms (Ganzel 2005). Some of the farmers moved west to the Great Plains searching for any work they could find and some moved to the west coast and became migrant farm workers (Ganzel 2005). Money was in short supply, but some farmers managed not only to survive but found the money to invest in new agricultural technologies like bigger and better tractors and combines (Ganzel 2005). The adoption of new methods of farming changed their lives and farming forever (Ganzel 2005).

Soil analysis became a very useful tool in farming as early as 1939 (Reich Undated). The goal of soil testing was to provide counseling to farmers on such issues as how much fertilizer should be applied to obtain an optimum yield, or how much lime should be applied to raise the pH of the soil (Reich Undated). Over time, the soil amendment recommendations derived from the analyzed results gained credibility for increasing the desired characteristics of crops and lowering agricultural costs (Reich Undated). The North Carolina Department of Agriculture and Customer Service (NCDA&CS) adopted the first local program for soil analysis. The NCDA&CS analyzed 65,000 soil samples in 1940 and 85,000 samples in 1949 (Reich Undated). Many environmentalists were at first concerned by the results, which could have led to the use of more fertilizer (Reich Undated). However, the fertilizer was now being placed in the right places at the appropriate time which helped to avoid nutrient leaching (Reich Undated). Other states and nations wanted to see the results of the soil testing program in order to establish similar programs of their own (Reich Undated). By the 1960's farmers were spending 10-20% of their gross income on fertilizer and lime, based on the results of the soil tests (Reich Undated). In 1999, the NCDA&CS analyzed over 300,000 soil samples (Reich Undated).

The 1940's brought about a revolution of farming practices (Ganzel 2005). There were many technological advances in agriculture during this era. These advances included the creation of combines, rubber-wheeled tractors, hybrid seed corn, modern pesticides, electricity, and indoor plumbing (Ganzel 2005). The revolution in farming came about as a direct consequence of World War II (Ganzel 2005). The war brought an end to the Great Depression and created a greater need for American farmers to feed the world (Ganzel 2005). As farming techniques advanced, farmers began producing more food in less time (Ganzel 2005).

Productivity increased as a result of the creation of better machines to use on the farm (Ganzel 2005). The tractor became smaller but more powerful, and the creation of self propelled combines replaced threshing which is the process of removing the grain from the stalk (Ganzel 2005; Implements Used on the Farm 1999). Hydraulic systems were invented to control the three-point hitch, lift more weight, and improve precision (Ganzel 2005). Machines replaced operations that before had to be done by hand (Ganzel 2005). The invention of hydraulics was also instrumental in the design and manufacture of large implements for tractors (Ganzel 2005).

Tractors replaced horses because it took more time and money to produce food for horses than buy gas for tractors (Ganzel 2005). In 1915, 93 million (27%) acres of farmland was used to grow feed for horses and cows, but by 1960 only 4 million acres were being used to grow feed. This created more available land for the growth of cash crops (Ganzel 2005). There was also a downside to using a tractor; dependency on outside sources for fuel made farms less self-sufficient (Ganzel 2005).

Even though farmers now had the money to spend on equipment during the early 1940's and were expected to produce more food, tractors were still in limited supply (Ganzel 2005). Companies that once manufactured tractors were now making military vehicles. These companies were ordered by the government to make a limited supply of any product that was not war related (Ganzel 2005).

The planting of new crops also began in the 1940's (Ganzel 2005). The USDA publicly encouraged the growth of soybeans, which contain 36% protein in each bean (Ganzel 2005). Soybeans, which are legumes, fix atmospheric nitrogen in their root system. Nitrogen fixation reduces fertilizer costs and naturally replenishes nitrogen-depleted soil, which makes them a valuable crop to grow in rotation (Ganzel 2005). Soybeans may also be grown in acidic soil and have the ability to tolerate limited rainfall (Ganzel 2005). The combine was adapted to harvest beans (Ganzel 2005). Farmers often plowed the soybeans into the soil to provide nutrients for next year's crops (Ganzel 2005). By the 1940's, the United States was exporting soybeans (Ganzel 2005). The USDA also began creating new hybrid varieties of beans that could produce higher yields and were resistant to diseases (Ganzel 2005).

In the 1930's, the science of producing hybrid plant varieties was discovered for corn (Ganzel 2005). Corn was the first hybrid seed that was mass marketed, and economically it is still the most important cash crop grown in the United States (Ganzel

2005). Hybridization involves the crossing of two pure lines of plants (Ganzel 2005). The hybrid plant is more vigorous and produces higher yields than its parents (Ganzel 2005). Today, 99% of corn grown in the United States is grown from hybrid seeds (Ganzel 2005).

In 1943, the first hybrid soybean, known as "Lincoln," was produced (Ganzel 2005). Many other hybrids followed and new markets were developed for new soybean products (Ganzel 2005). During this time, soy oil was used in the manufacturing of plastics, soy meal was put in livestock foods, and soybeans had even become a small part of the human diet (Ganzel 2005).

The manufacture and use of fertilizer greatly increased in the 1940's (Ganzel 2005). As early as the 1940's, scientists and farmers knew the importance of the sixteen essential nutrients for crop production, but they did not know how to produce the millions of tons of nitrogen, phosphorus, and potassium that was needed for crops (Ganzel 2005). Phosphorus was produced by chemical processes and/or the mining of phosphate rock (Ganzel 2005). The use of "normal superphosphate" fertilizers peaked in the 1940's (Ganzel 2005).

Nitrogen was one of the chief components of TNT and other explosives that were manufactured during World War II (Ganzel 2005). The United States built ten new manufacturing plants during the war to supply nitrogen for bombs (Ganzel 2005). By the end of the war, these plants were producing 730,000 tons of nitrogen per year, and had the capacity to produce 1.6 million tons of nitrogen (Ganzel 2005). After the war was over, the plants were used to make nitrogen-rich ammonia for fertilizer, which resulted in an increase in crop yields (Ganzel 2005).

During this period farmers also changed their production techniques. Farmers began mono-cropping, which involves planting only one or two cash crops per year

(Ganzel 2005). While this change made for more efficient use of the new equipment, less crop rotation resulted in the depletion of nitrogen in the soil (Ganzel 2005). Thus, fertilizer was needed to artificially restore nitrogen in the soil (Ganzel 2005). By 1943, researchers had discovered how to inject anhydrous ammonia, which has the highest nitrogen content (82.5%) of any fertilizer, into the soil (Ganzel 2005).

Chemical pesticides were introduced in the 1940's (Ganzel 2005). World War II was the first war in which fighting killed more people than disease, partially as a result of new technologies (Ganzel 2005). The insecticide DDT was first developed in 1939 by the Swiss scientist Paul Müller (Ganzel 2005). Since fleas and lice were known to carry typhus, and mosquitoes carry malaria, United States soldiers were supplied with DDT powder to put in their sleeping bags to prevent typhus and malaria (Ganzel 2005). Before the development of DDT, farmers were using arsenic compounds to combat insects on their crops. This use of arsenic resulted in fruit being sold to the consumer that contained arsenic residues (Ganzel 2005). DDT was cheap, persistent, insoluble, and effective (Ganzel 2005). Sales of DDT to the military were $10 million in 1944, but agricultural sales of DDT were $110 million in 1951 (Ganzel 2005). DDT application peaked in 1959, when 80 million pounds were used (EPA 2004). The use of DDT declined after 1959 due to the fact that insects were becoming resistant to it. The public's concern about DDT's increasing adverse effects on the environment also contributed to the decline in its use. Other more effective pesticides were soon developed to replace DDT (Ganzel 2005). However, the success of DDT marked the beginning of the development of other insecticides and herbicides (Ganzel 2005).

Problems with DDT were discovered as early as 1944 (Ganzel 2005). The U.S. Public Health Service warned the public that DDT could be a health hazard if absorbed through the skin and that it was killing beneficial insects and wildlife (Ganzel 2005).

Some flies had developed a resistance to DDT as early as 1946 (Ganzel 2005). In 1949, the first government study on human health problems that were caused by DDT was published (Ganzel 2005). Trace amounts of DDT were also being found in the milk of dairy cows that were being sprayed with the chemical. The USDA warned dairy farmers not to use DDT on milk producing cows, but a full ban on the chemical was never issued (Ganzel 2005).

The 1950's and 1960's saw a decline in populations of predatory birds, which specifically included birds that fed on fish (Bryant 2002). It was known that DDT was toxic at high levels, but people were unaware that even low levels of DDT in birds interfered with calcium deposition in eggshells. This interference caused birds to lay eggs that had thin and fragile shells, which could easily be cracked (Bryant 2002). When the birds were analyzed, scientists discovered a high concentration of DDT in their bodies (Bryant 2002). This led to the discovery that DDT bioaccumulates inside an animal's body, which means that its concentration steadily increases at increasing levels in the food chain (Bryant 2002). DDT does not break down inside the body and is more soluble in fat than in water, which causes it to accumulate in body fat and not be excreted (Bryant 2002). The ban on the use of DDT in the United States took effect on January 1, 1973 (EPA 2004). This ban was called for after three years of an intensive study by the government, which concluded that DDT posed risks to human health and the environment (EPA 2004) as a potential carcinogen (Bryant 2002).

The end of the war signaled the birth of the agro-chemical age (Ganzel 2005). In 1945, 2,4- dichlorophenoxyacetic acid (2,4-D), the first and most important herbicide, was put on the market. In 1946, 631,000 pounds of 2,4-D was sold. By the next year, this amount increased to 5,315,000 pounds (Ganzel 2005). Today, farmers spend $11 billion on pesticides every year (58% on herbicides, 28% on insecticides, 8% on fungicides, and the remaining on other chemicals) (Ganzel 2005). Killing weeds is a farmer's top priority (Ganzel 2005).

Aerial crop dusting using pesticides began in 1929 (Ganzel 2005). After the war, aerial crop dusting became more popular due to the fact that during the war, useful chemicals had been produced for farmers, thousands of pilots had been trained, and thousands of surplus military training aircraft were available (Ganzel 2005). Later planes were designed specifically for crop dusting (Ganzel 2005).

Pesticide regulations were first issued by the federal government with the issuance of the Federal Insecticide, Fungicide, and Rodentacide Act (FIFRA) of 1947 (Ganzel 2005). This bill required pesticide manufacturers to register all chemicals with the USDA and provide a label that states the chemical contents, directions for use, and antidotes if humans ingested it (Ganzel 2005). There were no regulations of these chemicals concerning the protection of the public or the environment during the 1940's (Ganzel 2005). The bill also required the chemicals to be colored to prevent them from being mistakenly used for another purpose, such as baking powder (Ganzel 2005). By 1952, 10,000 separate new pesticides were registered with the USDA (Ganzel 2005).

The 1940's also saw the advancement of irrigation technology (Ganzel 2005). Irrigation was important because it could control the amount of water a crop received and the time of day that a crop gets watered (Ganzel 2005). The number of acres of farmlands that were using irrigation technology during this era had increased by 143% (Ganzel 2005).

The application of petroleum-derived pesticides and fertilizers, and the implementation of numerous government policies starting in the 1950's have provided the United States with the biggest farm economy in the world (Hatherill Undated). Fewer farmers feed more people then they ever fed in the history of farm production (Hatherill Undated).

The success of and changes in farming has not been without consequences (Hatherill Undated). For instance, insects have developed resistance to some insecticides (Hatherill Undated). Broad-spectrum pesticides kill natural predators that could keep the pests in check (Hatherill Undated). The use of synthetic pesticides has increased thirty-three fold in the last half century. Today, 37% of the United States food supply is lost to pests, compared to 31% in the 1940's. Crop losses due to insect damage have almost doubled from 7% to 13% (Hatherill Undated). About 75% of the pesticides used in the United States are applied to soybeans, wheat, corn, and cotton (Hatherill Undated).

Over the last 40 years, ranchers and livestock farmers have fed their poultry, pigs, and cattle low levels of penicillin, tetracycline, and other antibiotics. This type of feeding increases the animal's growth rate and keeps them healthy, thus cutting costs and reducing losses (Hatherill Undated). About one third to one half of all the antibiotics sold in the United States are used for this purpose (Hatherill Undated). Scientists have argued that the use of these antibiotics increases the growth of bacteria that are resistant to antibiotics, thus jeopardizing human health (Hatherill Undated).

Sustainable farming

The idea of sustainable agriculture was hatched in 1980 by Wes Jackson of The Land Institute in Salina, Kansas. The concept came forth due to the growing environmental concern about increased soil erosion, pesticide use, and groundwater contamination (Diver 1994). Jackson wanted to develop an alternative system of agriculture that emphasized resource conservation and quality of rural life (Diver 1994).

The 1985 Farm Bill mandated the Department of Agriculture to start a low-input sustainable agriculture program (Diver 1994). In 1988, the USDA implemented the Low-

Input Sustainable Agriculture (LISA) research and education program (Diver 1994). The program's name was changed to the Sustainable Agriculture Research and Education (SARE) program in 1991 (Diver 1994). This program made funds available for land-grant research and extension programs to focus on sustainable agriculture (Diver 1994).

Sustainable farming has become popular for a number of reasons (Humpert 2000). Many pesticides and herbicides that were commonly used by farmers are now restricted or are gradually being phased out by the Environmental Protection Agency (Humpert 2000). Sustainable farming can also save farmers money by decreasing their dependency on pesticides and herbicides (Humpert 2000). Consumers are now more health conscious, and their demand for organic food has increased by 24% each year since 1990 (Humpert 2000). Some supermarkets are now testing non-organic produce for pesticide residues (Humpert 2000). Today's farmers are being educated by their local Cooperative Extension to understand the importance of organic matter in keeping their soil healthy (Humpert 2000). In addition, farmers are also being criticized by environmental groups for the pollution of watersheds (Humpert 2000). Urban areas are now becoming enmeshed with rural areas, which in effect have caused urban populations to start making demands on farmers (Humpert 2000).

Sustainable farming has three dimensions (Hall and Kuepper 1997). To be a truly sustainable farm, the farm must be economically, ecologically, and socially sustainable (Hall and Kuepper 1997). To be economically sustainable, a farm must be able to generate enough income to support the farm family and to provide the community with an economic base (Hall and Kuepper 1997). To be environmentally sustainable, farming practices must use non-renewable resources efficiently, effectively utilize and store solar energy, and improve water and mineral cycling and recycling (Hall and Kuepper 1997). The community dynamics of the farm rely on biodiversity (Hall and Kuepper 1997).

Social sustainability may be achieved by promoting the physical, spiritual, cultural, and economic health of farm families and the communities in which they live (Hall and Kuepper 1997).

Farm diversity results in farms that are more resilient both economically and ecologically (UCSAREP 1997). Farms are less affected by market fluctuations in supply and demand (UCSAREP 1997). There are many methods that may be employed to assist farmers in sustainable farm management practices (UCSAREP 1997). Crop rotation may help suppress both weeds and insects (UCSAREP 1997). Cover crops may help keep soil and nutrients in place, conserve soil moisture, and increase the soil's water infiltration rate (UCSAREP 1997). The integration of crops and livestock buffer farmers against price fluctuations (UCSAREP 1997). Manure can also be used to enhance soil quality, which decreases the need for commercial fertilizers (UCSAREP 1997).

The main principle behind sustainability is that the needs of the people today must be met, while assuring that future generations will be able to meet their own needs (UCSAREP 1997). Sustainable agriculture varies from farmer to farmer. There are no set rules in place for sustainable farming, but rather many effective procedures that may be implemented for each unique farm situation (Hall and Kuepper 1997).

There are many conservation practices that may be used by farmers to preserve the environment (Gregory 2004). Many of these practices may result in environmental trade-offs (Gregory 2004). One conservation practice may compromise another environmental practice (Gregory 2004). Farmers must take into account all the consequences of every procedure implemented on their farm and make their choices wisely (Gregory 2004).

Sustainable farmers respect the soil and treat it as a living medium that must be protected (UCSAREP 1997). A healthy soil will produce healthy crops (UCSAREP

1997). There are many practices that help produce a healthy soil (UCSAREP 1997). The use of cover crops, crop rotation, compost, and conservation tillage may assist in the enhancement of soil productivity (Humpert 2000, Hall and Kuepper 1997).

For more information about Sustainable Farming practices, see Appendix 1.

Types of Farming

Organic Farming

The public became more aware of organic farming during the 1960's and 1970's (Baker Undated). People became more environmentally aware during this period, after the publication of Rachel Carson's Silent Spring which brought to light ecological problems associated with the use of agricultural chemicals, particularly the use of synthetic insecticides (Baker Undated). The consequences of modern farming practices became evident in the pollution of our watersheds, which led to pesticide regulations (Baker Undated). Consumers began demanding foods grown by farming practices that were not ecologically destructive and did not require the use of toxic chemicals for production (Baker Undated).

Organic farming is one of the methods that can be implemented to achieve sustainability. This method avoids or minimizes the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives (Diver 1994). Organic farming also promotes and enhances biodiversity, biological cycles, and soil biological activity (Kanter 1999). Pesticides that are derived from natural sources are considered an organic source (EPA 2005b). Organic farmers employ other practices such as crop rotations, crop residues, animal manures, legumes, and green manures to protect and enhance the soil. These biological practices help maintain soil productivity and control weeds, insects, and other pests (Diver 1994).

The USDA developed a national program to develop universal standards for organic farming as stipulated in the Organic Foods Production Act (Diver 1994). The intention of part of the 1990 Farm Bill was to lay out national standards, certification requirements, and food labeling for organic products (Diver 1994). Due to lack of funding, the 1990 Farm Bill never took effect (Diver 1994).

On October 22, 2002, the USDA finally issued national organic standards. Any producer or handler of organically grown food must be accredited by the USDA in order to sell, label, or market their products as organic (EPA 2005b).

Conventional Farming vs. Organic Farming

Organic farming accounts for only approximately 1% of the world's total agricultural production (Stacey 2004). However, these percentages are higher in certain regions (Stacey 2004). There are conflicting reports on crop yield differences between organic and conventional agriculture. One source states that crop yields for organic farms are 10 to 30 percent lower, and that crop losses on organic farms are significantly higher than conventional farming systems (Stacey 2004). USA organic wheat yielded 43% less than conventionally grown wheat (Stacey 2004). Other studies show that crop yields increase with organic farming, but these studies are exceptions to the norm. Long-term field studies that were done over 104 seasons (26 years) demonstrated that organic farms were 75% less productive than conventional farms (Stacey 2004). Some scientists believe that organic farming has caused a serious decline in productivity (Stacey 2004). They also state that the widespread adoption of organic farming practices would worsen food security problems and increase the amount of land needed for agricultural purposes (Stacey 2004).

Another source states that results from an eight-year project demonstrated that organic systems had comparable yields to conventional systems when growing tomatoes, safflower, corn and beans. Some of the yields for these specific crops were actually greater in the organic systems (Vasilikiotis Undated). The tomato yields in the study took a few years to reach the conventional systems yields, but eventually surpassed conventional yields (Vasilikiotis Undated). The study's corn production yields in organic systems had a higher variability, which resulted in lower and higher yields than conventional systems during different years (Vasilikiotis Undated).

Organic farming produces a higher organic carbon content in the soil, with larger pools of stored nutrients (Vasilikiotis Undated). Nitrogen availability is a limiting factor in organic systems. This is due to the fact that the high carbon input from cover crops and composted poultry manure, which may be used as fertilizer in an organic system, needs to associate with nitrogen in order to decay (Vasilikiotis Undated). After a few years, the organic matter starts to stabilize, which results in more available nitrogen for crops (Vasilikiotis Undated). The soil on the organic farm was shown to have larger and more active microflora, better soil structure, and more fertile topsoil due to less erosion (Reganold 1992). Higher yields in organic farming systems may be attributed to a reduction in soil erosion and the maintenance of organic matter in soil (Reganold 1992).

In one study, organic farming systems were shown to be more profitable than conventional farming systems (Vasilikiotis Undated). This was attributed to lower production costs and the outperforming of conventional farming systems in dry climates (Vasilikiotis Undated). Other studies have stated that conventional systems have appeared to be more profitable over a shorter time period (Reganold 1992). These results may be attributed to the fact that agricultural research and policy have promoted conventional agriculture over the last four decades (Reganold 1992). Subsidies for conventional farms are greater than those for organic ones (Reganold 1992). If the external costs of repairing the environmental and health damage related to conventional farming systems was shouldered by the farmer instead of the taxpayer, the profitability of conventional farming systems would be much lower (Reganold 1992).

This study stated that both organic and conventional farms have the potential for failing when faced with unfavorable weather or marketing problems. However, alternative farms have a higher diversity of crops and more efficient practices, which leads to a greater chance of succeeding (Reganold 1992). Alternative systems were shown to have lower yields, but operating costs were lower by about the same cash equivalent, which created a net income that was equal for both systems (Reganold 1992). The energy consumption on the organic farm was 66% less than that of the conventional farm (Reganold 1992).

Precision Farming

Precision farming is a method of farming that helps increase productivity, yet at the same time decreases production costs and detrimental effects on the environment (Shibusawa 2002). The key agricultural concept of precision farming is variability, the variability within each field (Shibusawa 2002). The three aspects of variability that a farmer must understand in order to practice precision farming are spatial, temporal, and predictive techniques (Shibusawa 2002).

Variable-rate technology (VRT) is the technique that is used to adjust the agricultural inputs of fertilizers according to the amount that is needed for each part of the field (Shibusawa 2002). The information necessary for variable rate applications is the correct position in the field, the correct information for each location, and the timely application at each site (Shibusawa 2002).

The Global Positioning Satellite (GPS) system was developed approximately 30 years ago by the Department of Defense as a navigational aid for the military (Kolling 1995). In 1992, it became available for commercial use, and the Top-Soil Testing

Service of Illinois was one of the first agricultural consulting firms to offer this technology to farmers (Kolling 1995). Only about three to five percent of the farmers in the United States use GPS systems (Kolling 1995) which are very costly to implement. Farmers may pick up signals from 24 satellites orbiting the earth. These satellites assist them in determining how much fertilizer needs to be applied to each section of their field (Kolling 1995).

A 20-inch antenna is installed on the top of a combine, and a monitor is placed inside the driver's cabin (Kolling 1995). The antenna picks up satellite signals, and these signals inform the monitor of the combine's location within a three to five-foot spacing accuracy (Kolling 1995). Connected to the monitor is a sensor which relays measurements of the amounts of grain growing on any given part of the field (Kolling 1995). The information is displayed on the monitor, and saved on an electronic card inside the monitor (Kolling 1995). The data on the electronic card is then transferred to a computer, which combines the data with up to 50 measurements on soil quality for each 2.5 acre grid (Kolling 1995). This information helps farmers determine the amount of fertilizers and pesticides needed to treat each area of the farm (Kolling 1995). This equipment may help reduce the use of fertilizers and pesticides by 20%, which in turn reduces the cost for farmers and the detrimental effects on the environment (Kolling 1995).

Costs may be a factor in determining if farmers are able to implement precision farming methods (Kolling 1995). The monitor and GPS unit cost between $5,000 and $7,000 (Kolling 1995). The initial soil sampling cost between $5,000 and $7,000 for each 1,000 acres (Kolling 1995). Controllers are also available at an additional cost to automatically apply the correct amount of fertilizer to each section of the field (Kolling 1995). A new truck that automatically controls the fertilizer application may cost up to

$250,000, but an existing fertilizer truck may be modified for about $25,000 (Kolling 1995). These costs might not be economically feasible for small farmers (Kolling 1995).

Farmers who have commercial pesticide licenses believe that precision farming reduces most of the record keeping that is otherwise required (Kolling 1995). Farmers that do not have commercial pesticide licenses would have to employ someone to keep track of their pesticide records (Kolling 1995). These recordings would include the type of pesticide used, the amount used, the location where the pesticide was applied, and the direction in which the wind was blowing. The GPS unit records all this information automatically (Kolling 1995).

Agricultural Biotechnology

Some sources state that biotechnology may be the solution to providing an adequate diet to the 840 million hungry people in the world (Vasilikiotis Undated). Agricultural biotechnology consists of using genetic engineering to improve, create, or modify plants, animals, and microorganisms (Ganzel 2005). Genetic engineering allows specific genes to be transplanted from one organism to another (Ganzel 2005). Genes may be moved among unrelated species, creating plants with novel features that could not have been produced by traditional breeding (Ganzel 2005). Some varieties of these genetically engineered crops may now resist herbicides that used to kill them along with the weeds that were sprayed (Ganzel 2005).

Herbicide-resistant soybeans reduce the need for weed-controlling plowing, decrease the amount of chemical herbicides that need to be applied, increase crop yields, and assist the farmer with getting a healthier harvest at less cost (Ganzel 2005). About 25% of the corn grown in the United States comes from genetically modified seeds (Ganzel 2005). Proponents of genetically engineered crops state that the crops' nutritional value is higher than that of traditional crops, and that they reduce the need for chemicals and pesticides (Ganzel 2005). Proponents also state that genetically engineered crops are known to reduce tillage, improve crop yields, increase drought resistance, and reduce the amount of water that must be applied to produce a healthy crop (Ganzel 2005).

Critics argue that some of the consequences of genetically engineered crops may be the extinction of microbial, plant and animal species, and the potential contamination of all non-genetically engineered life forms (Genetically Engineered Crops Undated). The majority of genetically engineered crops do not produce higher yields (Vasilikiotis Undated). Monsanto Company, a leading provider of agricultural products, claims that the genetically engineered Roundup-ready soybeans produce greater yields than regular soybeans (Vasilikiotis Undated). A report reviewed 8,200 university trials in 1998, and found that the Roundup-ready soybeans actually produced a 7 – 10 % less yield than natural soybeans (Vasilikiotis Undated). The report also discovered that farmers used five to ten times more herbicide (Roundup) on the genetically modified soybeans (Vasilikiotis Undated). The only advantage to using the Roundup-ready soybeans was that it simplified the management of large-chemically intensive farms and allowed these farms to spray larger doses of herbicides from planes on crops (Vasilikiotis Undated).

Other critics question whether biotechnology is environmentally safe (Ganzel 2005). They are concerned about herbicide resistant “super weeds” that may be produced if genes from genetically modified plants escape through cross fertilization (Ganzel 2005). Plants that produce their own pesticide and/or herbicide may also encourage the development of insects that are resistant to the chemical, which in turn could produce “super bugs” (Ganzel 2005). Another aspect that needs to be considered is whether the food made from bioengineered crops will have a toxic or allergic effect on the human body (Ganzel 2005).

The European Union does not want genetically engineered crops as a part of their food supply (Ganzel 2005). They placed a moratorium on imported bio-engineered crops in 1997, which caused the United States export of corn to Europe to decline from $191 million a year before the ban, to less than $2 million in 2002 (Ganzel 2005).

Critics also argue that genetically engineered crops will not solve the starvation problem in poor countries (Pretty 1998). The technology is expensive to develop, with the cost estimated at $1 million per gene (Pretty 1998). Companies also expect to recoup their costs in addition to making huge profits (Pretty 1998). It is also argued that hunger is a problem of poverty, distribution of food, and access to food (Vasilikiotis Undated). Many large farms in third world countries grow luxury crops for export rather than growing staple foods for their own growing population (Vasilikiotis Undated).

Important Maryland Agricultural Products

Growing tobacco as a cash crop was established in Southern Maryland in 1635 (USGS 2003). In colonial times, tobacco was used as currency in Maryland (Yancy 2004). The air-cured, low tar, and nicotine tobacco grown in Maryland was known as "Type 32" (Barnes 2001). This type of tobacco was highly favored by Europeans (Kelderman 2001). Tobacco auctions were a fixture in Maryland for its entire 367-year history (Kelderman 2001). The tobacco was packed in barrels and shipped to Baltimore for auctions until 1939, when the auctions were moved to Southern Maryland (Kelderman 2001). The demand for tobacco declined over the years as the public became convinced of health hazards associated with its use. In 1999, the Maryland's State government agreed to a Master Settlement Agreement from the major tobacco companies (Yancy 2004). The state government agreed to give 5% of the settlement to the Maryland farmers (Yancy 2004). This marked the loss of the oldest cash crop in Maryland history (Barnes 2001).

By 2004, 780 (77%) of Maryland's eligible tobacco farmers had signed on for the Maryland Tobacco Crop Conversion program, which was otherwise known as the "tobacco buy-out" (DeGregorio 2004). This "tobacco buy-out" began in 2001. Tobacco farmers that signed the contract agreed to convert their crop production from tobacco to any crop of their choice. By joining the program, farmers also agreed to keep their property in some sort of agricultural production for the rest of their lifetime (Barnes 2001). Farmers' payments from the State of Maryland were based on average tobacco crop sales in pounds during 1987 through 1999 (Barnes 2001). The settlement paid the farmer $1 per average pound for ten years (Barnes 2001). If the farmer happened to die within the ten years, the payments would be paid to the farmer's estate (Mussendon 2000). If the land was sold to a new owner, the new owner would not be bound by the ten-year contract (Mussendon 2000). One stipulation of the agreement was that it allowed participants to grow tobacco as long as it was not used for human consumption or smoking (Mussendon 2000). Participants may also help non-participants on their tobacco farms for a limited time, with permission (Mussendon 2000). If the agreement is violated, farmers could be taken to court and forced to re-pay the buy-out money with six percent annual interest (Mussendon 2000). The average payment to each farmer is $11,000 per year (DeGregorio 2004). The intention of the buy-out payments was to help farmers transition into growing a new crop, but the average tobacco farmer is 62 years old, which is older than the age of the average Maryland farmer (DeGregorio 2004). Most of the older farmers are not interested in learning how to raise new crops, so they are using the buy-out money as a retirement fund (DeGregorio 2004). Finding a new niche market for the tobacco farmers has also been difficult (DeGregorio 2004).

Broilers are the most important agriculture product in Maryland, with a market value in 2004 of $583 million dollars (Myers 2004). Broilers also consume more grain than the state of Maryland produces; therefore, Maryland farmers are paid a premium for their corn and soybeans (Hansen 1998). They are paid approximately 40 cents per bushel more than corn prices in the Eastern Corn belt (Hansen 1998). Production in Maryland of grain and oil crops like canola and sunflowers would drop greatly if broiler production declined (Hansen 1998).

Over the past 20 years, the number and size of chicken farms on Maryland's Eastern Shore has increased dramatically, and broiler production has become a major component of the Eastern Shore's economy (Natural Resource Defense Council 1998). Runoff from poultry manure applications poses a serious pollution problem for the Chesapeake Bay (Natural Resource Defense Council 1998). The Eastern Shore has a very shallow groundwater table, which makes it highly susceptible to nitrogen pollution (Natural Resource Defense Council 1998). The type of soil being fertilized with chicken manure has difficulty assimilating the nutrients due to the fact that the soil is already phosphorus-rich. This could have been caused by past applications of manure and/or the soil's natural makeup (Natural Resource Defense Council 1998). There are hundreds of chicken houses on the Eastern Shore that raise more than 300 million chickens annually (Bay Journal 2004). These chicken houses produce approximately 720 million pounds of chicken manure, which contains twice as much phosphorus as the human waste generated by Maryland's entire population annually (Natural Resource Defense Council 1998). A typical chicken farmer in Maryland raises 200,000 chickens annually, creating enough nitrogen and phosphorus in the manure to fertilize more than 100 acres of crops (Natural Resource Defense Council 1998). This amount is twice as large as the average farm size (Natural Resource Defense Council 1998). Forty percent of the nitrogen and 48 percent of the phosphorus entering the Chesapeake Bay comes from manure (Natural Resource Defense Council 1998).

A study by the University of Maryland estimated that if Maryland's poultry production decreased by as little as four percent, 1,000 jobs and $74 million would be lost from our state (Goodman 1999).

Trends in Farming: Statistics

Agriculture has been important to the economy in Maryland and in the entire United States. In the last half century, agriculture has experienced downward trends in scale and in the economic viability of the industry. Today, the future of agriculture in Maryland is questionable. As well as being a vital part of the states economy, farming has also prevented land throughout the state from being lost forever to urbanization. In losing farms, Marylanders also lose the general understanding and the distinct culture of farming as a way of life.

Of the total 6.2 million acres of land in Maryland, the number of acres devoted to farming has decreased by 50%, from 4.2 million acres in 1945 to 2.1 million acres (CANRP 2004). The average rate of loss of farmland has decreased from 65,000 acres per year in 1945 to 7,800 acres per year in 1997 (CANRP 2004). In spite of the declining rate of farmland loss, the Natural Resource Conservation Service ranks Maryland fifth in the country for its percentage of developed land that is used for urban uses (roads, housing, industry, commercial). Sixteen percent of Maryland's land area (1.25 million acres) is characterized as urban (CANRP 2004). Therefore, as the percentage of farmland has decreased in Maryland from 87.7% in 1973 to 81.6% in 1997, the percent of urban land uses has increased from 12.3% in 1973 to 18.4% in 1997 (CANRP 2004). Even though farmland is declining, the agricultural industry is still a very important sector in Maryland's state economy and culture. Agriculture contributes an average of 3% of the state product and yields an annual revenue of $17 billion (EPA 2001).

Along with changes in the amount of land devoted to farming, the size of farms has changed. Between 1949 and 1978, the average size of farms increased from 112 acres per farm to 168 acres per farm (CANRP 2004). Although the total acreage of farmland has decreased, the average size of Maryland farms today is 172 acres per farm and has been in that range since the 70's (USDA 2005b). This increase in the average size of Maryland's farms can be attributed to the increase in corporate owned and managed farms and a decrease in family owned farms. In 1974, there were approximately 13,000 family owned farms and 500 corporate owned farms. By 2002, the number of family owned farms decreased to 10,000 and the number of corporate owned farms increased to 725 (USDA 2005b). The total number of farms in Maryland has decreased from 15,163 farms in 1974 to 12,190 farms in 2002 (CANRP 2004). The average value of land and buildings per acre in Maryland has quadrupled from $184,000 in 1974 to $694,000 in 2002 (USDA 2005b). Maryland's land is rated fifth most expensive in the United States (MCE 1997). This increase in the value of land makes it much more difficult for an individual or a family to purchase land in order to increase farm size or to enter the agricultural industry.

Trends in the decreasing number of farms and land devoted to agriculture are not only characteristics of Maryland, but also for the entire Mid-Atlantic region (CANRP 2004). The main reasons for these trends are caused by the urban development pressures of suburban sprawl and increasing populations. In addition, economic pressures caused by weak markets and costs of environmental regulations (local, state, and national) contribute to the decline. While the average age of the Maryland farmer is increasing and fewer young Marylanders are drawn to farming, smaller more diversified farms try to corner the more specialized markets. The variety in terrain and environmental conditions in Maryland enables farmers of different regions in the state to focus on different types of agricultural production, while advances in technology allow fewer farmers to produce all the food this nation requires. Less than two percent of the United States' population is involved in the production of the nation's food supply. The decrease in the amount of land used for farming causes the remaining farmland to be farmed more intensely and the former farmland to be open to further development.

The Environmental Movement

Pioneers of the United States settled in the New World with the pre-ingrained mindset of materialism and human domination over the environment (Kline 2000). The idea that worth consisted simply of materialistic possessions was encouraged by religious beliefs and scientific reasoning originating from the Middle Ages and Enlightenment (Kline 2000). These beliefs sanctioned the idea of inferiority of nature to man (Kline 2000). Natural resources were exploited and poorly managed turning fertile land into exhausted and eroded land (Kline 2000). The majority of land throughout the United States was expended in a reckless, unabated manor during the 1400's through the 1700's (Kline 2000). Settlers perceived the land as being an inexhaustible resource that could supply an infinite amount of resources to support human needs (Kline 2000).

At the turn of the 19^{th} century, during the Industrial Revolution, individuals such as Emerson, Thoreau, and Catlin began to endorse an alternative view on the environment (Kline 2000). They believed that the value of the environment far outweighed what was gained economically from its exploitation (Kline 2000). However, during this time environmentalists were a minority in the United States who chose to ignore costs and focus on mechanization and advancement in technology (Kline 2000). The majority of farmers embraced the age of innovation, which allowed them to farm more land and dramatically increase their yields (Kline 2000). With the same mentality seen in owners of encroaching factories, farmers began to see the success of mass production, cost efficiency, and profits (Kline 2000). This new economic perspective replaced the environmental friendly relationship that farmers once had with their land (Kline 2000).

Despite the negative environmental impacts that were caused by the industrial revolution, society continued to strive for prosperity and ignore environmental degradation. The repercussions from centuries of exhausted farm land and resources became alarmingly evident throughout the early 1900's. The Great Dust Bowl was a time of hardship and poverty for farmers who could no longer produce significant yields to support human populations (Kline 2000). Farmland soil was no longer fertile enough to produce crops, which resulted in massive soil erosion on farms throughout the U.S. (Kline 2000). In 1933, the Roosevelt administration decided to tackle the Great Depression problem through a series of policies and programs that were aimed at promoting economic growth and the interests of society (Kline 2000).

Consumption continued to be the indicator of success and prosperity; however, more attention was focused on the management and conservation of the nation's natural resources (Kline 2000).

Environmental policies have changed since the realization that farmland provides ecosystem services by simply existing. Ecosystem services are natural processes that benefit humans and are not accounted for in any economic markets (Fields 2001). Exploiting an ecosystem to the point that it can no longer provide environmental services will actually decrease the value of the land for human activity (Primack 2002). When the governments of Bangladesh, India, Thailand, and the Philippines realized that catastrophic floods were directly related to extensive logging, they implemented massive tree-planting programs in the Himalayas (Primack 2002). Plants and other organic materials in the environment decrease the impact that rain has on soil and plant roots, which creates a more stable environment for soil dwelling organisms (Primack 2002). This stability allows organisms to become more efficient in aerating the soil which also increases the soil's absorption capacity (Primack 2002). Even though humans do not pay to maintain this process, the economic burden is certainly felt when ecosystem services are not functioning and cities are destroyed as a result. Based solely on the wetland's ability to prevent flooding in the Boston, Massachusetts area, its value is estimated to be $72,000 per hectare (Primack 2002). In order to improve the quality of drinking water, New York City's government paid $1.5 billion dollars to rural counties in New York State to preserve forests in the watershed and improve farming practices (Primack 2002). If the city would have chosen to use technology to replace ecosystem services, such as water filtration plants, it would have cost $8-9 billion (Primack 2002).

In the past people had been able to ignore the many negative environmental effects of exhausting natural resources. However, now that people are aware of how the loss of ecosystem services negatively impacts economic markets they have become more willing to protect ecosystems. This slight shift in mindset signified the onset of the environmental conservation movement and the proper atmosphere for the creation of environmental policies to come.

Agricultural Policies

Agricultural policies are regulated by the federal, state, and local government. Many federal laws related to food and agriculture are considered, revised, and renewed through the Farm Bill. It also lays out budget plans regulating how much can be spent on specific agricultural programs (2002 Farm Bill). Federal agricultural policies are currently regulated under the 2002 Farm Bill and the next revision will be in 2007. The

2002 Farm Bill had ten titles including: commodities, conservation, trade, nutrition, credit, rural development, research, forestry, energy, and miscellaneous (2002 Farm Bill). Programs and policies are established, changed, and regulated under each title. The United States Department of Agriculture (USDA) is currently holding public forums regarding the 2007 Farm Bill to discuss strategies and address current and future needs (USDA 2005c).

Founded in 1862 by President Abraham Lincoln, the United States Department of Agriculture (USDA) was established to provide leadership in public policy, science, and management (USDA 2005c). The USDA is divided into a number of different agencies; one of the most important is the Farm Service Agency. The Farm Service Agency (FSA) administers its services through its state, district, and county offices. Its mission is to stabilize farm income, help farmers conserve land and water resources, provide credit to new or disadvantaged farmers or ranchers, and provide disaster relief for farming operations (USDA 2004). FSA's services include: farm loans, financial inquiries, price support, conservation programs, disaster assistance, commodity operations, and environmental services.

The Farm Service Agency makes it a priority to act in accordance with the National Environmental Policy Act of 1969 (NEPA). This act requires federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and developing reasonable alternatives to these actions (EPA 2005c). Each FSA State Office has a State Environmental Coordinator whose job is to provide oversight, support, and training to District and County personnel to ensure that NEPA compliance is fully implemented (USDA 2004). FSA have also established programs such as the Conservation Reserve Program (CRP). Agricultural landowners who volunteer to participate in CRP can receive annual rental payments in exchange for enacting environmentally sound policies. They may also receive cost-share assistance which helps them set up long-term conservation practices (USDA 2004).

The 2002 Farm Act allows FSA to help farmers with programs such as marketing loans and direct payments (USDA 2004). Some farmers and ranchers are temporarily unable to establish private, commercial credit; therefore FSA provides credit counseling and supervision to them. Farmers can apply for Farm Storage Facility loans which grant them money to build or renovate storage structures, or install grain handling and drying equipment (USDA 2004). Marketing assistance loans give farmers alternatives to selling crops during harvesting periods when prices are low. When prices rise, the farmers have an opportunity to pay back the loans (USDA 2004).

State governments also have their own policies and programs to regulate agricultural practices. As a result of the growing importance and economic influence of agriculture within the state, the Maryland General Assembly created the Maryland Department of Agriculture (MDA) in 1972 as a primary agency within the state government (MDA 2005b). Acting primarily as a regulatory agency, MDA is also committed to public service, education, and promotional aspects of agriculture. MDA's primary goal is to "achieve excellence in programs and in services that preserve and protect agricultural resources and the environment, promote profitable agriculture and consumer confidence, and enhance the quality of life for all Marylanders" (MDA 2005c).

Specifically for the purpose of targeting the health of the Chesapeake Bay, the Chesapeake Bay Critical Area Law was passed by the Maryland General Assembly in 1984 (SCCW 2005). The law was created to link development to the declining health of the Bay (SCCW 2005). The Critical Area Law was the first legislation in which the state and local government recognized the negative effects of land development on habitat and aquatic resources (Critical Area 2005).

These federal and state programs, along with local ones, work together to establish regulations and policies that suit a specific area and address specific issues. Nutrient management is a key issue in the agricultural business nationwide. Plans for nutrient management are developed for different areas based on policy requirements from the Natural Resources Conservation Service (NRCS). Nutrient planning is based on soil tests developed in accordance with the Land Grant University (USDA 2003). These tests analyze nutrients in the soil to get specific information that will help create a nutrient plan. The tests are conducted by state certified programs, the North American Proficiency Testing Program, or any laboratory whose tests are accepted by the Land Grant University in the state in which the tests are to be used (USDA 2003). Plans are then developed that specify the source, amount, timing, and application method of nutrients on each field to achieve realistic production goals while minimizing nitrogen and phosphorus movement to surface and groundwater (USDA 2003).

Nutrient management is extremely important to the State of Maryland because of the high value that the public places on the Chesapeake Bay. Upon hearing the public's desire for a cleaner bay, the Maryland Nutrient Management Program was established by the MDA and University of Maryland/Maryland Cooperative Extension to initiate the reduction of nutrient runoff from agricultural non-point sources (MCE 2005b). Approximately ten years after the implementation of MNMP, the Water Quality Improvement Act (WQIA) was created to accelerate the progress of improving the health of the Chesapeake Bay watershed (MCE 2005b).

All farmers grossing $2,500 a year or more and those who are livestock producers with 8,000 pounds or more of live animal weight are strictly required under WQIA to follow the guidelines within the Nutrient Management Program (MDA 2005d). The nutrient management regulations were put into effect in May 2005 to assist in the implementation of WQIA by administering a licensing and certification program for consultants, compliance activities, and education and training programs (MCE 2005c, MDA 2005e).

The Cost Share Assistance for Nutrient Management Plans is a sub-plan within MACs. As required under the Water Quality Improvement Act, farmers must submit a Nutrient Management Plan, and the Cost Share program provides financial assistance to farmers who hire a private, non-governmental consultant to develop or update a nutrient management plan for their farms (MDAORC 2004). For those farmers wishing to manage and create their own nutrient management plan, the Maryland Cooperative Extension was developed, and made available to the public, "NuManMD," which is advanced software for the sole purpose of Nutrient Management Planning (MDA 2005f).

There are currently a number of government sponsored incentive policies for farmland preservation. On the state level there are programs such as The Maryland Agricultural Land Preservation Foundation (MALPF), which was created in 1977 to "preserve sufficient agricultural land to maintain a viable local base of food and fiber production for the present and future citizens of Maryland" (MALPF Undated). An effective public policy that MALPF and other organizations nationwide offer is the property rights policy known as conservation easements. This policy allows property owners to sell development rights to a conservation organization or government agency for the purpose of protecting land from development in the future. Private owners still own the land, but they give up the right to subdivide or develop it. This is fairer than other policies because the price is mutually agreed upon between buyers and sellers, so the price accurately reflects the value of the land. This internalizes the positive social values of the land that may not usually show in the price of the land. State and local governments have spent over $1.5 billion to purchase development rights to private lands and by doing so nearly two million acres of farmland had been protected through 1995 (Miller 1995). Through the purchase of easements, Baltimore County has preserved 27, 438 acres of farmland with the private sector preserving 500 acres per year (Helfin 2000). Baltimore County has the highest number of privately donated easements in the State of Maryland (Bartenfielder et al. 2000). These privately donated easements represent the equivalent of millions of dollars donated to the county's easement programs each year (DEPRM 2001).

The Use Value Taxation policy taxes agricultural land for the value at its existing use, rather than for its potential best use. This benefits farmers by encouraging them to stay in business even when they feel pressure to develop their land (Lawrence 1997). The downside of this policy is that land may be used for a different purpose than if there was a uniform tax applied to it; therefore the farmers get all the benefits, and the non-farming land owners are at a loss (Lawrence 1997). Another current policy is agricultural zoning. This grants local governments the authority to regulate which farmlands are preserved. This policy is controversial because some farmers may argue that it is not fair to designate particular land for agriculture when some may want to develop it. It is also difficult for a farmer to decide which land should be preserved since different aspects of land are more or less valuable to different people.

Land trust programs are nonprofit conservation organizations that aim to protect natural, scenic, recreational, agricultural, historic, or cultural property. The United States currently has almost 900 independent land trusts that have helped protect nearly 2.7 million acres of land (Lawrence 1997). Land trusts are organized by citizens who are concerned about the loss of open land, farmland, and other resources in their communities (DEPRMa 2005). Land trusts can be local, regional or statewide. Baltimore County's Department of Environmental Protection and Resource Management (DEPRM) works with the county's land trust assisting with mapping, documentation and grant implementation (Bartenfielder et al. 2000). Each of the county's land trusts has been awarded state and county funds under Maryland's Rural Legacy Program (DEPRMa 2005). Baltimore County landowners have preserved over 12,000 acres through land trusts (Bartenfielder et al. 2000).

Zoning is a major source of land use control in Baltimore County (DEPRMb 2005). Baltimore County's zoning regulations protect the county's agricultural industry (Bartenfielder et al. 2000). Land use and development regulations and standards are adopted by the Baltimore County Council (DEPRMc 2005). The Baltimore County zoning regulations specify what land uses can be developed on a piece of property based on the property's designated zoning classification (Heflin 2000). The Development Regulations elaborate the procedures required to subdivide and develop land, including requirements for the preparation and review of site plans (Bartenfielder et al. 2000). The Department of Permits and Development Management is the principal agency responsible for administering site plan reviews (Weaver 2002). Baltimore County has the Development of Prime and Productive Land Ordinance, which directs a landowner to maintain farm use on a specific property (Bartenfielder et al. 2000).

III. Environmental Issues Related to Farming

Nutrients

The use of fertilizer in agriculture is thousands of years old, though its use has changed significantly over the last few hundred years. Some early forms of fertilizers used by ancient civilizations are plant residues, manure, wood ashes, human bones, and human wastes (Eckert 2000). Around 400 years ago, scientists began studying plants in order to enhance the productivity of crops for farmers and the growing population. After considerable experimentation it was found that there are minerals in the soil that plants need, including nitrogen, phosphorus, and potassium. Early agricultural chemists soon learned that when fields were let to be fallow (left vacant of crops for a season), the essential nutrients were replenished assuring a successful crop when it was finally used. Early research also revealed that yields increased when chemical fertilizers were added (Eckert 2000).

Types of Fertilizer

Ammonium sulfate and ammonium chlorides, which were used at the turn of the 20th century, were among the first types of manufactured fertilizers. Currently, the most common fertilizers used for agriculture are anhydrous ammonia, urea, ammonium sulfate, and ammonium nitrate (Mosaic Company 2005). All of these fertilizers provide nitrogen in forms that plants can use readily, but differ in their specific molecular structures and nitrogen content.

Anhydrous ammonia contains 82% nitrogen and is a gas under normal conditions (Mosaic Company 2005). It is obtained as a liquid under pressure and is applied directly into the soil to avoid any loss of ammonia to volatilization (Mosaic Company 2005).

After being applied, the fertilizer dissolves and is converted to NH_4^+, a form that can be used by plants. Of all the nitrogen fertilizers, anhydrous ammonia is the slowest form of fertilizer to convert to nitrate, which dissolves in water and is easily leached (Vitosh 1995). This is beneficial to the environment because it yields the smallest chance that nitrate will be lost to leaching (Vitosh 1995). Anhydrous ammonia, when applied to the soil, lowers the pH of the soil in and around the area of application (Mosaic Company 2005). At first, this can be harmful to surrounding crops and slow their growth. This change is temporary, because the soil returns to its normal conditions after a couple weeks (Mosaic Company 2005).

Urea $[CO(NH_2)_2]_2$ is 42 % nitrogen and can be bought in solid and liquid forms. Urea is converted to ammonium carbonate fairly quickly due to an enzyme in the soil called urease (Eckert 2000). Plants use urea nitrogen after it has been broken down into ammonium; it is then converted to nitrate. Since nitrate dissolves in water, urea produces nitrate rather rapidly. Urea nitrogen is more susceptible to leaching than other fertilizers (Vitosh 1995). If the ammonia is not attached to the soil it can be lost to volatilization, which occurs when soils are warm and moist (Eckert 2000). Urea needs to be applied when climate and soil conditions are right, to decrease the chance of leaching.

There are also nitrogen fertilizers which are solutions of urea and/or ammonium nitrate dissolved in water. They normally contain between 19-32 % nitrogen; the one most commonly used is urea ammonium nitrate (Eckert 2000). These types of fertilizers are very efficient because they can be combined with herbicides and applied in irrigation water. They can be applied by injecting or banding into the surface of the soil. This method of application is good in places with no-till to minimize the loss of urea to volatilization (Eckert 2000).

Ammonium nitrate contains 34 % nitrogen and is used as a solid fertilizer. It is also found in many types of dry and liquid fertilizers. This type of fertilizer contains both usable forms of nitrogen in NO^{3-} and NH^{4+} (Eckert 2000). Ammonium sulfate is another type of fertilizer, but it is not used very often. It is used in special situations because of its sulfur content (Eckert 2000). It contains 20 % nitrogen and 24 % sulfur. Soils with sulfur deficiencies would benefit from ammonium sulfate.

Recommended nitrogen fertilizer rates are different from place to place and need to be followed closely so that there is no harm done to the environment, and farmers do not incur unnecessary cost. The recommended rates depend on a number of factors that include the crop being grown, yield goal, and quantity of nitrogen that might be provided by the soil (Eckert 2000). The decisions needed to determine rates are usually acquired by the farmer through soil practices, local recommendations and experience (Eckert 2000).

Alternative Fertilizer Use

There are other forms of nitrogen available as fertilizer for crops. Organic compost, manure, and plant waste all contain nitrogen. Organic materials do not have as much bioavailable nitrogen as commercial fertilizers do. When contemplating using organic materials, the carbon-nitrogen ratio needs to be considered (Barbarick 2005). A fertilizer or organic compost with a C:N ratio of 20:1 has enough carbon to supply organisms in the soil with energy and enough nitrogen for the soil organisms to synthesize proteins, which leaves enough nitrogen for plants and crops to use (Barbarick

2005). Sawdust, which is a plentiful source of organic material, has a C:N ratio of 400:1, which means that if used it, would not supply crops with adequate nitrogen (Barbarick 2005). Some commercial fertilizer would need to be added to adjust the ratio. When this type of organic compost is available, the cost of buying fertilizer and the amount of applied nitrogen, which has the potential to be leached into groundwater, can both be lowered.

One form of adding or retaining nitrogen in crop fields is through the use of legumes. Legumes, which include peas, alfalfa, soybeans and clover, replenish nitrogen in the soil. Bacteria that inhabit the root nodules of legumes fix atmospheric nitrogen (Deacon 2005). The root nodules contain rhizobia, which convert atmospheric nitrogen into a form that is usable for plants (Deacon 2005). These crops are often planted after crops like corn, which use tremendous amounts of nitrogen to help replenish the soil.

Nutrients and Water Quality

Agriculture has been reported to be the primary cause of non-point nitrogen and phosphorus pollution to waterways (Carpenter et al. 1998). This occurs because there are usually more nutrients added to soils as fertilizer than are removed by crops (Carpenter et al. 1998). The nutrients that are left in the soil after the crops are harvested become susceptible to nutrient runoff. It has been estimated that only 18% of nitrogen added to soils as fertilizer leaves as produce in the United States (Carpenter et al. 1998). Nitrogen is usually more likely than other nutrients to run off or be leached out of the soil because it is soluble in water (Smith and Smith 2001). Nitrogen can escape from the original site of application through runoff, infiltration, and volatilization (Carpenter et al. 1998). Phosphorus tends to build up in soils because it is not easily leached (Smith and Smith

2001). This can become a problem when phosphorus finally does leach into waterways, it will enter the water in large doses. Manure runoff is also a major source of non-point pollution (Carpenter et al. 1998). The issues that are associated with manure are similar to the issues of human waste (Carpenter et al. 1998). Human waste disposal is regulated and processed and is therefore point source pollution; however, excess manure is very common on farms and can be used to fertilize crops, therefore making it a possible cause of non point source pollution (Carpenter et al. 1998).

Just as crops require nutrients for growth, aquatic vegetation, such as algae, requires nutrients as well. In the natural environment, aquatic vegetation will continue to grow until there is not enough of one essential nutrient to continue growth. This nutrient is considered limiting, in that the vegetation is limited in its ability to grow by the amount of the limiting nutrient present in the environment. When nutrients are added to waterways, this limiting nutrient often becomes available in excess, and the first response to the increased nutrient is an increase of algal growth (Carpenter et al. 1998). This increase in algal growth causes the water to become clouded and turn a green color, which, in turn, blocks sunlight from reaching the bottom of the waterway where many organisms live (Carpenter et al. 1998). The lack of sunlight lowers the rate of photosynthesis in plants and decreases the amount of biological habitats due to possible dead zones (Carpenter et al. 1998). Additionally, the abundance of algae increases the population of the bacterial decomposers, by providing them with an excessive food source as the algae dies and sinks to the stream or lake bed (Carpenter et al. 1998). The respiration rates of the bacterial community quickly exhaust the dissolved oxygen supply within the lower depths of the body of water (Carpenter et al. 1998). An extreme loss of dissolved oxygen makes it very difficult for fish to survive, resulting in fish kills (Carpenter et al. 1998). Algal blooms may also release toxins into waterways resulting in red and brown tides (Carpenter et al. 1998). These tides are not only harmful to the organisms that live in the waterways but they can be harmful to humans and other terrestrial animals (Carpenter et al. 1998). These impacts from excessive inputs of nutrients are collectively referred to as eutrophication. The damage that results from eutrophication imposes a great threat to the health of the waterway. The chain of events initiated by the addition of nutrients moves throughout this complex ecosystem, ultimately resulting in a marked decline in health of the entire ecosystem.

Nutrients and Soil Quality

Plants utilize nutrients, water, and gasses in the soils for plant growth, maintenance, and reproduction. A hypothetical healthy soil is composed of about 25 percent water, 25 percent air, 7 percent organic matter, and 43 percent mineral constituents (Hull 2005). The capacity of a soil to produce plants is termed the soil productivity (Hausenbuiller 1985). The best or maximum plant growth for productive soils occurs when the factors essential to growth are optimal (Hausenbuiller 1985). If any of the factors are below optimal for plant maintenance and growth, then that factor is said to be limiting. For instance, depending upon location, nutrients such as N, P, or K tend to be limiting in terrestrial ecosystems (NCDA&CS 2005).

Nutrients are absorbed by plants through leaves and roots. Most carbon dioxide intake occurs through the stomata in leaves, but water can be absorbed other ways as well (Donahue et al. 1977). The majority of water that enters the plant takes place in the soil via root systems (Donahue et al. 1977). Available soil nutrients, in the form of ions attached to particles and in the soil/water solution (Donahue et al. 1977), are absorbed by plant roots across a concentration gradient from the soil to the plant (Hull 2005). The availability of soluble soil nutrients is largely affected by pH (Donahue et al. 1977).

The pH of soils may determine the equilibrium state of certain nutrients, thus affecting the concentration of soluble nutrients available for plant uptake. The cation exchange capacity depends upon the dynamic of pH variation (Hausenbuiller 1985). As the soil pH increases, so does the cation exchange capacity, and as pH decreases, so does the ability of plants to absorb ions (Hausenbuiller 1985). Acidic soils can make nutrients unavailable to plants, and could also cause the leaching of nutrients into ground water and streams (Donahue et al. 1977). Acid soils tend to accumulate organic or inorganic acids that may affect the ability of microorganisms, especially bacteria that break down organic materials (Donahue et al. 1977). Highly acidic soils also tend to release toxic amounts of minerals detrimental to plant growth, such as aluminum (SUNY-ESF 2005). Under basic conditions, micronutrients are less soluble and phosphate may become locked up (Donahue et al. 1977). The ideal soil pH for optimal plant growth is between 6.0 and 7.0 (CETS-UMES 2004). This provides the optimal environment for the nutrient requirements of most plants.

Other factors involved in soil productivity are aeration and porosity within soils. Air and water are located in the pore spaces between organic materials and sand, silt, and clay particles. The supply of oxygen in the soils' pore space is variable depending on water conditions within the soil (Hausenbuiller 1985). Oxygen is necessary for the expansion of roots, and plant respiration (Hausenbuiller 1985). Waterlogged soils tend to be less productive for most agricultural purposes (Hausenbuiller 1985), and lack of gaseous oxygen also inhibits microbial breakdown of organic matter (Hausenbuiller 1985). Porosity is important for gaseous exchange because larger pores drain quickly after rain events (Hausenbuiller 1985). Clayey soils tend to have small but numerous pore spaces and hold a lot of water. For this reason, loamy soils containing sand, silt, and clays are the best suited for agriculture. Loams hold enough water for plant requirements, and they provide enough aeration that plants require as well (Donahue et al. 1977).

Water is an important catalyst for soil formation and is an essential factor in the production of plants. It is also responsible to some extent for fluctuations in soil temperature (Hausenbuiller 1985). Water is the medium by which nutrients in the form of soluble ions reach plants, so plants require a regular supply of water for growth and maintenance (Donahue et al. 1977). Soil erosion occurs when water from heavy rain events flows over and through the top of the soil. The amount of water a soil can hold is called its field capacity (Hull 2005). When the field capacity is reached the soil is too saturated to hold any more water, so some of the water runs off into streams or will percolate as groundwater flow. When water moves as overland flow or percolates to groundwater flow, it has the capacity to transport nutrients to water sources.

Properties of Nitrogen and Phosphorus

Nitrogen plays an important part in the mechanics of plants (Eckert 2000). Nitrogen is necessary for photosynthesis, the mechanism by which plants use to gain energy from water, carbon dioxide, and sunlight (Eckert 2000). Nitrogen is the most abundant element on Earth, making up about 79 % of our atmosphere in its gaseous state. This form of nitrogen (N_2) is unusable by plants and animals because of its triple bond

(Deacon 2005). Because it is unusable by plants, it needs to be converted or fixed into usable forms by fixation, decomposition, and nitrification (Eckert 2000). Usable forms of nitrogen include ammonium (NH_3^-), nitrite (NO_2^-), and nitrate (NO_3^-). Nitrogen is fixed into usable forms by:

- Atmospheric fixation - Lightning rips apart nitrogen molecules allowing them to combine with oxygen (nitrogen oxides). These are dissolved in rain to form nitrates (Deacon 2005).
- Biological fixation - certain bacteria can use N_2 and the enzyme ATP to produce ammonia, which can gain a proton to become ammonium (Deacon 2005).
- Industrial fixation - commercial fertilizer manufacturers create fertilizer in various ways, such as the Haber-Bosch process (Deacon 2005).

Nitrogen travels through nutrient webs just as energy travels through food webs. At each trophic level, organisms consume nutrients and dispose of them in the form of wastes. Microorganisms in the soil break down this waste and simultaneously release ammonia, allowing nitrogen and other nutrients to be returned back into the soil. Nitrification adds bioavailable nitrogen to the soil through bacteria. Ammonium can be taken up directly by plants, but most of it is converted into nitrates in two ways:

- Bacteria, *Nitrosomonas* oxidize NH_3 to nitrites (NO_2^-) (Deacon 2005)
- Bacteria, *Nitrobacter* oxidize the nitrites to nitrates (NO_3^-) (Deacon 2005)

Denitrification converts nitrates back to N_2 gas (Deacon 2005). Denitrification is accomplished by bacteria that live in anaerobic conditions and use nitrates as an alternative to oxygen during respiration (Deacon 2005). This can result in major losses of nitrogen when soils are warm and remain saturated for more than a few days.

Phosphorus is essential for photosynthesis and it is a major constituent of the nuclear parts of cells, however it only constitutes a small part of the atmosphere (Smith and Smith 2001). Phosphorus is only available to plants when it is in its fixed form, which is known as phosphate (Smith and Smith 2001). When phosphorus is lacking in the soil, the plant is probably suffering from a nutrient deficiency (Hopkins 2003). When phosphorus is present in the soil in excess, the plant is probably suffering from nutrient toxicity (Shober et al. 2003). Phosphorus reacts with clay, iron, and aluminum compounds, and is converted to less available forms by the process of phosphorus fixation (Griffith 2005). Because phosphorus is fixed in the soil, it moves very little and stays close to its place of origin, which results in minimal leaching into groundwater (Griffith 2005). Phosphorus is lost primarily through soil erosion and crop removal (Griffith 2005). Phosphorus is also present in certain types of manure and it can be used as fertilizer in agricultural practices (Hopkins 2003).

Suggestions for Reducing Nutrient Pollution

There are many different approaches that could be taken to reduce the amount of nutrient pollution entering waterways. The most obvious approach is to reduce amounts of nutrients added to soil by fertilization (Carpenter et al. 1998). The amounts of fertilizer applied should be limited to the amount of nutrients that the crops require for growth, rather than applying them in excess (Carpenter et al. 1998). By lowering inputs of nitrogen and phosphorus, the likelihood of excess nutrients entering waterways will decline (Carpenter et al. 1998). Another solution to nutrient pollution is wetland restoration (Carpenter et al. 1998). Wetlands are sites of denitrification; denitrification allowing more nitrogen to be released into the atmosphere through volatilization thereby decreasing the amount of nitrogen entering aquatic ecosystems (Carpenter et al. 1998). Over the years there has been a decrease in the number of wetlands in Maryland, so it is very important that wetland restoration become a priority (Gresens 2005). Also, vegetation along waterways forms a riparian buffer, which traps nutrients before they enter the water (Carpenter et al. 1998). Riparian buffers can be replaced where they have been removed or enlarged as necessary. Cover crops will also help to decrease nutrient pollution (Carpenter et al. 1998).

Another important way to regulate nutrient pollution is to monitor livestock waste (Carpenter et al. 1998). In order to control livestock waste it is necessary to monitor it and create regulations similar to those set for human waste (Carpenter et al. 1998). By doing this, livestock waste would change from non-point source pollution to point source pollution, which is much easier to regulate and control (Carpenter et al. 1998). This transformation would make it easier to lower the amount of pollution released into our waterways.

Erosion

Soil erosion is the movement of soil particles by wind or water (Smith and Smith 2001). Erosion is a natural process, accelerated by farming activity that removes topsoil, reduces levels of soil organic matter, and contributes to the breakdown of soil structure (Crosson and Stout. 1983). The reduction of levels in organic matter and the breakdown of soil structure in turn affect soil fertility, the movement of water into and from the soil surface, and crop yields (Foster et al. 1985). The problem may become so severe that the land can no longer be cultivated (Brown and Wolf 1984). A study at Iowa State University on forty soil samples reported that the impact of soil erosion on soil productivity was largely determined by subsoil properties because they effect root growth, soil water availability, and plow layer fertility (Al-Kaisi 2000).

Soil is often removed from landscapes by erosion faster than it can be replaced (Smith and Smith 2001). A loss of only one thirty-second of an inch can represent a five ton per acre soil loss (USDA 1996). Once the top layer of soil is removed it exposes the layers below that are less stable, which are then susceptible to erosion (CBF 2004). The loss of the topsoil can have considerable impact on yield where nutrient availability, root growth environment, and soil water availability are essential for plant development (Vanderwel and Abday 2001).

Soil erosion often occurs as a result of rainfall runoff, or wind and tillage (National Academy of Sciences 1986). Soil erosion is effected by: rainfall, crop rotations, amount of crop cover, soil type, topography, length of fallow time, cultivation practices, size of machinery, size of fields, height and type of field boundaries (hedges, trees, woodlands) (Dickey et al. 1984). Other causes of soil erosion include: construction, agriculture, leaving a field empty after it is harvested, tillage of soil, and increased slopes (USDA 1996). Soil erosion causes sediment to run into waterways (Smith and Smith 2001). Carried within that runoff are all of the nutrients that are in the top layer of soil (Smith and Smith 2001). When these nutrients enter waterways the result is eutrophication (CBF 2004). Eutrophication, a process where water bodies receive excess nutrients that stimulate plant growth causes increased algal growth (Smith and Smith 2001).

Wind erosion is most common on flat land or on a hilly landscape (Smith and Smith 2001). When soil erosion occurs it removes the top layer of soil, also known as humus, which is nutrient rich and contains organic matter (CBF 2004). This results in soils that are less ideal for plant growth (CBF 2004). Wind erosion causes the most extensive damage where the climate is dry and large expanses of fields are unprotected and fallow (IECA 2005). Water erosion is most common on a sloped landscape (Smith and Smith 2001); the severity of the slope is proportionate to the severity of erosion (Smith and Smith 2001). Water erosion risk is greatest on land under extensive cultivation (Vanderwel and Abday 2001). Fine-textured, erodible soils are especially vulnerable to erosion by rainfall and runoff (IECA 2005). Tillage erosion is mostly caused by the way a farmer tills the land (Baker and Lafnen 1983). The kind of equipment a farmer uses, how often the farmer tills the fields, and how the farmer manages the fields during the winter months affect how much soil may be lost (Foster et al. 1985). Heavy machinery, frequent tilling, and lack of cover crop during winter months contribute to soil erosion (Conservation Tillage Information Center 2002). Types of erosion include: sheet, rill, and gully (Smith and Smith 2001). Sheet erosion occurs over open fields (Smith and Smith 2001). Rill erosion occurs when water that is traveling down hill in small streamlets causes the streamlets to become larger and produce small channels (Smith and Smith 2001). Gully erosion occurs in larger channels than rill erosion and is more destructive (Smith and Smith 2001).

Soil erosion has short-term damage as well as long-term economic effects (Dickey et al. 1984). Short-term damage and increased costs can result from: loss of seeds, seedlings, fertilizer and pesticides, the need to repeat field operations, soil being washed from plant roots, young plants being hit by wind erosion, extra cultivation to level out eroded surfaces, increased fuel consumption and man hours (Baker 1985).

Long-term damage with large scale loss from erosion can result in at least two major environmental and economic problems (Stewart et al. 1995). Erosion can severely and sometimes permanently alter productive capacity of a soil to support physical and economic crop production (IECA 2005). Cropland becomes less productive because the soil left after erosion is less fertile and is unable to supply plants with necessary nutrients (Vanderwel and Abday 2001). The soil's ability to retain water is also greatly diminished (Dickey et al. 1984). There is a reduction in the amount of water in the root zone and thus an increased susceptibility to drought (National Academy of Sciences 1986). These changes result in higher production costs due to the increased need for more fertilizer, more careful tillage operations (requiring more man hours) and other changes in management, in order to attain a given crop yield (IECA 2005). Sedimentation in waterways from runoff threatens aquatic life and hinders water flow (Foster et al. 1985). The erosion of soil by water carries nutrients and agricultural chemicals into rivers, streams, lakes, and reservoirs (Foster et al. 1985). Increased sediment can cloud the waterways and decrease the amount of sunlight that reaches the bottom (CBF 2004). This can result in a decrease in photosynthesis. Increase in sediments entering in streams can also result in a decrease of habitat for bottom-dwelling organisms. Both of these impacts lower water quality (CBF 2004).

Erosion can occur in one part of a field while not affecting other parts (Foster et al. 1985). Signs of erosions are: dust clouds, soil deposited at the base of slopes, sediment entering waterway, pedestals of soil supporting small stones, and large gullies (Crosson and Stout 1983).

Good management practices can reduce erosion; methods are: leaving crop residue, strip-cropping, grassed waterways, contour tillage, no till methods, and planting winter crops (EPA 2005d, USDA 1996). Modifying tillage practices to keep crop residue on the surface can greatly reduce erosion (Vanderwel and Abday 2001). Crop residue left on the soil surface can slow the flow of runoff that can displace and carry away soil particles (National Academy of Sciences 1986). Conservation tillage leaves at least thirty percent of residue left behind such as stems, stalks and leaves on the soil surface from harvest time to the next planting (Conservation Tillage Information Center 2002). Conservation tillage methods include no-till, where no tillage is done at all and seeds are placed directly into a crop cover or the previous season's crop residue; strip-till, in which only a narrow, five to seven inch strip is created down each row; ridge till; and mulch till (Conservation Tillage Information Center 2002). Ridge till is a system whereby ridges on which the crop is planted are formed during cultivation or after harvest and maintained from year to year in the same location (Sullivan 2003). Planting is done on the ridge top (Conservation Tillage Information Center 2002). Mulch till is used after the harvest, leaving the soil undisturbed until just prior to planting (Reeder et al. 2005). Mulch till systems limit soil and residue disturbance to maintain crop residue cover at or above thirty percent (Sullivan 2003b). Increased infiltration with high residue cover can reduce water runoff (Reeder et al. 2005). Crop residue cover conserves soil moisture and improves soil tilth and fertility for better crop rotation (Al-Kaisi 2000).

Changes in agricultural technology and management practices can increase awareness of erosion and develop practices that are effective in controlling it (Al-Kaisi 2000). Issues currently important in dealing with the problem of erosion include: soil conservation planning, rehabilitation of degraded soil, and rural water quality (EPA 2005d).

The Impacts of Other Land Uses

Water quality in the Chesapeake Bay watershed is affected by pollution from point (known) and non-point (unknown) sources. The watershed's worst problem is nutrient pollution, which is caused by the overabundance of nitrogen and phosphorus in surface and ground waters (Chesapeake Bay Program 2001). Of the total nutrient load delivered to the Bay through tributaries, 20% is due to point sources, which can often be directly regulated and controlled by the government (Phillips and Lindsey 2003). If control is not feasible, at a minimum, the pollutant contribution of these sources can be quantitatively determined. Non-point sources comprise the remaining 80%, and the nature of these sources makes them difficult to regulate or even identify (Phillips and Lindsey 2003). Estimating the amount of nutrient inputs that non-point sources, such as agriculture and residential land area, contribute to surface and ground waters is an increasingly popular area of scientific study, although the relationship between the amount of nutrients applied to a land area and the amount of nutrients flowing out of this system is still relatively ambiguous.

In general, agriculture is often cited as a major source of pollution. Worldwide, agricultural activities comprise about half the Earth’s productive land, and are the leading cause of habitat degradation (Badgley 2003). In the Chesapeake Bay watershed, agriculture has been traditionally blamed for a large role in the nutrient pollution of the Bay. Yet in recent years, other land uses and sources are beginning to be recognized as more of a problem. Declining acres of farmland are one cause of the shifting focus to other sources of non-point pollution. Another factor is that remaining farmers are dutifully adopting nutrient management and runoff control techniques. But perhaps most importantly, a large cause of this shifting focus is that the land uses that are replacing farming are creating more of an environmental impact than agriculture ever did.

The Natural Resource Conservation Service ranks Maryland fifth in the country for its percentage of land that is developed for urban uses (roads, housing, industry, commercial) (CANRP 2004). The percentage of urban land uses has increased from 12.3% in 1973 to 18.4% in 1997 (CANRP 2004). If current trends continue, urban development in the Chesapeake Bay watershed may expand by more than 60% over the coming 30 years (Boesch and Greer 2003). Among the major land use categories, urban and suburban lands contribute, per acre, the largest amount of nutrients to the Bay when septic and wastewater treatment plant discharges are factored in (Chesapeake Bay Program 2001). Waste management, the proliferation of impervious surfaces, and residential land use are the three primary pathways by which urban and suburban land pollute ground and surface waters and degrade habitat within the Bay watershed.

Septic systems are emerging as a major source of nutrient pollution. As development spreads farther into the countryside, beyond the reach of sewer systems, nutrients from septic systems are increasing throughout the watershed (Chesapeake Bay Program 2001). A 1999 survey of 363 Chesapeake Bay watershed residents indicated that roughly half of all residences are served by septic systems on site, with a mean age of 27 years old (Swann 1999). The average design life of a septic system is 20 years, and 46% of residences had septic systems over this age (Swann 1999). Of residents served by septic systems, 50% had not had their systems inspected in the last three years, and 46%

had not had their systems cleaned in the last three years (Swann 1999). When questioned about their awareness of the connection between septic system maintenance and water quality, one-third of all septic owners either disagreed that septic system maintenance was necessary to protect water quality or responded that they did not know (Swann 1999). This stresses the importance of septic system owner awareness, to reduce the impact of these systems on Bay quality as they become more widespread.

Also, as land is developed, storm water runoff from urban and suburban areas increases as groundwater infiltration and soil retention of rainwater decreases, preventing the removal of pollutants before they reach surface waters (Chesapeake Bay Program 2001). Wastewater treatment has also been a major (point) source of nutrient pollution in the Bay watershed; however, government regulation and new technologies have reduced the input of nitrogen and phosphorus in many surface waters within the watershed (Chesapeake Bay Program 2001).

Other land uses contribute significantly to non-point pollution of the Bay. For example, construction and development generate massive amounts of sediment that can flow to streams. Construction causes the highest erosion rates of all land-use categories, with sediment yields for a single year of construction equivalent to many decades of natural or agricultural erosion (Goude 1986). Soil conservation measures, such as silt fences, retention ponds, and planting of grass buffer strips, are currently utilized to reduce these impacts. Urbanization and the proliferation of impervious surfaces cause erosion of stream channels, which impair streams and increase sedimentation of the Bay. The reduced infiltration and high, flashy stream flows associated with urban environments allows for the rapid delivery of pollutants to surface waters (Goude 1986). In addition, the high peak flows associated with rainfall in urban environments increase the erosive power of the stream and cause channel degradation, and increase sedimentation downstream. Likewise, runoff from highly developed urban areas may be enriched with heavy metals as well as sodium and sulfate from road de-icers. Urban development is well-known to cause great changes to the natural ecosystem; however, suburban development poses an equally large threat.

Residential land use is a non-point source of nutrient and pesticide pollution that is becoming more widely recognized as urban ecosystem studies provide more data on the environmental impacts of homeowner lawn management. Numerous surveys have been conducted to estimate the percentage of homeowners that apply fertilizers, and the average amount of fertilizer applied (Swann 1999, Law et al. 2004).

While farmers in Maryland are required to submit an annual nutrient management plan, accounting for all nutrients applied to their farms in a year, homeowners have free range as to the type and quantity of lawn management products that they may apply to their lawns. In a 1999 survey of residents within the Chesapeake Bay watershed, 64% of homeowners that managed their lawns indicated that they did not obtain advice or information on lawn management issues before doing so (Swann 1999). Of the 50% of homeowners that fertilized their lawns, the prime source of information for the majority (54%) was the label on the fertilizer bag (Swann 1999). However, many extension agents recommend using far less than this amount. The Northern Virginia Soil and Water Conservation District recommends using half of the manufacturer's recommended application—generally less than 44lbs N/ ac. per application (Aveni 1995). By these figures, roughly one quarter of the total residential lawn area in the Chesapeake Bay watershed is receiving twice the nutrient load necessary for healthy turfgrass management.

It has been found that Americans apply fertilizers to their lawns at rates similar to or exceeding those of cropland systems (CWP 2002). A comparison of fertilizer application between land uses has shown that fertilizers are applied to cropland at rates comparable to residential land use and golf courses (See Table III-1). It is apparent that fertilizer application to other land uses is causing worrisome impacts that must be addressed as well.

Table III-1: Comparative Nitrogen Application Rates for Various Land Uses

Location	Year	kgN/ha/yr	Reference
Ontario	2003	65.7	
Long Island, NY (homeowners)	1988	120	Morton (1998)
Long Island, NY (lawn services)	1988	217-289	Morton (1998)
Cropland in Maryland*	1990	206	Klein (1990)
Golf fairways in Maryland	1990	168	Klein (1990)
Golf greens in Maryland	1990	239	Klein (1990)

**corn/soybean rotation*
Modified from CWP, 2002.

However, the physical difference between the farm ecosystem and the turfgrass ecosystem are such that the nutrient output from farms will inevitably be higher. Turfgrass, like that found on residential lawns and golf courses has been shown to be highly efficient at controlling erosion and protecting water quality (Beard and Green 1994). Studies in Maryland have shown that surface-water runoff losses from a cultivated tobacco site averaged 6.7 mm per hectare per month during the tobacco-growing season (May to September); whereas the surface-water runoff loss from perennial turfgrass on the same site averaged only 0.6 mm per hectare per month (Gross et al. 1990). Surface runoff losses of total N and P for tobacco were 2.34 and 0.48 kg per hectare per month, respectively. Losses of N and P from the turf averaged only 0.012 and 0.002 kg per hectare per month, respectively (Gross et al. 1990). This is due to increased productivity of the lawn area, through an increased number of shoots (Beard and Green 1994). Thus, although residential fertilizer rates are high, uptake of nutrients is also high and the nutrients are less likely to leach into groundwater or runoff into streams, when careful turfgrass management is applied. Poor turfgrass management can have the same detrimental environmental impacts as poor agricultural practices.

Agriculture remains a source of non-point pollution to the Chesapeake Bay watershed. However, as a primary source, it is decreasing. The land utilized for agriculture has been decreasing for decades and land uses replacing agriculture are proving to cause more environmental degradation than was previously occurring. Urban and suburban sprawl are emerging as the largest challenges to the water quality of the Chesapeake Bay watershed, and sprawl is projected to increase over coming decades. Protection of our ground and surface water resources will require growth policies that mitigate environmental disturbances, and the protection of agricultural and forested lands for the conservation of wildlife habitat and natural resources.

The Bay

The Chesapeake Bay is among the largest estuaries in the world and is the biggest in North America. An estuary is a body of water that is open to an ocean so that saltwater from the ocean can mix with freshwater running off from the surrounding land (Chesapeake Bay Program 2005). This surrounding land is a watershed, an area of land containing smaller waterways such as creeks, streams, and rivers which collect all rainwater falling onto the land and then flow or drain into a larger body of water (Chesapeake Bay Program 2005). The Chesapeake Bay watershed is comprised of hundreds of thousands of small waterways, spanning over 64,000 square miles across parts of six states: Maryland, Virginia, Delaware, West Virginia, Pennsylvania, and New York (Chesapeake Bay Program 2005). The Bay has long provided an environment in which many different living organisms have functioned and thrived and interacted with one another and non-living components of the Bay habitat. Currently, the Bay is home to more than 3,600 species of plants and animals and more than 16 million people (Chesapeake Bay Program 2005). The increasing human population within the watershed with its associated land use practices has resulted in greater levels of pollutants entering the Chesapeake Bay. These stresses have impacted the Bay in a way never before experienced.

The Chesapeake Bay Foundation estimated in their health index, the State of the Bay Report, that the Chesapeake Bay watershed was its healthiest in the 1600s, having a perfect rating of 100 (CBF 2005). A recent report indicates that the Chesapeake Bay received a rating of 27 out of 100, putting it on the Environmental Protection Agency's list of "dirty waters" (CBF 2005). The most significant cause in the decline of the Bay's health is excessive amounts of nutrients draining into the Bay. These nutrients, primarily nitrogen and phosphorus, are essential to the growth of all living organisms in the Bay, yet an over-abundance of them leads to water pollution or degradation of the water quality, as well as other devastating effects (CBF 2005). A major reason why the Bay has been susceptible to these effects is because of the size of its watershed. The Bay has more land draining into it relative to its volume of water than any other major body of water in the world, therefore nutrients have a greater chance to enter and impact the Bay (Pegg 2004). As the population grows, and as urban sprawl increases as a result, the amount of runoff from impervious surfaces will carry greater amounts of nutrients, heavy metals, and other contaminants into the Bay. There are numerous sources from which nutrients are exposed to the Bay, but much scrutiny has been on agriculture.

Agriculture is prominent in the Chesapeake Bay watershed and provides crops/food for the human population but growing crops requires cultivating the land and providing it with essential nutrients such as nitrogen and phosphorus. Farming practices such as manure applications are employed to help fertilize the soil and enhance the growth of crops, thus keeping the land fertile enough to continue crop production. Animal manure is the largest source of agricultural pollution, since it contains significantly high levels of nitrogen and phosphorus (Pegg 2004). There are three manure hotspots in the Chesapeake watershed, the Delmarva Peninsula, Rockingham Co., VA in the Shenandoah Valley, and in Lancaster Co., PA in the lower Susquehanna River basin (Horton 2003). The farmers in these agricultural areas produce far more animal manure than local farmers can use as fertilizer, and current handling techniques can be insufficient to deal with huge manure surpluses. There is an increase in the amount of nutrients, especially nitrogen, being lost from manure and entering the Bay (CBF 2005). It is estimated that roughly 300 million pounds of nitrogen, the biggest pollution problem for the Bay, reaches the Bay each year (CBF 2005).

Roughly 88 billion pounds of animal manure is produced in the Bay's watershed each year, with the waste containing about 600 million pounds of nitrogen, much of which is lost (O'Brien 2003). With the numerous types of manure come different concentrations of the nutrients within each manure type. Also, different areas of the Chesapeake Bay watershed can rely on different types of animal production, such as chickens or livestock. There are 185 million livestock animals in the watershed, more than 11 times the human population (Horton 2003). Chickens outnumber people approximately 1,000 to 1 on Maryland's Eastern Shore and produce 1.4 billion cubic feet (44 million tons) of manure a year (Horton 2003). In either case, they influence the amount of nutrients that are transferred into the environment. No matter what the manure or waste type, there is presently an increase in the number of animals and decrease in available farmland, causing many farms to produce more manure than what the land can use (O'Brien 2003). Additionally, soil tests in certain areas have shown that the soils do not need extra phosphorus, thereby reducing the need for manure to grow crops (O'Brien 2003). So the excess nutrients that are not applied to field crops or absorbed by the soil either leach into groundwater, runoff as surface water or are released into the air through volatilization, eventually ending up in the Chesapeake Bay (Pegg 2004). All together, agricultural runoff contributes 40 percent of the nitrogen and 50 percent of the phosphorus entering the Bay, resulting in the endangerment of the marine and coastal environments (CBF 2005).

The biggest impact that nutrient pollution has on the Chesapeake Bay is algal blooms. Algae, small or microscopic photosynthetic organisms, are the most well-known of a group of organisms that comprise phytoplankton (Anderson 1997). Since they are photosynthetic they produce their own food from sunlight (Anderson 1997). Phytoplankton are the basis of most aquatic food chains, and are one of the primary producers of the oxygen we breathe (Anderson 1997). There are many different types of phytoplankton living in the Chesapeake Bay and its tributaries including diatoms, dinoflagellates, and green algae (DNR 2005). Excessive levels of nitrogen and phosphorus cause algae to grow prolifically and build up on the surface of the water (Chesapeake Bay Program 2005). These collections or blooms of algae cloud the water and affect the health of the Bay's other living organisms (O'Brien 2003). They block the sunlight that is needed by underwater grasses or submerged aquatic vegetation (SAV) in the shallow parts of the Bay (Chesapeake Bay Program 2005). This vegetation is extremely important in the functioning of the Bay ecosystem, for they act as a food source for some types of birds and as a habitat for shellfish and other fishes (Chesapeake Bay Program 2005). This vegetation also acts as a buffer trapping the enormous amount of sediment that enters the bay. Sediment is trapped by underwater grasses keeping the bay clean and would decrease the amount of dredging needed each year. Harming this vegetation affects the other organisms that depend on the vegetation and the loss of SAVs can have a devastating effect on the ecosystem. Furthermore, when algae die, they decompose and the decomposers 'feeding' on the dead algae consume the dissolve the oxygen in the water producing areas of the Bay with very low levels of oxygen (Chesapeake Bay Program 2005). These areas are then referred to as "dead zones," for levels of dissolved oxygen are often too low to sustain life, resulting in the death of aquatic organisms (Parker and Wright 1999). The worst "dead zone" ever recorded was said to have covered 40 percent of the central portion of the Bay, stretching 150 miles (Pegg 2004). Nutrient pollution affects fisheries in the Bay, by contaminating spawning grounds and destroying habitats, thus leading to fishing restrictions (Chesapeake Bay Program 2005).

Nutrient pollution can lead to fish kills and it can also lead to a decrease in the populations of keystone species. Keystone species are organisms that are critical to the overall health of an environment or what is happening within the environment. Within the Chesapeake Bay, two notable keystone species are oysters and blue crabs. With declining oyster populations from over-harvesting and diseases, the water quality of the Bay has worsened (Chesapeake Bay Program 2005). If the current bay could experience an oyster population comparable to the 1600's levels, then the bay could be filtered entirely in just a couple days. Blue crabs have been highly abundant in the Chesapeake Bay, yet their numbers have been declining as well due to habitat loss from nutrient pollution. Keystone species are so significant that without them the Bay will be destroyed. Algal blooms from increased nutrient pollution not only threaten natural fisheries and aquaculture, but human health as well, as was seen with the *Pfiesteria* outbreak (Parker and Wright 1999). Algal blooms also known as "red tides" can also be brown or green. However, sometimes the algae in these blooms produce toxins that interfere with nerve signals in fish and in people. *Pfiesteria* is an organism that has been linked to fish kills in the Bay and other areas along the east coast of the U.S. (Chesapeake Bay Program 2005). This organism can reach toxic levels, cause lesions on fish, and cause symptoms in humans (CBF 2005). These symptoms include short-term memory problems, respiratory difficulties, headaches, skins lesions, and burning sensations when their skin comes in contact with water (CBF 2005). Despite the harsh human symptoms of *Pfiesteria*, they are only temporary (Parker and Wright 1999).

Another environmental problem associated with agriculture and the Chesapeake Bay is the destruction of forested buffers and wetlands. During the 1600s when the Bay watershed was its healthiest, its waterways were protected by forests/trees and wetlands which could absorb and filter nutrients from rainfall and other runoff (Chesapeake Bay Program 2005). Now, significant portions have been destroyed or wiped out by human developments, most notably suburban sprawl and cultivation of new agricultural lands. With the reduction of these natural buffers, the flow of nutrients into the Bay has increased throughout the Bay watershed, thereby increasing pollution and degradation of water quality (CBF 2005). Riparian forests are essential in healthy Bay ecosystems as well as their ability to remove nitrogen from agricultural run-off. On Maryland's Eastern Shore, scientists found that riparian buffers trapped 95 percent of the nitrates from agricultural runoff (Horton 2003). Recent studies northeast of Richmond, demonstrated that forested riparian buffers could reduce concentrations of nitrate-nitrogen in runoff from croplands by 48 percent (Horton 2003). The highest rates of nitrate removal occurred during the dormant season, when fields are most susceptible to leaching and/or runoff of nitrates (Horton 2003).

Sewage treatment plants, septic tanks, air pollution, and agricultural runoff are certainly some of the most threatening factors affecting the Chesapeake Bay watershed, yet it would appear that agricultural runoff is the most single significant cause. This threat can be reduced, especially from manure. We need to minimize nutrient losses to water and air from fertilizer and during manure handling, storage, and crop application (Parker and Wright 1999). It is also important to formulate alternatives for harmful agricultural practices and strengthening riparian buffers. Currently state efforts to implement agricultural portions of tributary strategies are weak. In order to fully reach the proposed goals it would cost about $450 million annually, of which only 80 million is currently available (Horton 2003). Farmers have made substantial progress in conservation, but the costs of implementation are difficult for farmers to bear alone; the proposed goals for cleaning the bay require tremendous increases in effort and funding.

Political Solutions

Much of the negative environmental attention directed at farms is associated with farm runoff and water quality. This has become a hot topic within Maryland and the Chesapeake Bay watershed states due to degradation of the Bay. Additionally, attention has been focused on soil and land conservation. Both soil loss and land activities are inextricably linked to the health of natural water resources, so conservation measures on land help to protect water quality. Generally, water pollution from farms is deemed non-point source pollution, where pollutants are diffused and cannot be regulated at a single point. Some people argue that conserving farmland, separate from soil conservation per se, serves multiple purposes beyond water quality issues. For instance, farms provide more wildlife habitat and are more pleasing to view than urban settings. Farmland preservation also limits urban sprawl and maintains a way of life for many families—a way of life that has been in decline due to economic factors (USBLS 2004). Not to mention, farms provide the human populations with most of their food.

Political solutions to the problems associated with farms, farming techniques, and farming inputs have been implemented at the federal, state, and local level with many being on a large scale. Program efforts focus on funding, incentives, research, education, dissemination of information, public involvement, implementation of improved farming techniques, and conservation programs. Many of these areas of focus are intended to achieve agricultural practices that regenerate the quality of the land and are sustainable, yet offer few detriments to the farmer. Most of the federal programs operate on a voluntary basis where interested farmers apply for assistance, and in turn, they must comply with the program's specific requirements.

For instance, under the Conservation Security Program (CSP) administered by the Natural Resources Conservation Service, farmers receive payments to maintain and improve the quality of their agricultural lands in order to encourage better stewardship practices (NRCS 2005b). This program is voluntary and farmers receive educational workshops and assistance before and during participation (MDNRCS 2005). In order to qualify for the program, farmers must meet prerequisites based on existing conservation practices, such as conservation tillage, nutrient management, presence of riparian buffers zones, and strip cropping (MDNRCS 2005). In 2005, Maryland had 377 farmers and 105,000 acres approved and registered under the CSP (MDNRCS 2005). Participating Maryland farmers will receive some $4.4 million dollars distributed by acreage registered in the program (MDNRCS 2005). Monetary allotments are also distributed based on the participant's level of conservation practice implementation, and additional funding will be rewarded to those farms with exceptional achievements (NRCS 2005b). The CSP is authorized under the Farm Security and Rural Investment Act of 2002 or 2002 Farm Bill, and will provide over $1.1 billion dollars to participating farmers over ten years (MDNRCS 2005).

Some political solutions in Maryland have directly regulated farmers such as the nutrient management program legislated in the Water Quality Improvement Act (WQIA) of 1998. In the late nineties, in response to the *Pfiesteria* scare of 1997, many scientists and government officials in Maryland became concerned about excessive nutrient inputs from farms (BRCPAC 1997). Particularly, phosphorus from large chicken farms on the Eastern Shore was identified as a potential cause for the *Pfiesteria* outbreaks (BRCPAC 1997). As a result, on April 10, 1998, Governor Glendening and Maryland legislative leaders agreed to the nations most comprehensive, mandatory limits on the use of farm fertilizers (Simpson 1998). Farmers, who had long opposed such a regulation, finally agreed to accept the bill in exchange for a delay in its introduction and milder penalties for those who do not comply with the law. The Water Quality Improvement Act of 1998 states that farmers using chemical fertilizers are to test their soil and draft plans limiting their nitrogen and phosphorus use by 2001, and the plans must be implemented by 2002 (Simpson 1998). Farmers using manure or sludge have till 2004 to have the plans drafted and 2005 to be implemented (Simpson 1998). Those who fail to comply with the new restrictions face fines up to $2000 a year (Simpson 1998). Government funding pays farmers subsidies of $3 an acre, roughly 50% of the total cost, to offset the cost of the management plans.

Farmers feel that this type of treatment by the state is unjust, because other sources of pollution, such as residential lawns, golf courses, and marinas, are not as closely regulated nor are they put under the pressure of a time line for mitigation (MDFB 2005). Farmers have been regulated not only for their pollution contributions to the bay, but also because they are an easy target. Not all farms pollute the same, yet all crop farmers must pay to incorporate nutrient management plans to avoid being fined. The identified cause of the toxic *Pfiesteria* blooms was from large scale poultry farms in the form of manure runoff (BRCPAC 1997). It might make more sense for large poultry companies, who employ Maryland farmers, to foot the bill for nutrient management and manure transport off of the farms, than to have the farmers pay the bill. The WQIA of 1998 was aimed at crop farmers and placed no liability on the major polluter—the poultry industry. Farmers are much easier to target for changing their farming practices than poultry industry. If too much restriction is placed on the poultry industry politicians risk destroying a billion dollar industry by having businesses relocate to states without regulations. For reasons such as this, farmers feel that they are unfairly targeted by environmental organizations and the government, which is why they think the government should foot the bill for nutrient management plans (MDFB 2005).

In June of 2003, Maryland's then newly elected Governor, Robert Ehrlich, announced that he would abandon efforts by the previous administration to force Maryland agriculture to reduce nutrient runoff though mandatory efforts. By 2004, Ehrlich and the General Assembly passed legislative amendments, based on input from the many stakeholders involved, to the WQIA of 1998 making it easier for farmers to comply with nutrient management laws (MDA 2004). Many of the changes are in effort to make the application and reporting process easier for farmers by simplifying the paperwork and providing educational outreach about nutrient management plans (MDA 2004). Both consulting groups and interested farmers can receive training to be certified to develop these plans (MDA 2004). The legislation also modifies programs to help the farmers comply with regulations such as adjustments to the manure transport program, and the Maryland Agricultural Cost-Share (MACS) Program which now offers additional grant money to farmers who apply (MDA 2004). In 2004, the poultry industry in the Maryland, Delaware, and Virginia region (Delmarva) matched the funds provided by the

Manure Transport Program contributing to a total of $581,200 to remove manure from areas of high concentration.

In 2005, Governor Ehrlich's office, the Maryland Departments of Agriculture and Environment, and the top four Poultry Companies on the Delmarva Peninsula developed a memorandum of understanding for an on-going collaborative and regional support for Bay restoration and a farm based economy (MDA 2005g). The agreement brings policymakers, farming stakeholders, and environmental stakeholders together to protect the Bay and address farming and economic issues of the region (MDA 2005g). Emphasis is placed on nutrient management education and water quality issues, as well as the poultry industries' development of new farming techniques, forums for discussion, and technical assistance to farmers (MDA 2005h).

Agricultural nutrient runoff and the related environmental issues that have subsequently resulted pose a difficult situation for Maryland politicians and lawmakers. On one hand, there is the Chesapeake Bay user community, which includes an assortment of Bay-based industries such as fishing, crabbing, and recreational activities, with strong support from environmental groups. On the other hand, there is the Maryland agricultural community, who fear stricter environmental constraints and remediation requirements will threaten the economic viability of their operations. Both parties involved in this controversial issue contribute significantly to the Maryland economy. Completely eliminating one in favor of the other is impractical and clearly not an option. The key to this issue is to find a resolution that brings about a reduction in agricultural non-point source pollution, yet still allows the agricultural industry to operate at a profitable level.

IV. The Reynolds Farm

A local farmer in Baltimore County, Tom Reynolds, graciously allowed us to use his farm for our studies of agriculture and its affect on the environment. This is just one small farm and cannot represent all small farmers in Maryland, but it allowed us to get a feeling for farming and farmers. In addition to learning about farming practices, we took samples of soil and stream and ground water during our project. Our attempts to carefully assess the soil and water were sincere but we are not professionals; therefore, the data that is reported here should be reviewed with that in mind. It would not be fair to draw any definite conclusions relating to the farms' effect on the environment from our results although we believe that the overall pattern we observed is probably accurate. The description of the farm and farming practices that follows comes from discussions with the Reynolds and our observations of their farm.

The Farm

The Reynolds farm, which has been in the Reynolds family for at least 40 years, is located in Reisterstown, MD (see Fig. IV-1)**.** The Reynolds have purchased a neighboring 17 acre parcel but this land is mostly stream buffer; of the original 50 acre farm approximately 45 acres are currently cultivated. At one point the farm was an orchard, but it is now being used for vegetable crop production. We were told that in the past some of the soil had been abused; it had been heavily farmed without much concern about soil being replenished. Now the Reynolds pay considerable attention to conserving and restoring the quality of the soil. When the farm was a peach and apple orchard, the fruit was sold at a farm stand on a nearby major road. Today, most of the crops on the

Reynolds' farm consist of fruits and vegetables, much of which is also sold at a nearby farm stand. Crops that are grown on the farm include: pumpkins, squash (3 varieties), tomatoes, sweet corn, zucchini, eggplant, watermelon, cantaloupe, cucumber, strawberry, and peppers. About 5 acres are devoted to small vegetables and fruit; the rest is used for producing sweet corn. Rye is used as a cover crop in the corn and pumpkin fields in the off season.

Fig. IV-1 An aerial image of the Reynolds farm in Reisterstown, MD.
Image courtesy of Baltimore County, Office of Information Technology.

Along with the sale of his vegetables, Mr. Reynolds raises and sells turkeys. About 1800 turkeys are sold each year during Thanksgiving and Christmas. He also raises cattle and pigs for the family's personal use and his wife trains a few thoroughbred horses. He does not administer any growth hormones or routine antibiotics to his animals. In addition, Mr. Reynolds produces garden mulch. He has created a market for wood chips which he makes from waste wood and sells them to local horse farms, where it is then used for bedding. He then collects the ‘used’ chips and processes these and the manure they contain into mulch. The finished wood mulch mixture is sold to the public and used on the farm. The mulch is used on the farm for fertilizer and is also placed between the crop rows to prevent soil erosion. The composted mulch helps heat up the soil, allowing crop seeds to germinate faster. It also helps replenish organic matter in the soil.

The soils on Reynolds Farm are loamy soils containing roughly equal parts of sand, silt and clay. The particular types of soils being farmed are from the Glenelg and Manor series (see Fig. IV-2, Glenelg soils are labeled with a G and Manor series with an M), and formed from the underlying bedrock, which is a type of schist common to the central portion of Baltimore County (Reybold and Matthews 1976). Both soils are acidic which allows for better nutrient uptake by crops (Reybold and Matthews 1976). For the most part these soils are well drained with moderate moisture capacities and are relatively easy to work compared to other types of soils in the county (Reybold and Matthews 1976). The Glenelg and Manor soils are suited for cultivation according to the Baltimore County Soil Survey, yet may be moderately to severely eroded, so care must be taken to prevent further erosion if possible (Reybold and Matthews 1976). Manor loams are considered to be among the soils more susceptible to erosion in Baltimore County (Reybold and Matthews 1976). The erosive potential by water is largely based on the slope of the land and the consistency of the soil. The Glenelg and Manor soils on the west and eastern sides of the farm are located on slopes with an 8-25 percent rise, and the Glenelg soil on the central portion of the farm is located on a 3-8 percent rise.

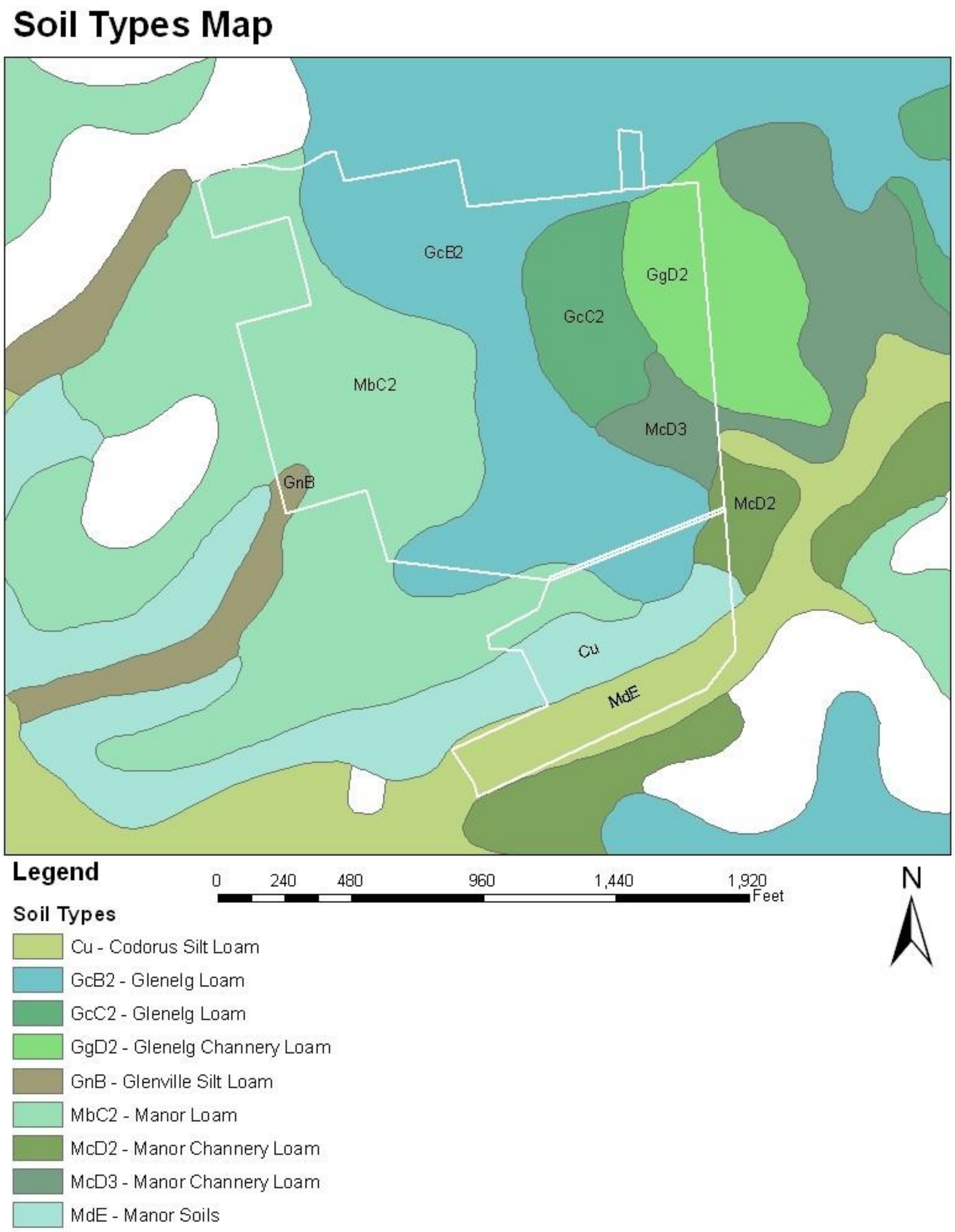


Fig. IV-2. A soil map of the Reynolds farm. The two major soil types on the farm are Glenelg and Manor.

Farming for Mr. Reynolds is a bit of a juggling act; he works hard to replenish his soils and minimize the negative impact of his farming practices for the environment while producing a yield that is sufficient to pay the bills and of a quality to keep his customers buying.   His farm has a gentle slope and he plants his crops across the contour of the hilly landscape (see Fig. IV-3). Planting across the contour reduces the amount of runoff and erosion. Grassy strips are left between rows of crops as another method to prevent erosion (Fig. IV-4). He works very hard to minimize land disturbance. He plants corn multiple times during the spring and summer to maintain young corn for his farm stand. Only the first planting of corn goes into tilled fields, the rest are planted no-till.

Fig. IV-3. A view of the vegetable fields at Reynolds Farm. The hill slopes down to the left of the picture and the rows are planted perpendicular to the slope.

After preparing his vegetable beds he covers some of them with black plastic which prevents erosion as well as keeps weeds under control (Fig. IV-5). He takes soil samples for nutrient analysis frequently; he has developed and follows a nutrient management plan. Nitrogen fertilizer is applied to all crops, but in different amounts, in the form of liquid nitrogen. The fertilizer is applied through the irrigation system for his vegetables.

Fig. IV-4. The placement of grassy strips between rows of vegetables is apparent in this view of the Reynolds farm.

Fig. IV-5. Newly prepared strawberry beds with black plastic. The plastic increases soil temperature, holds moisture and reduces weeds.

For the other crops (pumpkins and sweet corn) he applies fertilizer directly. He is aware that nitrogen remains in the soil after harvest and plants rye to take up that extra nitrogen. He finds that if he uses less nitrogen, his crop isn't as 'pretty' which hurts him at the market. The extra N followed by a cover crop is his compromise. He doesn't like to use pesticides, herbicides, and fungicides but will apply them to crops in the smallest amount possible in order to produce the needed crop.

The crops produced on the Reynolds' farm are sold through wholesale and retail markets. There is also a small produce stand close to the farm where strawberries, tomatoes, and corn are very popular. In the fall the farm has a "pick your own" pumpkin operation. Mr. Reynolds tries to minimize his dependence on the 'pick your own' market because many people are disrespectful to the land and he is concerned about liability issues. Mr. Reynolds limits what he sells to retail stores and is very careful about who he will sell to. This grew out of a bad experience. At one time one store was selling his produce using his name but when it was no longer fresh, it diminished the quality of the product. He says that this reflected back on him and reduced his profits because consumers then did not want to buy his produce at the farm stand. By making sure that only very responsible grocers receive his produce he is protecting his reputation.

The Reynolds farm is currently not involved in any government programs. The farm is a registered soil conservation farm. Mr. Reynolds chooses not to accept any support from the government. He is interested in conservation programs but the farm is considered too small for many of them.

Soil Sampling

Since the pollution problems associated with farming are related to nutrient runoff, we thought it important for us to investigate nutrient levels in the farm soils. While farming, in general, might be responsible for delivery of nitrogen to the waterways, we wanted to know more about the levels of soil nutrients relative to particular crops and specific farming practices. If a nutrient wasn't in the soil it wasn't going to be able to move into the water. The sampling and analytical techniques we used were new to us. Therefore, we have learned a great deal about soils and soil nutrient analysis, but again, we request that readers use caution accepting our data as a totally accurate reflection of the soils tested.

Materials and Methods

On September 25 and November 6, 2005, soil samples were taken at different locations around the Reynolds farm to assess levels of soil nitrogen. We analyzed our samples for levels of total extractable nitrogen (using a Carbon/Nitrogen (CN) analyzer), nitrite (NO_2^-) and nitrate (NO_3^-) (using an ion chromatograph). All of the fields that were sampled had received fertilizer. We also sampled a pasture located directly behind the composting operation, the compost piles themselves, and a grassy strip down hill from a fertilized section of a field.

We selected sampling sites that reflected different crops, slopes, planting dates and, in the case of the pasture, places that seemed at risk for high nitrogen. Within each selected field, sampling was random. Sampling was done using a garden trowel and soil corer and the samples were placed into clean and dry 120 mL cups or clean and dry plastic bags. Surface (the top one inch) and below surface (from soil four inches below the surface) samples were taken in the following fields (See Fig. IV-6). Soil corer samples consisted of one sample from the surface down to about 7 inches.

- A pumpkin field at the top of a slope
- A pumpkin field in the middle of a slope
- Harvested corn field, between the pumpkin fields
- Unharvested corn field
- Harvested cucumber/squash patch, within the 5 acre vegetable fields
- Tomato patch in the 5 acre vegetable fields
- A grassy strip below the sampled tomato patch

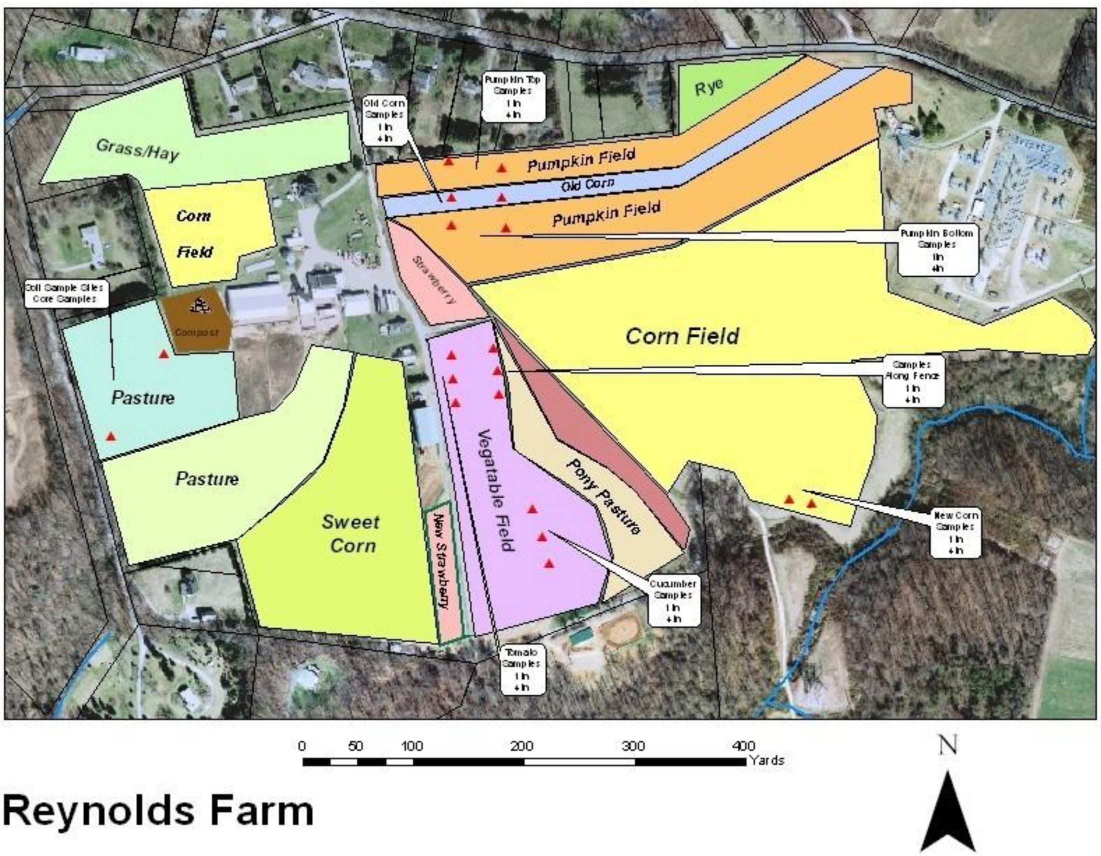


Figure IV-6. Soil sampling sites on the farm are indicated by red triangles.

Each one inch sample consisted of three separate random samples of the top one inch soil that were combined and mixed from each field sampled. The four inch samples were obtained by using the garden shovel to obtain soil from a four inch depth. Each four inch sample consisted of three separate random samples of four inch soil directly below the top inch sample that were combined and mixed from each field sampled. Core samples were taken using the soil corer at the following sites:

- The pasture field located directly behind the compost piles
- The bottom of the pasture field behind the compost piles
- The unharvested corn field also sampled above.

One duplicate core sample was taken from the unharvested corn field on the first sampling date, and a second duplicate sample taken from the 4 inch mid-slope pumpkin field on the second sampling date. Not all sites listed were sampled on the second date.

Small cups (approx 100 cc) of samples of compost, in duplicate, were taken from compost piles with distinctly different colors--light, medium and dark brown. The lightest color pile of compost is the most recently mixed compost. The darker compost is the oldest and has had more time for microorganisms to act on the substrate.

Total extractable nitrogen

To determine how much nitrogen was in the soil, we analyzed for Total Extractable Nitrogen. This test determines how much total soil nitrogen is readily extractable in water. The forms of nitrogen that make up the total extractable nitrogen are nitrite, nitrate, ammonia, and organic nitrogen. We also measured nitrite and nitrate levels specifically (see ion chromatography). The total extractable nitrogen analysis does not isolate specific forms of nitrogen; rather it reflects the water soluble and plant accessible nitrogen. Nitrate is the form of nitrogen that is most leachable into waterways. To measure the levels of the most readily leachable nitrogen in the soil (nitrate and nitrite), we used an ion chromatograph. For further information on CN analysis see Appendix 2.

Ion Chromatograph

Analysis by ion chromatography can be used to determine the concentration of specific anions present in the soil. Of particular concern to us were nitrate, nitrite, and phosphate because of their importance to plant growth and function. Anions (including nitrate, nitrite and phosphate), which are negatively charged ions, are highly moveable in the soil due to the fact that soil colloids also bear a negative charge. Because nitrates are soluble in water, they can move freely with the water depending on pH and concentration of other ions. Also, because soil colloids have negative charges, nitrates and nitrites are repelled, further increasing the tendency for nitrates and nitrites to be mobile. These are the reasons why nitrate possess a high susceptibility to leaching. For further information on ion chromatography analysis see Appendix 2.

Results and Discussion

The results of the total extractable nitrogen assay and the nitrate levels from the ion chromatograph for both sampling dates are presented in Table IV-1. It should be noted that prior to the first sample date, there had been no rain for many weeks: we call these ‘drought’ conditions. The second sampling date was taken after several very heavy rain events and we call these ‘flood’ conditions.

Our results show a decrease in total extractable nitrogen in most of the samples from crops soils after the heavy rain. There was also a decrease in nitrate after the rain events. There are several possible explanations for this. Nitrates are highly soluble in water and it is possible that they were leached from the soil by the rain, resulting in less available soil nitrogen, which would be reflected in both data sets (total extractable N and nitrate). These nutrients could have run off into another field, been lost to leaching through the groundwater, or taken up by other plants. The dry period had caused growth of many plants to slow down and the heavy rain could have produced a growth spurt in the weed populations; as the weeds grow and take up nitrates, the levels of nitrate and total extractable nitrogen in the soil would drop. Nutrients, especially nitrates are inherently leachable and this leaching cannot be avoided. In a farming situation

Table IV-1. Soil nitrogen levels on the Reynolds' Farm from selected sites sampled at two different times. The first sample was taken during a long dry-spell whereas the second sample was obtained after considerable rain. Nitrate levels determined by ion chromatography. Total extractable nitrogen includes within it nitrate levels.

	25-Sep-05		**6-Nov-05**		**25-Sep-05**	**6-Nov-05**
	<u>Total Extractable Nitrogen (mg/kg/soil</u>		**<u>Total Extractable Nitrogen mg/kg/soil</u>**		**<u>mg NO_3^- N per kg soil</u>**	**<u>mg NO_3^- N per kg soil</u>**
<u>Soil Sampling Sites</u>						
Pumpkin 1" top of hill	88.8		42.2		96.9	14.3
Pumpkin 4" top of hill	23.2		31		14.4	7.2
Pumpkin 1" mid-slope	26.3		29		24.8	3.3
Pumpkin 4" mid-slope	27.2		26.9		26.6	3.2
Harvested Corn 1"	72.1		32		84.2	8.6
Harvested Corn 4"	27.4		30.3		17.4	10.1
Growing Corn 1"	121.4		39.7			5.5
Growing Corn 4"	23.8		38.6		17.6	4.2
Pasture, top of hill	40.2		23.6		347.4 *	5.6
Pasture, bottom of hill	5.9		45.3		15.8	5
Cucumber harvested 1”	226.8*				276.3*	
Cucumber harvested 4”	12.7				24.7	
Tomato growing 1”	14.7				16.6	
Tomato growing 4”	0				10.2	
Grass strip below tom. 1”	34.4				31.0	
Grass strip below tom. 4”	22.9				25.2	
*** Outlying data point. Empty cells either missing data or close to 0.**						

in which fertilizer is applied to foster plant growth, some loss through leaching would appear unavoidable.

The soil samples taken from the pasture behind the composting area during drought conditions show a large difference in the levels of total nitrogen at the upper sample site, near the compost operation, compared to the lower site. When sampled after the rain, the sample site at the top of the hill had an almost 50% decrease in total extractable nitrogen, whereas the site at the bottom of the hill showed an increase in concentration by 8 fold (relative to before the rain). However, when nitrate levels were compared for flood conditions at top and bottom sites, they were nearly equal. The nitrate data for drought conditions cannot be compared due to an outlying (and untrustworthy) data point. We cannot tell from our data whether decreases in nitrogen levels come from nitrogen lost through leaching or nitrogen taken up by growing pasture grasses. The nitrite levels were always much lower than nitrate. The complete data set is presented in Appendix 4.

It is interesting that for the intensively managed vegetables, the total extractable nitrogen is similar to the measured nitrate soil levels. The grassy strip below the tomato patch has higher levels of nitrogen than the tomato patch itself, and the grassy strip appears to be effectively trapping soil (if any) and nutrients from up the hill.

The results of our nitrogen tests on the compost are presented in Table IV-2. It is apparent that compost is a good source of nitrogen. While the total amount of extractable nitrogen decreases with maturation, the amount that is in the readily accessible nitrate form increases. When tested, the darker compost pile had much higher nitrate content than the lighter compost pile but on average, the highest nitrogen levels were found in the mid-maturation compost.

Table IV-2: The levels of total extractable nitrogen and nitrate nitrogen found in compost piles at different stages of development. The darker piles were composted while the lighter piles were new. Nitrate and phosphate levels were determined by ion chromatography.

Sept 25 Compost Samples	**Total Extractable Nitrogen (mgN/kg)**	**mg NO_3^- N per K**	**mg PO_4^{-3} P per K**
Compost Light 1	2425.0	10.3	1002.8
Compost Light 2	2957.7		
Compost Med.1	2580.5	12.1	
Compost Med. 2	3856.3	14.1	1605.8
Compost Dark 1	952.7	309.1	92
Compost Dark 2	1052.9	282.8	96

Much of the nitrogen in the soil is found in the form of nitrate. Ammonium ions not immobilized or taken up quickly by plants are usually converted rapidly to NO_3^- ions by a process called nitrification. This is a two step process, during which bacteria called *Nitrosomonas* convert NH_4^+ to nitrite (NO_2^-), and then another type of bacteria, *Nitrobacter*, converts the NO_2^- to NO_3^-. This process requires a well aerated soil, and occurs rapidly enough that one usually finds mostly NO_3^- rather than NH_4^+ in soils during the growing season. The ease with which nitrogen changes form in the soil (from a form available to plants, then taken up by plants and converted into tissues, then decomposed and returned to the soil as organic nitrogen, etc.) makes it very difficult nutrient to monitor. We noticed that soil testing services don't even attempt to measure it (although it is critical to farm soils).

The measurements obtained for total extractable nitrogen for the compost piles were large due to organic nitrogen in manure and the amount of microbial growth that occurs in compost. The transformation of organic nitrogen into more readily available forms is the reason people use mulch in their gardens.

Overall, our data suggests that there is movement of leachable nutrients on the farm. Hydrology plays a part in how nutrients move on the farm or in any other soil system for that matter. Therefore, the fact that there are leachable nutrients on the farm is not a cause for alarm. In the pasture behind the compost, the total extractable nitrogen level in the soil decreased at the top of the hill in the pasture field after the rain and increased at the bottom of the hill. These changes could reflect movement of nutrients with rainwater. There is a considerable amount of vegetation in the pasture which can uptake nutrients and prevent them from leaving the farm through overland flow. It is also possible that a flush of grass growth after the rain could change the value of nitrogen in the soil. Possible errors in our data could be due to contamination, difference in sampling methods among samples taken, difference in lab techniques, or error in calculations.

Stream and Water Analysis

We were well aware that one of the major problems associated with nitrogen runoff was the impact of excess nutrients on stream water and stream biota. The local stream biota would reflect water quality conditions if nutrient pollution were a problem.

Norris Run, which runs by the farm, was monitored with the intent of assessing the impact of Mr. Reynolds management practices on the stream. Our stream monitoring program included both chemical analysis and single assessment of macroinvertebrates. Our first set of chemical monitoring was done on three different sites, which were named

W-1. W-2 and W-3 (see fig. IV-7). W-1 was the furthest upstream and located behind Franklin elementary school on Cockeys Mill lane. Our second sample site W-2, was located upstream from Reynolds Farm and below the culvert that crosses beneath interstate 795. Sample site W-3 was located adjacent to Reynolds Farm and was furthest downstream. On 09/25/2005 and 10/08/2005, each of the three sites was sampled and the following chemical parameters were assessed: pH, conductivity, dissolved oxygen, ammonia, chlorine, alkalinity, and hardness. Separate samples were also taken for

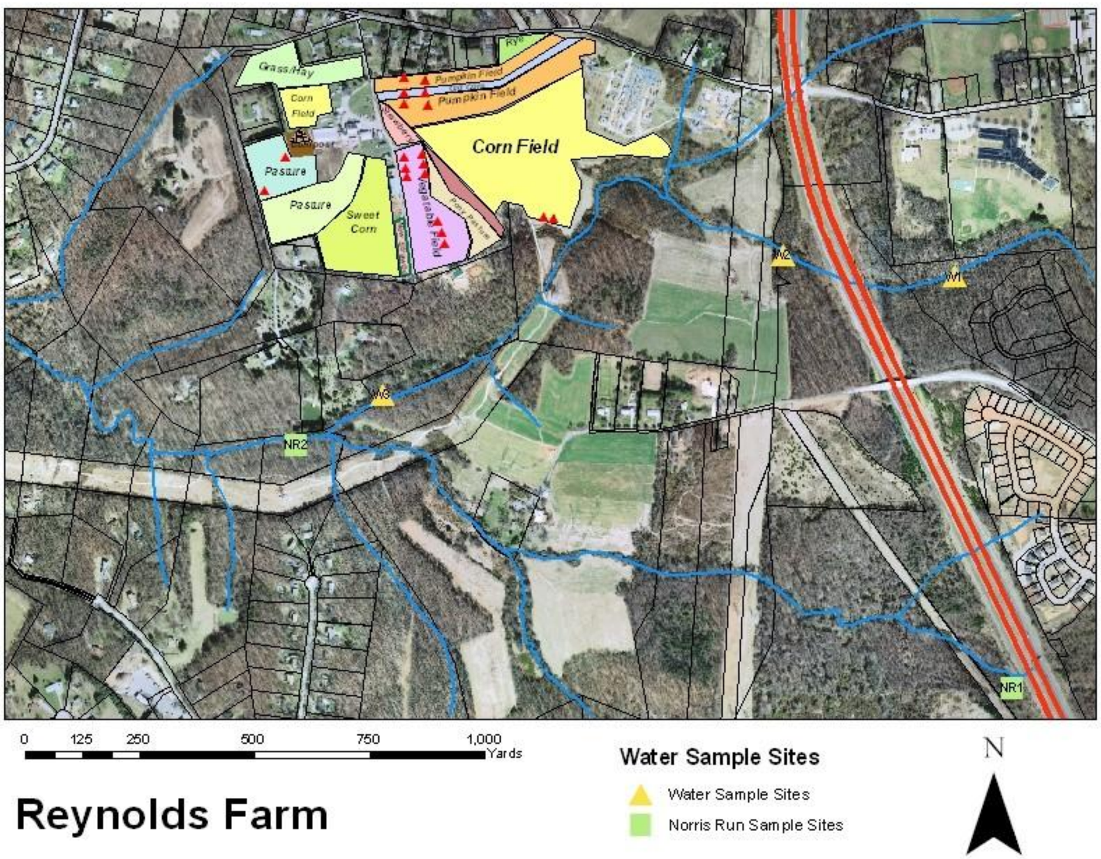


Figure IV-7. The water sampling sites are indicated by yellow triangles. W-1 is to the far right.

for nitrate, nitrite, and phosphorus for analysis at a later date using the ion chromatograph. We soon realized that our method had some flaws, and that we needed to sample reaches of the stream where the channels were more similar to one another. For this reason, we changed our stream monitoring protocol, and began a second round of chemical sampling.

For the second round of sampling we limited our program to only two sample sites, W-2', and W-3'. Sample sites W-2' and W-3' are in the same general area as sitesW-2 and W-3 we sampled earlier. However, changes were made by selecting new segments of the stream near those sites that had similar stream flow, structure, and vegetation to one another. This was done to keep the number of differences between the two sites to a minimum. We decided to discontinue the monitoring of site W-1. The data gathered from site W-1 might have been able to tell us of the impact to Norris Run occurring from interstate 795, however, we decided that aspect was beyond the scope of our project. In addition to sample site location changes, our second sampling plan also involved the addition of some parameters to our program: temperature and stream discharge. An additional field test kit procedure for determining phosphate and nitrate was also added. We added temperature to our program because we found in our research that most of the chemical and biological data we gathered are temperature dependent. Discharge, or the volume of water that flows through a site, was the most crucial addition to our program. When nutrients are measured, the values are reported in units of mg/L, and sometimes μg/L. Knowing the discharge rate at each site allowed us to calculate the amount of nutrients passing through each site per day. This was determined to be a better assessment of the nutrient load of the stream. Our second set of water samples were obtained on 10/23/2005 and 11/06/2005.

Chemical monitoring is a useful aid in detecting stream pollution, however the data will only reveal what is in the stream at the exact moment the sample was taken. Biological stream monitoring is a method of studying the level of pollution present in a stream by looking at its impact on organisms within the system. Monitoring methods, such as an invertebrate analysis, allow us to assess the impact to the stream over longer periods of time. Organisms are sensitive to different types of stress and disturbance; their presence, absence, or abundance, can shed light on stresses and disturbances that have occurred over time. A benthic macroinvertebrate analysis was applied to Norris Run because we felt it might give us a better idea of what pollutants, if any, were impacting the stream. Our macroinvertebrate samples were taken at sample sites W-2', and W-3' on 10/30/2005.

Another type of biological assessment we used to analyze the potential for pollution from the farm was a toxicity bioassay. A runoff sample was collected at the base of a gully running through the farm, and directly into Norris Run, between sites W-2' and W-3' on October 8, during a heavy rain event that ended the dry spell. The runoff sample was then used in a toxicity test to determine if toxic chemicals were being transported from the farm to Norris Run.

Methods

Chemical Analysis--Series One: For our first series of chemical analysis, two stream sites were selected upstream, and one site was selected downstream from the Reynolds farm. Prior to taking each sample, a 300ml sample jar was rinsed two times with the stream water from that site. The sample jar was then filled with stream water and sealed tightly. Stream samples were then immediately placed into a cooler filled with ice until they reached the laboratory refrigerator, where they were stored for no more then 48 hours, at approximately -3˚C. Other samples taken for nitrite, nitrogen, and phosphorus were also put on ice and taken to the lab and stored (see Appendix 7). For our chemical analysis, pH, conductivity, and dissolved oxygen were determined using Orion brand probes. For our measurements of ammonia, and chlorine, HACH pocket colorimeters were used. Finally, alkalinity, and hardness were measured by titration.

Chemical Analysis--Series Two: For our second set of chemical analysis, one stream site upstream, and one stream site downstream from the Reynolds farm were used. Our two stream sites were selected in straight segments of the stream with similar flow, structure, and vegetation. The chemical analysis methods described above were also applied for our second set of analyses and in addition we measured discharge and temperature. Temperature was measured in the field by placing a thermometer into our stream sample site. Nitrate and phosphate were measured on site using LaMott brand field test kits, and additional samples were taken and frozen for further nitrite, nitrate, and phosphorus analyses using the ion chromatograph (see Appendix 7). For our discharge measurements, a stream flow meter was used and we followed the method of Michaud, 1991 for all measurements and calculations. To calculate discharge, the width of the stream segment was first measured and then flow measurements were taking at small intervals across that stream segment. The discharge value was then used to calculate our nitrate load.

In addition to the in-stream sampling we took seven different runoff water samples at various locations on the farm during a rain event on 10/7/05 so we could see what levels of nutrients were in the runoff, and what might possibly be entering Norris

Run (see Fig. IV-8). However, the overland flow of water encountered grass strips and vegetation on its way through the farms watershed, which would have lessened nutrient loading, and some of the nutrients would have entered the soil. We just wanted to know what possible nutrient levels there might be in runoff.

Biological Assessments: For the toxicity test a water sample was collected on 10/08/05, during a large rain event, at the point where a gully, running across the fields and through the farm, meets Norris Run. This sample was then placed on ice until it got to the lab, where it was stored for less then 24 hours at approximately -3˚C. The sample was then divided into six aliquots and each aliquot diluted with specifically designed

Figure IV-8. Sites where runoff samples were collected during a heavy rain event are indicated.

laboratory water to make different concentrations of runoff water. The concentrations of runoff water used for the test were 0%, 20%, 40%, 60%, 80%, and 100%. Eight *Ceriodaphnia dubia*, a small aquatic invertebrate which is also a standard test organism for fresh water toxicity testing, were placed into individual vials at each concentration. Each sample concentration received the same quantity of food for the *Ceriodaphnia* (200µl of yeast and cerophyll® and 300µl of algae in each vial). The vials were then incubated at 25˚C for 48 hours, after which survivorship was determined. The toxicity test began on 10/09/05 and ended on 10/11/05.

Another method of biological assessment we utilized involved benthic assessment of macroinvertebrates. We sampled macroinvertebrates using multiple square-foot sample plots at both sites W-2', and W-3'. The samples were gathered using a Surber square-foot stream bottom sampler. All sample sites occurred within riffle areas of the stream. Once a riffle site was selected, the sampler was placed on the stream bottom, and all rocks and sand in that marked off area were rinsed and stirred into the sampler. After sampling, the collected materials were immediately stored in 90% ethanol. The samples were then taken to the laboratory where they were sorted, i.e. organisms were separated from sand, sticks, leaves, and detritus. After each sample was sorted, they were then checked an additional time to insure that all of the organisms had been removed. The organisms were then identified to the family level using a microscope with aid from a taxonomic key.

Results

In our first series of chemical monitoring, we found that the data from each sample site were similar with the exception of conductivity (a complete listing of results can be found in Appendix 4). We found that conductivity tended to be lower at the sites below the farm, W-3 and W-3', then our other sites (see fig. IV-9).

Data on nitrate load is presented in Figure IV-10 and ion chromatograph data for nitrite and nitrate can be found in Appendix 7. According to the LaMott kit, total nitrate loads are higher at site W-3' than they are at site W-2', and there is no change in nitrate levels at W-2' between the October 23 and November 6, whereas there is a decrease at W-3'. This suggests that the higher level on the first sampling date were associated with specific events, i.e., rain storms and that with time, nitrate input decreased. The complete results from the second round of our chemical analyses are presented in Appendix 5.

In our toxicity test, we observed a death rate of 12.5% among our test organisms in the 80% and 100% runoff water concentrations--one of the eight test organisms died at each of these concentrations. There was 100% survivorship at each of the other runoff water concentrations.

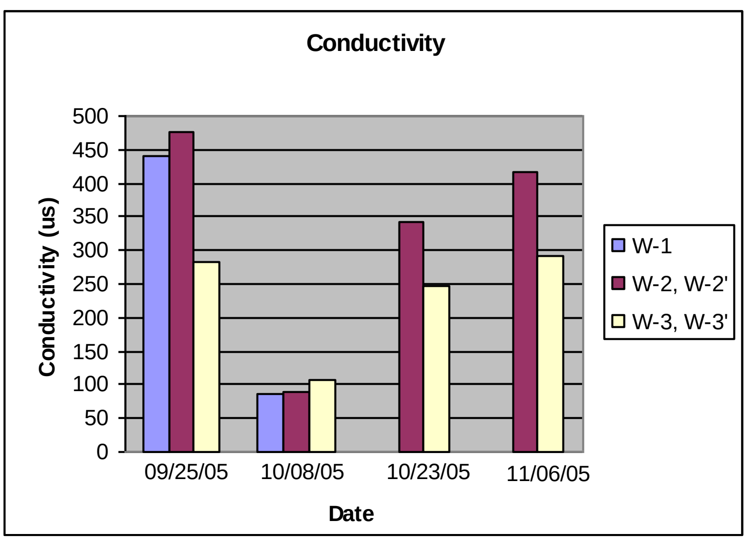


Figure IV-9. The conductivity of Norris Run on four different days at three sampling sites, near the beginning of the stream (W-1) after it passes under interstate 795 (W-2) and as it flows by the farm (W-3). The weather had been extraordinarily dry in September but the drought broke on October 8.

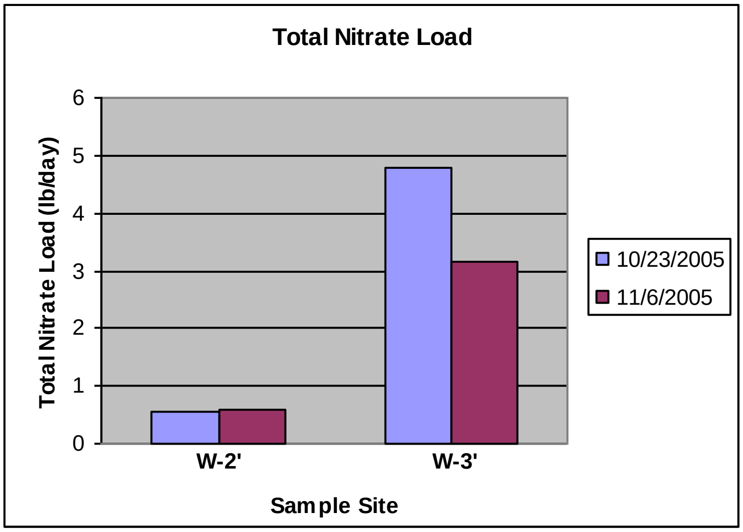


Figure IV-10. The total nitrate load into Norris Run on two different days. The first site is just downstream from interstate 795 (W-2'), and the second site is slightly downstream from the farm (W-3').

In our second method of biological assessment, our macroinvertebrate sampling, we notice several differences between our two sample sites. In figure IV-11, it is apparent that sample site W-2' has a larger abundance of organisms present then site W-3'. From Fig. IV-12 we can see that the diversity, or taxa richness is greater at site W-2' than at W-3'.

From our invertebrate data we were able to calculate a Family Biotic Index (FBI) for each sample site. The FBI, a scale based on 'known' sensitivity of different taxa to pollutants, indicates that the two sites are not very different from each other (as assessed by the invertebrates in the water). From Fig. IV-13, we can see that our FBI values for each site are similar, with a difference of only 0.4 units on a scale of 1-10. We were also able to calculate EPT (Ephemeroptera, Plecoptera and Trichoptera) values, which is a value that corresponds to the number of specific pollution sensitive organism at each site. In our EPT calculations we found that 80% of the organisms from sample site W-3' were those specific, sensitive organisms, while only 47.8% of the organisms found at site W-2' were composed of those organisms. The complete data set is presented in Appendix 6.

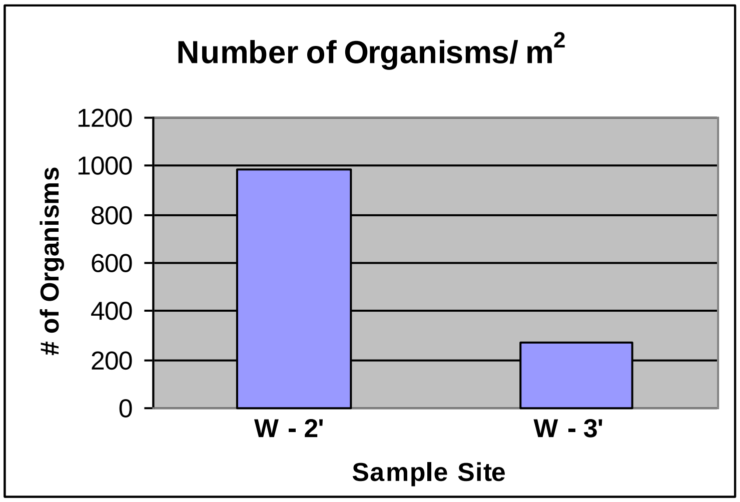
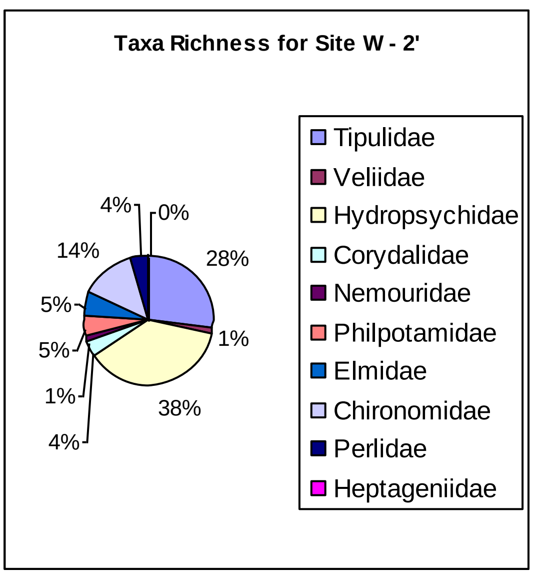


Figure IV-11. The calculated number of benthic macroinvertebrates for every square meter of Norris Run at two sample sites. The first sample site is just past interstate 795, and upstream from the farm (W-2'), and the second site was slightly downstream from the farm (W-3').



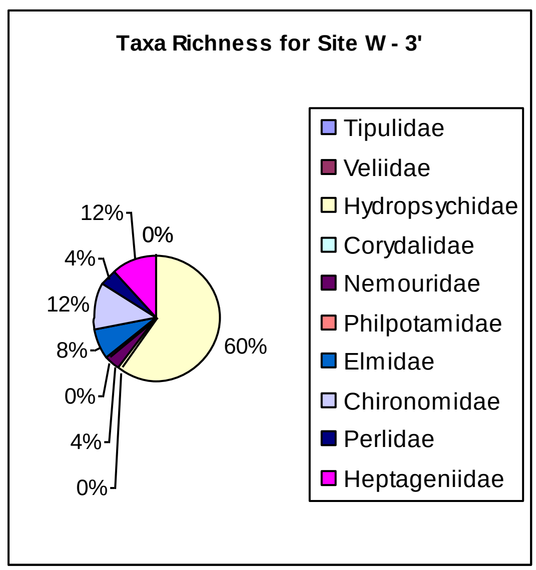


Figure IV-12. The percentage of each family of benthic macroinvertebrates found in Norris Run, just downstream from interstate 795, and upstream from the farm (W-2') and slightly downstream from the farm (W-3').

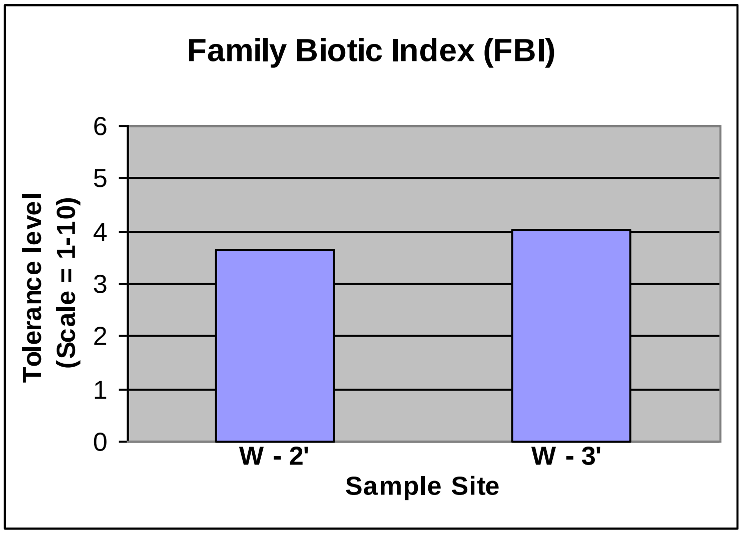


Fig. IV-13. The Family Biotic Index (FBI) for the benthic macroinvertebrates found at two sites on Norris Run. The first sample site is just past interstate 795, and upstream from the farm (W-2'), and the second site was slightly downstream from the farm (W-3').

Discussion

From the two sets of chemical data we collected, we can see that the stream water upstream from the farm is similar to the stream water downstream from the farm, with the exception of conductivity and nitrate levels. Conductivity levels are affected by the presence of ions or charged sediments, such as clays, in the water column. The high levels of conductivity at W-2 and W-2' probably reflect the proximity of that site to the interstate. Salts used to clear roads of ice and snow during the winter, tend to leach off of roadways and remain in streams. The lower conductivity level on Oct 8 probably reflects the magnitude of the rain event. Over 6 inches of rain fell within a relatively brief time around this sampling event. The rain probably diluted the salt sufficiently to decrease the conductivity of the receiving waters. The increase in conductivity at sites W-2' and W-3' on the later sampling dates may indicate increased sediment or nutrient loading due to the effect of multiple rain events.

There were two sets of nutrient measurements taken. The procedures we used were learned through the course of the semester, and for the most part we only got one chance to analyze our measurements due to time constraints. Therefore, our data may not be as accurate as what a professional water resource manager would produce. One set of data was taken using the LaMott field kit, which generally is thought to measure nitrate and phosphate less accurately than laboratory procedures, however it is easier to get quick results. The nitrate levels as measured by the LaMott kit were lower than those analyzed using the ion chromatograph. For site W-2' the nitrate levels were less than 1.0 mg/L for both dates. For site W-3', the nitrate levels were slightly higher between 2.0-3.0 mg/L. These values fall in the low to moderate range of "acceptable" nutrient limits from a set of stream quality criteria from the Maryland Stream Symposium in October of 2005 (Carroll Community College 2005).

The measurements from the ion chromatograph (IC) showed nutrient levels that were much higher than the LaMott measurements. There is a definite difference between the way the first measurements on 9/25/05 and 10/8/05 were handled, compared to the rest of the IC measurements at later dates. The first two dates were refrigerated, rather than frozen, for a considerable length of time. As a result, the nutrients in the samples could have changed during storage. These measurements, which were taken during drought conditions and after the first rain event, were very low between 0.24 and 0.56 mg/L for sites W-1, W-2, and W-3. We cannot validate the accuracy of these measurements due to the way they were handled. The measurements from the other dates we handled properly and the samples were frozen immediately upon returning from the field. Proper procedures were used for running this set of samples. The runoff measurements from this set can be seen in Appendix 7. The stream measurements show nutrients upstream at site W-2' to be around 5.0 mg/L, and the downstream site W-3' to have nutrient values at 8.41 and 11.01 mg/L. Any nitrate concentrations above the 5 mg/L threshold are considered to be high (Carroll County Community College 2005). It is evident that there are differences in our nutrient data that reflect the learning process involved in obtaining these measurements. It would have been better to have used only one method consistently, had replicated our samples and taken the samples over a longer period of time but time constraints and technical difficulties prevented us from doing so. Care should be taken in concluding how the farm is impacting Norris Run when looking at this data.

Our two sites, W-2' and W-3', were similar chemically (with the exception of nitrate and conductivity) which would lead us to expect similar populations of macroinvertebrates. From the data that we gathered in our invertebrate sampling we see that the number of organisms per square meter is much greater upstream from the farm. In general, one might think that more organisms would correspond to better quality water. However, the EPT value calculates the percent of Ephemeropterans, Plecopterans, and Trichopterans (mayflies, stoneflies, and caddisflies), which are highly pollutant sensitive species. When looking at our EPT scores for our two sites we see that our site downstream from the farm has almost twice the percentage (EPT=80%) of these pollution sensitive organisms then our site upstream. One wouldn't expect these particular species to inhabit a polluted stream reach. The other pollution calculation made was the family biotic index (FBI) for each site. In calculating our FBI values, we used a standard scale which assigns each family a number from 0-10. This number represents the overall organic and nutrient pollution sensitivity for each macroinvertebrate family; a low number corresponds to a low pollution tolerant species, whereas a higher number indicates a more pollution tolerant species. The FBI is an average pollution sensitivity score for the macroinvertebrate community at each site. So, FBI values that are low correspond to a community that is less impacted and a FBI value that is higher corresponds to a community that is more impacted. Site W-2' received a score of 3.63, while site W-3' received a score of 4.04. Both scores indicate that the water quality is "very good" for both reaches according to the FBI field test criteria, and that there is only a slight effect from organic pollution. Site W-3', downstream from the farm, has an FBI score that is 0.41 higher then our site upstream. This suggests that the downstream site contains species that are slightly more pollution tolerant than those upstream and that there could be more of an organic pollutant downstream (fig. IV-13). But, this is to be expected in a farm setting. What matters is that the FBI value at site W-3' indicates a good water quality for this reach and there were a variety of pollution sensitive organisms present. It appears that the nutrient runoff from the farm does not negatively affect the benthic macroinvertebrate community.

In summary, our invertebrate data suggests that quantity does not necessarily equal quality. Our sample site downstream from the Reynolds farm should reflect any stream pollution from the farm when compared to our site upstream from the farm. In comparison we can see that according to our FBI and EPT values, the stream appears to be "healthy" with pollution sensitive organisms present at both sample sites, although there is a noticeable difference in abundance. Since the proportion of pollution sensitive organisms did not decrease at our downstream site from the number at our upstream site, this leads us to believe that stream "health" is similar both before and after the farm. The decline in numbers of overall organisms downstream from the farm could be due to other factors such as predation, or food supply.

The toxicity test that we performed was to determine if toxic levels of any chemicals were being carried by the runoff from the farm. If toxic levels of something were present we also needed to know at what concentration they were toxic. This is because when the runoff hits the stream it is diluted instantly. In our data we found no significant signs of toxicity, even in our 100% effluent concentration. This leads us to believe that the runoff water, which travels over the farm, and into the stream, is not toxic. Mr. Reynolds did say he uses as little fertilizer as possible, and it appears that what he does apply has little or no effect to the biota.

Our Overall Evaluation

The Reynolds are working hard to minimize nutrient runoff. Their use of plastic and grass buffers between fields demonstrated that to us. We did see an impact of a large rain event on the levels of nitrogen in the soil (and in runoff to the stream depending upon the data). Did that nitrogen run off the fields or did it run into grass buffers below the fields (where we didn't sample)? Did the rain (it had been very dry) initiate a growth spurt in the weeds in the fields and did these weeds take up the available N? In order to answer these questions we would need to conduct further research.

The soil data suggests that there is movement of leachable nutrients on the farm. Hydrology plays a part in how nutrients move on the farm and everywhere in the world. The total nitrogen decreased at the top of the hill in the pasture field where it can run off, and increased at the bottom of the hill where the runoff would collect. There is a considerable amount of vegetation in the pasture field, which helps in reducing runoff and increases nutrient uptake. It is possible that a flush of grass growth after the rain could change the value of nitrate in the soil. The Reynolds currently practice sustainable agriculture by using grass buffers, cover crops, and contour farming which deters nutrient runoff and leaching. This practice would alter the amount of nutrients in the fields and could lead to incorrect inferences of where nutrients might have come from and how they got there. There are many factors and variables in the nitrogen cycle, which makes it difficult to monitor. With best management practices being utilized on the farm, the fact that there are leachable nutrients is not a red flag or cause for alarm.

Our water sampling suggest that runoff from I 795 is impacting the stream, Norris Run. Chloride increased after the rain suggesting that road salt residues are still coming off the road. Levels of dissolved oxygen were higher downstream than upstream. High levels of dissolved oxygen are critical for stream biota. Nitrate levels were higher near the farm but still in the acceptable range.

Invertebrate samples indicate a higher diversity and more total organisms upstream. Our EPT index, an index reflecting abundance of pollution sensitive invertebrates, was higher at the downstream site. A second index, the FBI, which measures stream health based on the known sensitivity of organisms to pollutants was also assessed. The two sites were very similar in their FBI index with the upstream site having a score that was lower than the downstream by only 0.41units.

V. Suggestions for Improving and Ensuring the Future of Farming in Maryland

Consumers expect Maryland's small farmers to provide a high-quality, blemish-free product at a competitive price. The farmers are expected to do this using minimal amounts of fertilizers and pesticides, and to adopt conservation practices that can often be prohibitively expensive. Farmers are unable to meet both of these contrasting expectations, and thus are unable to please everyone. This, along with other frustrations and difficulties of farming, has caused the agricultural community to shrink considerably, and has simultaneously allowed development to occur over vast expanses of farmland in Maryland.

It has become apparent that the proliferation of development poses a great threat to the Chesapeake Bay watershed. Finally, the importance of farms in Maryland is being recognized. However, this revelation also comes with the sad realization that farming in Maryland is unsustainable; our agricultural community cannot survive without major changes. In any given year, farmers are lucky to break even. The work is back-breaking and the hours are long. One local farmer remarked that he once went seven years without a day off. In this industry, vacations are few and far between. Instilling conservation practices into agriculture is becoming increasingly important, and most farmers adopt as many as they can economically afford. A farmer will jump at the chance to reduce his inputs and costs, and gain productivity from his fields while reducing his environmental footprint. But many conservation practices require expensive machinery or other large investments, and strapped-for-cash farmers simply are unable to take on the additional financial burden. Subsidies are available to help farmers with conservation practices and even simply remaining in business, but such subsidies are often inadequate. Many subsidies only compensate farmers for cleaning up an environmentally damaged site, rather than rewarding them for taking pro-active steps to prevent environmental degradation. Others only subsidize large conservation changes, and give no help for making small, incremental changes that are often more economically viable for farmers. Finally, the farmer-consumer relationship is strained, as consumers demand the blemish-free, cheap products that they can find in grocery stores. Farmers are forced to meet their needs, or lose their clientele and go out of business.

To ensure the survival of our agricultural community, the inequalities of the farming equation must be addressed at all levels. State and federal legislators can change policies to more effectively meet farmers' needs while encouraging them to reduce their environmental impacts. Farming agencies can help educate consumers and can help assure farmers that conservation practices will help increase their profits. Scientists conducting agricultural research can develop ways to prove to farmers that conservation efforts benefit the environment and increase their productivity. Educators can teach children the importance of farming and the best ways a society can support agriculture. With education, the general public can become responsible consumers of agricultural items and can reduce their own environmental impact. If a concerted effort is made to make small farms in Maryland sustainable, the benefits will be shared by all.

Governmental policies and programs pertaining to agriculture traditionally fall into two categories. There are those designed to regulate farming in order to reduce pollution, such as nutrient management plans, and there are those designed to support farming as it becomes more unsustainable, such as subsidies. While these policies have indeed caused improvements in the agricultural community, they could be modified to accomplish even more, and with greater efficiency. For example, certain programs created by the Farm Service Agency (FSA), an important division of the U.S. Department of Agriculture, offer farmers subsidies for planting certain crops or building storage units to hold grain. These activities, while worthwhile in some respects, are a potential source of frustration for farmers who may feel as if they are being offered welfare.   As an alternative, the FSA could provide subsidies to farmers for installing conservation structures, such as wind breaks, cover crops, or grass buffers, which could give a farmer the sense that he or she is earning the money by providing a service, rather than simply accepting charity.

State and federal programs which reward farmers for conservation efforts are available to farmers, but the design of such programs may cause them to be inefficient. These programs, such as Maryland's Agricultural Water-Quality Cost Share Program (MACS), compensate farmers for installing conservation or best management practices on their farms. However, full funding is hard to get, the requirements for the conservation practices are exceptionally stringent, and the large volume of paperwork that farmers must fill out to receive funding or determine eligibility, make programs such as these less attractive to farmers. A better program would be one that compensated farmers for their conservation practices based upon their degree of compliance. For example, if the ideal riparian buffer is at least 50 feet wide and 10 acres long, then farmers could receive 100% of the offered compensation for installing such a buffer, but could still receive 75% of the compensation for installing a buffer that was 45 feet wide and 7 acres long. More flexibility would increase compliance considerably. Also, since farmers have very full schedules, programs need to place a high value on farmers' time. Agency officials could visit farmers, rather than forcing farmers to come see them, and paperwork could be simplified as much as possible. Finally, training courses for continuing education programs, such as nutrient management, could be completed online.

Farmer support agencies, such as cooperative extension services, help farmers deal with challenges and solve problems. Yet as the agricultural community shrinks, such programs seem to shrink as well. For example, for decades, the University of Maryland Cooperative Extension provided soil testing for the agricultural community as well as the general public. This program has been discontinued in recent years, and the shrinking agricultural community has certainly been a factor. Funding must be available for such agencies to continue to serve their purpose of assisting farmers, especially now, as the sustainability of the farming community is threatened. Furthermore, these agencies must expand their operations to assist traditional farms convert their operations to sustainable agriculture, and to help farmers develop the kinds of specialty markets that are necessary to ensure their economic success.

Specialty markets may be the saving grace for many Maryland farmers. Soybeans, a traditional feed crop in Maryland, may become a much more lucrative crop in the next few years as demand for specialty beans increases. According to Tom Horton, writer with On the Bay, a Chesapeake Fields farm is currently working out a deal to sell 44,000 pounds of edamame, a soybean used in soyburgers and Japanese hors d'oeuvres. Another type of soybean, the natto bean, has been shipped from a Maryland farm to Japan, where it is used in snack foods (Horton, 2005). The buyers of these specialty products demand high quality, non-GMO (genetically modified) products that can be tracked to their original field, and they are willing to pay a premium price to ensure this (Horton, 2005). This is an example of value-added farming, in which traditional bulk crops such as wheat, soybeans, and grapes, are transformed into specialty crops and products, such as pasta, edamame, and wine (Horton, 2005). The benefits are significantly increased profitability, which is crucial for farms to become sustainable.

Economic sustainability also will help propagate other types of sustainable behavior, such as environmental sustainability, because the farmers will have increased resources to devote to reducing their environmental impacts. To determine which conservation practices will be most successful in reducing farmers' environmental impacts, society must depend upon the scientific community. The research that scientists conduct in agricultural sciences leads to the development of conservation practices and ultimately, their adoption by the farming community. However, the benefits of these conservation practices are often imperceptible to the farmer who has worked diligently to install them.

Preventing nutrient losses, and in particular, nitrogen losses, is the goal of many conservation practices, yet farmers have no way of knowing how much nitrogen their farm is actually losing. Scientists should develop a rapid assay for nitrate or nitrogen pollutants. Farmers know that nitrogen is essential for plant growth, and so they apply nitrogen fertilizers accordingly. Farmers are also told that they must reduce their nitrogen inputs and install conservation practices, such as grass buffers and cover crops, to reduce the amount of nitrate leaching out of their soil and into the groundwater and streams. However, no one monitors or tests for nitrate, and soil tests, which help a farmer determine how much nitrogen to apply, only give an estimate of the total nitrogen available. Therefore, farmers never know if their cutbacks in fertilizers and their other conservation efforts are doing any good, and this is understandably frustrating. The scientific community should design an assay that could relatively quickly and easily give farmers feedback as to how much nitrate is leaching out of their soils. The would help farmers who are doing their best to reduce their environmental impacts see the fruits of their labor, and would encourage farmers who are doing less to increase their conservation practices.

The scientific community also must continue to study the effects of conservation practices on productivity, the environment, and the economics of farming. This research is invaluable to convince the agricultural community to try new conservation techniques, and assures that the attempts to reduce pollution are efficient.

It is clear that efforts must be made to reduce the environmental impacts of farming and support farmers in developing sustainable practices. However, agriculture is only one source of nutrient pollution. As a non-point source, it is impossible to quantify the inputs of agriculture alone. Homeowners and turfgrass managers apply fertilizers and pesticides that contribute to the impairment of water quality just as agriculture does. Additionally, poorly maintained septic systems are a major source of non-point nutrient pollution in the Chesapeake Bay watershed. It is vital that homeowners understand the ways their actions affect the environment and make efforts to reduce these impacts. The public must be educated on ways to apply fertilizer to ensure that it does not threaten water quality, and how to care for their septic systems. This is essential for reducing pollution in our waterways.

The general public also has a responsibility to reduce pollution related to agriculture, and making it possible for farmers to become sustainable. It is extremely important for consumers to purchase food that has been grown locally (within approximately 50 - 100 miles of their homes). The transportation of food over long distances causes excessive pollution. Also, purchasing food in season is critical to reducing pollution, and for supporting local farmers. For example, buying citrus in December requires the fruit to be shipped over great distances. Consumers also must be aware that by consistently demanding blemish-free fruit, they force farmers to use pesticides, about which consumers then complain. If consumers truly want farmers to reduce pesticide use, they must be willing to buy imperfect produce, and must understand that a spot or a small blemish does not take away from the quality of the product they are purchasing. To increase public awareness and appreciation of farming, more people must try farming for themselves. Compared to produce grown in another state and picked several days ago, locally grown produce is richer in nutrients and taste. Getting people to realize that is it fun and rewarding growing a few tomato plants on their porch, or a small garden plot in the backyard, will help reduce pollution. If growing your own food is not possible, eating seasonally and regionally may be made easier by shopping at your local farmer's market. To locate locally grown or sustainable food, Local Harvest, an information source for the Buy Local movement, provides a searchable database by region (LocalHarvest.org). As more people try these things, the ideas will spread and help to further educate the public.

Agricultural education is necessary for farming to become sustainable in Maryland, and the responsibility must be shared by all parties involved. Farmers are uniquely able to give the public a first-hand experience of the farming lifestyle. To gain the public's support and to educate consumers, farmers must be willing to occasionally open their operations to the public. Seeing the conservation efforts being made by farmers will help people understand the importance of supporting these efforts, by doing things such as buying fruits and vegetables that have not been exposed to pesticides. Agricultural education can also occur in a classroom setting, both for children and adults. Children and adolescents can learn through schooling at all levels about the value of the environment and how it relates to agriculture and contemporary issues surrounding the industry. Adults can participate in workshops and community-supported agriculture events to gain an appreciation of farming. Farmers are very well aware of the issues society has with agriculture, so it is only fair to ask society to understand the issues farmers have with the general public.

The survival of small farms in Maryland is threatened by a lack of sustainability that has slowly evolved as land becomes more economically valuable for development, as food prices are driven down by large, commercial farms, and as the environmental degradation of our water resources continue. Yet Maryland's small farmers provide the state with environmental, social, and economic benefits that are undeniably important and cannot be replaced. To ensure that farming in Maryland has a future, society must work at all levels to improve the farmer's situation and to help farms handle the difficult challenges they face. Through sustainable farming, not only in the environmental sense, but also in the social and economic sense, and supported by the government, private support agencies, scientists, homeowners, educators, and the general public, the future of farming in Maryland will be successful and bright.

Works Cited

A & L Eastern Laboratories. Undated. Agricultural services. (8 November 2005; http://www.al-labs-eastern.com/).

Al-Kaisi M. 2000. Soil erosion: an agricultural production challenge. (6 November 2005; http://www.ipm.iastate.edu/ipm/icm/2000/7-24-2000/erosion.html).

Anderson D. 1997. Turning back the harmful red tide. Nature, August 1997, 513-4.

Apperson J. 1999. Chemicals, conflict in air near farmland. The Baltimore Sun. (April 19, 1999)

Aveni M. 1995. Homeowner survey reveals lawn management practices in Virginia. Technical Note 26. Watershed Protection Techniques. 1(2):85-86

A welcome message from the coordinator. 2005. University of Maryland College of Agriculture and Natural Resources Small Farm Institute. (10 October 2005; http://www.agnr.umd.edu/MCE/SmallFarmInstitute/index.cfm?ID=168).

Badgley C. 2003. The farmer as conservationist. American Journal of Alternative Agriculture, 18(4):206-212.

Baker B. Undated. Brief history of organic farming and the National Organic Program. Organic Material Review Institute. (31 October 2005; http://www.sarep.ucdavis.edu/Organic/complianceguide/search='farming%20history).

Baker D. 1985. Regional water-quality impacts of intensive row-crop agriculture. J. Soil Water Conserv.

Baker J., Lafnen J. 1983. Water quality consequences of conservation tillage. J. Soil Water Conserv.

Baltimore County Council. 2005. History of Master Planning. Baltimore County, MD Office of Planning. October 25, 2005. (25 November 2005; http://www.baltimorecountyonline.info/Agencies/planning/master_planning/history_of_master_planning.html).

The Baltimore Sun. 2005. Leaner, greener farms. (11 November 2005: http://www.baltimoresun.com/news/opinion/baled.farmaid30oct30,1,7403438.story?ctrack=1&cset=true).

Barbarick K. 2005. Organic materials as nitrogen fertilizers. CSU-Cooperative Extension-Agriculture. (25 October 2005; http://www.ext.colostate.edu/pubs/Crops/00546.html).

Barnes R. 2001. Maryland’s former tobacco farmers need a crop as good as gold. (31 October 2005; http://www.bayweekly.com/year01/issue9_47/lead9_47.html).

Bartenfielder J., Moxley S., Kamenetz K., McIntire B., Skinner W., Gardina V., Olszewski J. 2000. Master Plan 2010: Baltimore County, MD. Baltimore County Office of Planning: 232-250.

Bay Journal. 2004. Proposed poultry waste permits draw ire of MD poultry concerns. Associated Press. (29 October 2005; http://www.bayjournal.com/article.cfm?article=983&print=yes).

Beard J., Green R. 1994. The role of turfgrasses in environmental protection and their benefits to humans. Journal of Environmental Quality, 23 (3): 1-16.

Beyer D. 2001. The plow. (7 November 2005; http://www.sutie101.com/print_article.cfm/3521/56026).

Blankenship K. 1995a. How growth impacts water quality. Bay Journal: Alliance for the Chesapeake Bay. (11 November 2005; http://www.bayjournal.com/newsite/article.cfm?article=1083).

Blankenship K. 1995b. Chewing up the landscape: Is our appetite for sprawl killing the Chesapeake? Bay Journal: Alliance for the Chesapeake Bay. (11 November 2005; http://www.bayjournal.com/newsite/article.cfm?article=1082).

Boesch D., Greer J. 2003. Chesapeake futures: Choices for the 21st century. Chesapeake Research Consortium, Inc., Edgewater, MD, USA.

[BRCPAC] Blue Ribbon Citizens *Pfiesteria pisicida* Action Commission. 1997. Hughes Commission Report. (25 November 2005; http://www.dnr.state.md.us/bay/cblife/algae/dino/pfiesteria/hughes_commission report.pdf)

Brown L., Wolf E. 1984. Soil Erosion Worldwatch Institute, Washington, D.C.

Bryant P. 2002. Biodiversity and Conservation: A Hypertext Book. Chapter 14: Habitat pollution. (5 November 2005; http://darwin.bio.uci.edu/~sustain/bio65/lec14/b65lec14.htm).

Buy a horse: racing buyers guide. Undated. 4aHQRSE. (10 October 2005; http://www.4ahorse.com/racingguide.html).

[CANRP] Center for Agricultural and Natural Resource Policy. 2002. Economic Situations and Prospects for Maryland Agriculture. (23 November 2005; http://www.mda.state.md.us/pdf/agfuture.pdf).

[CANRP] Center for Agriculture and Natural Resource Policy. 2004. Economic situation and prospects in Maryland agriculture. (15 September 2005; http://www.mda.state.md.us/geninfo/agfuture.pdf).

Carroll Community College. 2005. The Second Maryland Streams Symposium. Westminster, Maryland

Carpenter S., Caraco N., Correll D., Howarth R., Sharpley A., Smith V. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Issues in Ecology: Number 3.

[CBF] Chesapeake Bay Foundation. 2004. Soil erosion. (6 November 2005; http://www.cbf.org/site/PageServer?pagename=action_simples_ways_soil).

[CBF] Chesapeake Bay Foundation. 2005. Water pollution in the Chesapeake Bay. (7 November 2005; http://www.cbf.org/site/PageServer?pagename=resources_fact_water_pollution).

[CETS-UMES] Communication and Education Technology Services, University of Minnesota Extensions Service. 2004. Soil pH Modification. (23 October 2005; http://www.extension.umn.edu/distribution/horticulture/components/1731- 03.html).

Chesapeake Bay History. 1999. There goes the neighborhood. Chesapeake Bay Program Office. (7 November 2005; http://www.chesapeakebay.net/info/hist4.cfm).

Chesapeake Bay Program. 2001. Nutrient pollution. (8 November 2005; http://www.chesapeakebay.net/stressor1.htm).

Chesapeake Bay Program. 2005. Bay FAQ. (7 November 2005; http://www.chesapeakebay.net/info/bayfaq.cfm).

Comis, D. 2004. Fractals—a bridge to the future for soil science. USDA Agricultural Research Service. (10 October 2005; http://www.ars.usda.gov/is/AR/archive/apr98/frac0498.htm).

Conservation Tillage Information Center. 2002. Conservation tillage and plant biotechnology: how new technologies can improve the environment by reducing the need to plow. (7 November 2005; www.ctic.purdue.edu/CTIC/Biotech).

Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. 2005. (10 October 2005: http://www.dnr.state.md.us/criticalarea/).

Crosson P., Stout A. 1983. Productivity effects of cropland erosion in the United States. Resources for the Future, Washington, D.C.

[CSD] The Corn and Soybean Digest. 2004. Survey says public has high opinion of U.S. farmers. Primedia Business Magazines & Media Inc. (11 November 2005: http://cornandsoybeandigest.com/news/Public-Opinion-Farmers/).

Culpin C. 1992. Plow. Farm Machinery: USDA publication. (7 November 2005; http://www.bartleby.com/65/pl/plow.html).

[CWP] Center for Watershed Protection. 2002. Nutrient movement from the lawn to the stream. Article 4. Watershed Protection Techniques, 2(1):239-246.

Deacon J. 2005. The microbial world: The nitrogen cycle and nitrogen fixation. Institute of Cell and Molecular Biology, The University of Edinburgh. (14 October 2005; http://helios.bto.ed.ac.uk/bto/microbes/nitrogen.htm).

DeGregorio J. 2004. Tobacco buyout program in Maryland half succeeds. (8 November 2005; http://www.foxnews.com/printer_friendly_story/0,3566,114861,00.html).

[DEPRM] Department of Environmental Protection and Resource Management: Resource Management Fact Sheet. 2001. (8 October 2005; http://www.co.ba.md.us/deprm).

[DEPRM] Department of Environmental Protection and Resource Management: preserving our land heritage: Baltimore County's Land Preservation Program. 2005a. (8 October 2005; http://www.co.ba.md.us/Agencies/environment/ep_landpres.html).

[DEPRM] Department of Environmental Protection and Resource Management: Facts about land preservation. 2005b. (8 October 2005; http://www.co.ba.md.us/Agencies/environment/ep_landfact.html).

[DEPRM] Department of Environmental Protection and Resource Management: County recognized as leader in farmland preservation-awarded federal grant to build on record of success. 2005c. (8 October 2005; http://www.co.ba.md.us/News/2005/May/0526_farmranchgrant.html).

Dewar H. 1999. *Pfiesteria* found in five Maryland rivers. The Baltimore Sun. (February 23, 1999).

Dewar H. 2000. Manure cleanup on the shore. The Baltimore Sun. (December 31, 2000).

Dewar H., Horton T. 2000. Seeds of solution to nitrogen glut. The Baltimore Sun. (September 28, 2000).

Dickey E., Shelton D., Peterson T. 1984. Conservation tillage. University of Nebraska, Lincoln.

Diver S. 1994. Introduction to low-input sustainable agriculture. (21 October 2005; http://www.ibiblio.org/intergarden/permaculture/mailarchives/2/msg00293. html).

Dobbins C., Robbins P. 1983. Setting farm management priorities. Journal of Extension. (10 October 2005; http://www.joe.org/joe/1983july/a2.html).

[DNR] Department of Natural Resources. 2005. Algae - Chesapeake and coastal bay life. (8 November 2005; http://www.dnr.state.md.us/bay/cblife/algae/index.html).

Donahue R., Miller R., Shickluna J. 1977. Soils: An Introduction to Soils and Plant Growth. 4th edition. Englewood Cliffs, New Jersey: Prentice-Hall.

Eckert D. 2000. Nitrogen, back to basics. (20 October 2005; http://www.back-to-bascis.net/efu/pdfs/nitrogen.pdf).

[EPA] Environmental Protection Agency: Mid-Atlantic Integrated Assessment. 2001. Maryland agriculture and your watershed. 903/R-00/009. (21 September 2005). http://www.epa.gov/emfjulte/tpmcmaia/html/mda-intr.html).

[EPA] Environmental Protection Agency. 2003. Polluted runoff (nonpoint source pollution): Nutrient management measure. (5 November 2005: http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2c.html).

[EPA] Environmental Protection Agency. 2004. DDT ban takes effect. (5 November 2005; http://www.epa.gov/history/topics/ddt/01.htm).

[EPA] Environmental Protection Agency. 2005a. *Pfiesteria piscida* fact sheet: what you should know about Pfiesteria piscida. (5 November 2005; http://www.epa.gov/owow/estuaries/pfiesteria/fact.html#9).

[EPA] Environmental Protection Agency. 2005b. Pesticides: health and safety. (1 November 2005; http://www.epa.gov/pesticides/food/organics.htm).

[EPA] Environmental Protection Agency. 2005c. National Environmental Policy Act. (9 October 2005; http://www.epa.gov/compliance/nepa/).

[EPA] Environmental Protection Agency. 2005d. Soil preparation. (7 November 2005; http:www.epa.gov/agriculture/ag101/cropsoil.html).

[ESLC] Eastern Shore Land Conservancy. 2004. 2004 Public opinion poll: Summary of results. Attitudes and perceptions about land use on the Eastern Shore. Susquehanna Polling and Research. (11 November 2005: http://cornandsoybeandigest.com/news/Public-Opinion-Farmers/).

2002 Farm Bill: Side by side comparison and economic analysis. (10 October 2005 http://pdic.tamu.edu/pdicdata2/FarmBill/welcome.htm).

Farm Foundation. April 2004. Issue report. Farmland preservation. (8 November 2005; http://www.farmfoundation.org/documents/FINALIssueReport4-15-04.pdf).

Fields B. 2001. Natural Resource Economics: An introduction. Long Grove: Waveland Press Inc.

Foster G., Young R., Romkens M., Onstad C. 1985. Processes of soil erosion by water. American Society of Agronomy, Madison, WI.

Ganzel B. 2005. Farming in the 30's and 40's. Wessel's Living History Farm. (4 November 2005; http://www.livinghistoryfarm.org/index.html).

Gardner B. 2002. Department of Natural Resources. Issues in the future of Maryland agriculture. (8 November 2005; http://www.dnr.state.md.us/education/growfromhere/lesson20/econag.pdf).

Genetically engineered crops. Undated. The Center for Food Safety. (15 November 2005; http://www.centerforfoodsafety.org/geneticall2.cfm).

Goldstein M. 2004. Maryland's Population Growth Moderates in 2003. (29 October 2005; http://www.mdp.state.md.us/msdc/Pop_estimate/Estimate_03/StatePopEst_03.pdf).

Goodman P. 1999. An unsavory byproduct. (29 October 2005; http://www.upc-online.org/990801wpost_poultry_pollution.html).

Goude A. 1986. The Human Impact on the Natural Environment, 2nd Edition. Oxford, UK.

Greer J. 2005a. Saving farm country from Bay country. Chesapeake Quarterly. 4:1.

Greer J. 2005b. Vanishing farms?. Chesapeake Quarterly. 4:1l.

Gregory, M 2004. Watershed conservation on Northfield Farms. St. Olaf College Environmental Studies Senior Seminar. (1 September 2005; http://www.stolaf.edu/depts/environmental-studies/courses/es-399%20home/es-399-04/Projects/Gregory_Project/Web%20Pages/Watershed_Conservation_on_Northfield_Farms.html).

Gresens S., 2005. Associate Professor, Department of Biological Sciences. Towson University, Towson, MD. lecture, October 18, 2005.

Griffith, B. 2005. Phosphorus. Back to basics. (20 October 2005;http://www.back-to-basics.net/efu/pdfs/phosphorus.pdf).

Gross C., Angle J., Welterlen M. 1990. Nutrient and sediment losses from turfgrass. Journal of Environmental Quality, 19:663–668.

Guidelines for estimating cost of raising dairy steers for weight range of 100 – 530lbs. 2002. Manitoba. (10 October 2005; http://www.gov.mb.ca/agriculture/financial/farm2002/cac01s20.html).

Hall B., Kuepper G. 1997. Making the transition to sustainable agriculture: Fundamentals of sustainable agriculture. National Center for Appropriate Technology. (1 September 2005; http://www.resourcesaver.org/file/ toolmanager / O16F21724.pdf).

Hanson J. 1998. Trends in Maryland agriculture. (30 October 2005; http://www.mdagnrpolicy.org/Conferences/OutlookConference/AOPC1998/ hanson/hanson.html).

Hanson J., Johnson D., Lessley B. 1988. Cost and Revenue in Farm Management. University of Maryland. (25 November 2005; http://www.agnr.umd.edu/MCE/Publications/Publication.cfm?ID=189).

Hanson J., Johnson D., Lessley B. 1998. Accessing and improving farm profitablility. (15 October 2005; http://www.agnr.umd.edu/MCE/Publications/PDFs/FS539.pdf).

Hatherill J. Undated. Commercial agriculture: facts and figures. (5 November 2005; http://www.vegsource.com/articles/chemical.farming.htm).

Hausenbuiller R. 1985. Soil Science: Principles and Practices. 3rd edition. Dubuque, Iowa: Wm. C. Brown Publishers.

Heflin S. 2000. Countywide program-formed in 1979. (12 October 2005; http://www.aftresearch.org/PDRdatabase/15.htm).

Hopkins C. 2003. The Project Gutenberg Ebook of The Farm That Won't Wear Out. (12 October 2005; http://www.gutenberg.org/catalog/world).

Horton T. 2001. Summer of 1997 still is debated. The Baltimore Sun. (December 21, 2001).

Horton T. 2003. Turning the tide- saving the Chesapeake Bay. Chesapeake Bay Foundation. Island Press.

Horton T. 2004. Fear of 'blame' stifles honesty about pollution. The Baltimore Sun. (Sept. 24, 2004).

Horton, Tom. Top End Soybeans Good for Bottom Line. On the Bay. twh@intercom.net (2005, Nov.22).

How to buy a thoroughbred racehorse. 2005. eHow. (10 October 2005; http://www.ehow.com/how_110813_buy-thoroughbred-racehorse.html).

Hull J. C. 2005. Professor, Department of Biological Sciences, Towson University, Towson, MD, lectures, October 2005.

Humpert C. 2000. New trends in sustainable farming build compost use. Biocycle, 41 (7): 30. (16 September 2005; Masterfile/EBSCO Database).

[IECA] International Erosion Control Association. 2005. Erosion control products, etc. (8 November 2005; http://www.ieca.org/Resources/Article/ArticleECProductsWorkonFarm.asp).

Implements used on the farm: threshing machine. 1999. American Memory. Library of Congress. Institute of Regional Studies, NDSU, Fargo, N.D. (22 November 2005; http://memory.loc.gov/ammem/award97/ndfahtml/ngp_farm_threshing.html).

Juday D. 2003. *Pfiesteria* hysteria. Center for Global Food Issues. (8 November 2005; http://www.cgfi.org/materials/articles/1999/jun_28_98.htm).

Kantor S. 1999. Moving toward sustainable farming practices. Washington State University Cooperative Extension. (16 September 2005; http://www.metrokc.gov/WSU-CE/Agriculture/PDFs/SustFrming.pdf# search='moving %20toward%20sustainable%20farming%20practices').

Kelderman E. 2001. Farmers grumble about low tobacco prices. (30 October 2005; http://www.newsline.umd.edu/business/specialreports/tobacco/ tobacco032301.htm).

Klein R. 1990. Protecting the aquatic environment from the effects of golf courses. Community and Environmental Defense Association. Maryland Line, MD. 54p. (410)329-8194.

Kline B. 2000. First Along the River: A Brief History of the U.S. Environmental Movement. 2nd Edition. Lanham, MD: Acada Books.

Knapp G., Sohn J., Frece W., Holler E. 2003. Smart growth housing markets, and development trends in Baltimore-Washington corridor. (13 November 2005; http://www.smartgrowth.umd.edu/research/pdf/ConstraintsCauseUrban Sprawl.pdf)

Kolling A. 1995. High–tech farmer receives aid from heaven. Capital News Service. (29 October 2005; http://www.journalism.umd.edu/cns/wire/1995-editions/10-October- editions/951027-Friday/Farmer_CNS-UMCP.html).

Kraft M. E. 2004. Environmental Policy and Politics. 3rd Edition. New York, NY: Pearson Longman.

Law N., Band L., Grove J. 2004. Nitrogen input from residential lawn care practices in suburban watersheds in Baltimore County, MD. Journal of Environmental Planning and Management, 47: 737-755.

Lawrence L. 1997. Farmland Protection Policy: An economic perspective. Center For Agriculture in the Environment. (29 October 2005; http://www.aftresearch.org/researchresource/wp/wp97-1.html).

Local Harvest. 1999. (9 December 2005 http://www.localharvest.org/)

[MALPF] Maryland Agricultural Land Preservation Foundation. Undated. (18 October 2005; http://www.malpf.info/).

Martin R., Stanton L. 1988. Jefferson's plow moldboard of least resistance. Monticello Research Department. (15 November 2005; http://www.monticello.org/reports/interests/moldboard.html).

Marx P. 2005. Financing Chesapeake Bay restoration. Northeast Midwest Institute. (8 November 2005; http://www.nemw.org/ERchesapeake.pdf).

Maryland Agricultural Web Links. Undated. Maryland Cooperative Extension. (29 October 2005; http://www.agnr.umd.edu/users/wmrec/djohnson/home.html).

[MCE] Maryland Cooperative Extension Service. 1997. Managing change in agriculture to enhance profitability and environmental quality: The agricultural situation in Maryland. (16 September 2005; http://www.agnr.umd.edu/users/jwade/ag.htm).

[MCE] Maryland Cooperative Extension. 2005. College of Agriculture and Natural Resources, University of Maryland. (29 September 2005; http://www.agnr.umd.edu/MCE/index.cfm).

[MCE] Maryland Cooperative Extension's: Agricultural Nutrient Management Program. 2005b. (9 October 2005; http://www.agnr.umd.edu/users/agron/nutrient/About/Bkgrnd/ Bkgrnd.html).

[MCE] Maryland's Cooperative Extension's Agricultural Nutrient Management Program. 2005c. Maryland Nutrient Management Regulations. (11 October 2005; http://www.agnr.umd.edu/users/agron/nutrient/About/Regs/Regs.html).

Maryland highlights for 2003. 2005. Maryland Agricultural Statistics Service. (15 October 2005; http://www.nass.usda.gov/md/Highlights.pdf).

Master Plan 2010: Baltimore County MD. Last updated February 22, 2000. (23 November 2005; http://resources.co.ba.md.us/Documents/Planning/imported_documents/ masterplan2010.pdf).

McCord J. 2000. *Pfiesteria*'s role in fish kill challenged by some scientists. The Baltimore Sun. (February 7, 2000).

[MDA] Maryland Department of Agriculture. 2004. Nutrient Management Program 2004 Annual Report: Moving Forward. (1 December 2005; http://www.mda.state.md.us/pdf/nutmgmt_ar_04.pdf).

[MDA] Maryland Department of Agriculture. 2005a. (29 October 2005; http://www.mda.state.md.us/).

[MDA] Maryland Department of Agriculture. 2005b. About MDA. (8 October 2005; http://www.mda.state.md.us/about_mda/index.php).

[MDA] Maryland Department of Agriculture. 2005c. Vision and Mission Statement. (8 October 2005; http://www.mda.state.md.us/about_mda/vision_mission_statement.php).

[MDA] Maryland Department of Agriculture. 2005d. Farming information. (10 October 2005; http://www.mda.state.md.us/resource_conservation/nutrient_management/ farmer_information/index.php).

[MDA] Maryland Department of Agriculture. 2005e. Nutrient management. (11 October 2005; http://www.mda.state.md.us/resource_conservation/nutrient_management/ index.php).

[MDA] Maryland Department of Agriculture. 2005f. Nutrient management planning software for Maryland "NuManMD." (10 October 2005; http://www.mda.state.md.us/resource_conservation/nutrient_management/ consultant_information/software_order_form.php).

[MDA] Maryland Department of Agriculture. 2005g. Governor Ehrlich and poultry companies announce environmental management agreement. (1 December 2005; http://www.mda.state.md.us/article.php?i=675).

[MDA] Maryland Department of Agriculture. 2005h. Memorandum of Understanding. (1 December 2005; http://www.mda.state.md.us/pdf/poultry_mou_final_w-o_signs.pdf).

[MDAORC] Maryland Department of Agriculture Office of Resource Conservation. 2004. Cost-share assistance for nutrient management plans. Brochure.

[MDFB] Maryland Farm Bureau. 2005. Chesapeake Bay cleanup. (1 December 2005; http://www.mdfarmbureau.com/2005/Policy/ChesapeakeBayCleanup.pdf).

[MDNRCS] Maryland Natural Resources Conservation Service. 2005. Maryland farmers sign nations first CSP contracts for 2005. (21 November 2005; http://www.md.nrcs.usda.gov/news/newsreleases/nrcsp.html).

Michaud, Joy. 1991. A Citizen's Guide to Understand & Monitoring Lakes and Streams. (21 September, 2005; http://www.ecy.wa.gov/pubs/94149.pdf)

Miller M. 1995. How preservation pays-farmland preservation. Mother Earth News. Ogden Publications. (11 October 2005; www.findarticles.com/p/articles/mi_m1279/is_n151/ai_17306038/pg_3).

Morton T., Gold A., Sullivan W. 1988. Influence of overwatering and fertilization of nitrogen losses from home lawns. Journal of Environmental Quality 17:124-130.

Mosaic Company. 2005. Back to basics. Agriculture Education Program. (20 October 2005; http://www.back-to-basics.net/cnu/index.htm).

Mountford K. 2004. The real dirt on the history of Bay's nutrients. (7 November 2005; http://www.bayjournal.com/article.cfm?article=1333&print=yes).

Mulching. Undated. Stormwater Authority. (10 October 2005; http://www.stormwaterauthority.org/assets/Mulching.pdf).

Mussendon S. 2000. Buyout response could determine tobacco future. (8 November 2005; http://www.newsline.umd.edu/business/specialreports/tobacco/tobacco 102000.htm).

Myers R. 2004. Maryland farming remains strong, poultry dominates diversification increases. College of Agriculture and natural Resources. University of Maryland. (29 October 2005; http://www.agnr.umd.edu/AGNRNews/Article.cfm?&ID=4091&NL=61).

National Academy of Sciences. 1986. Soil conservation: Assessing the national resource inventory, Vol. I. Board on Agriculture. Washington, D.C.

[NCDA&CS] North Carolina Department of Agriculture and Consumer Services. 2005. Plant nutrients. (22 October 2005; http://www.agr.state.nc.us/cyber/kidswrld/plant/nutrient.htm# Micronutrients).

[NRCS] Natural Resource Conservation Service. 2005a. United States Department of Agriculture. (31 October 2005; http://www.nrcs.usda.gov/partners/for_farmers.html).

[NRCS] Natural Resources Conservation Service. 2005. Farm Bill 2002: Conservation Security Program. (25 November 2005; http://www.nrcs.usda.gov/programs/csp/pdf_files/csp_fs3_05.pdf).

Natural Resource Defense Council. 1998. Chapter 11: Maryland. (30 October 2005; http://www.nrdc.org/water/pollution/factor/stmar.asp).

O'Brien S. 2003. Time is running out to reduce agricultural runoff to the bay. Chesapeake Bay Foundation. (7 November 2005; http://www.cbf.org/site/News2?page=NewsArticle&id=7162).

Parker H., Wright R. 1999. Agriculture and marine environments. Agricultural Research. (7 November 2005; http://web12.epnet.com).

Pegg J. 2004. Animal manure fouling Chesapeake Bay. Environmental News Service. (7November 2005; http://www.ens-newswire.com.ens/jul2004/2004-07-30-10.asp).

Phillips S., Lindsey B. 2003. The influence of ground water on nitrogen delivery to the Chesapeake Bay. U.S. Geological Survey Fact Sheet FS-091-03.

Plowshare. 2003. The Collaborative International Dictionary of English. (15 November 2005; http://www.wkonline.com/d/plowshare.html).

Pretty J. 1998. Feeding the world?". SPLICE, 4:6. (19 September 2005; http://members.tripod.com/~ngin/article2.htm).

Primack R. 2002. Essentials of Conservation Biology. 3rd edition. Sunderland: Sinauer Assoc., Inc. Publishers

Reeder R., Ozkan E., Griffith D., Parsons S. 2005. Ridge tillage: an alternative system. (7 November 2005; http://ohioonline.osy.edu/aex-fact/0505.html)

Reganold J. 1992. Effects of alternative and conventional farming systems on agricultural sustainability. (29 October 2005; http://www.fftc.agnet.org/library/article/bc44001.html#0).

Reich R. Undated. History of soil testing in North Carolina." (10 October 2005; http://www.soil.ncsu.edu/about/century/historysoiltestingNC.html).

Reybold W. U., Matthews E. D. 1976. Soil Survey of Baltimore County, Maryland.Washington, D.C.: US Department of Agriculture Soil Conservation Service.

Reynolds T. 2005. Farmer, Reisterstown, MD, interview, September 13, 2005.

Rodricks D. 2005. The developers are winning – fish, Maryland are losing. The Baltimore Sun. (April 17, 2005).

[SARE] Sustainable Agriculture Research and Education. 2005. (2 November 2005; http://www.sare.org/about/index.htm).

[SCCW] Somerset County Chesapeake Watch. 2005. The Chesapeake Bay Critical Area Law and the Bay Program. (10 October 2005: http://www.somersetbaywatch.org/Legislation.html).

Service Center Locator. 2005. United States Department of Agriculture. (2 November 2005; http://offices.sc.egov.usda.gov/locator/app).

Shibusawa S. 2002. Precision farming approaches to small farm agriculture. Agro-Chemicals Reports, 2 (4). (19 September 2005; http://www.fadinap.org/nib/nib2002_4/octdec02-5-focus-2.PDF#search='environmental%20impact%20of%20farming').

Shober A., Stehouwer R., Macneal K. 2003. On-farm assessment of biosolids effects on soil and crop tissue quality 32: 1873-1880.

Simpson T. Citizen's Guide to the Water Quality Improvement Act of 1998. (21 November 2005; http://www.agnr.umd.edu/waterquality/CitizWQ.html).

Small Farm Success Project. 2005. (30 September 2005; http://www.smallfarmsuccess.info/index.cfm).

Smith M. 1999. The evaluation of Maryland's statewide nutrient management program. (5 November 2005; http://www.agnr.umd.edu/users/agron/nutrient/Resources/Studies/Studies.html).

Smith R., Smith T. 2001. Ecology and Field Biology. San Francisco, CA: Benjamin Cummings.

Smith Z. 2004. The Environmental Policy Paradox. 4th Edition. Upper Saddle River, NJ: Prentice Hall.

Stacey S. 2004. Is organic farming sustainable?. (1 November 2005; http://www.sustainablefarming.info).

Stewart B., Woolhiser D., Wischmeier W., Caro J., Frere M. 1995. Control of water pollution from cropland. Vol I. U.S.EPA, Washington D.C.

Sullivan P. 2003. NCAT Agriculture Specialists. ATTRA: National Sustainable Agriculture Information Service. Fayetteville, AR.

[SUNY-ESF] SUNY College of Environmental Science and Forestry. 2005. Soil pH: What it means.(23 October 2005; http://www.esf.edu/PUBPROG/brochure/soilph/soilph.htm).

Swann C. 1999. A survey of resident nutrient behavior in the Chesapeake Bay. Center for Watershed Protection (CWP). Ellicott City, Maryland. 50 p.

[USBLS] US Bureau of Labor Statistics. 2004. Farmers, ranchers, and agricultural managers. (25 November 2005; http://www.stats.bls.gov/oco/ocos176.htm).

[UCSAREP] University of California Sustainable Agriculture Research and Education Program. 1997. What is sustainable agriculture?. (19 September 2005; http://www.sarep.ucdavis.edu/concept.htm).

[USDA] United States Department of Agriculture. 1996. Soil quality research concerns: soil erosion. (2005 November 8; http://soils.usda.gov/sqi/files/sq_two_1.pdf#'soil%20erosion%20on%20crop).

[USDA] United States Department of Agriculture. 2003. Natural Resources Conservation Service. Conservation practice standard: nutrient management (10 November 2005; http://www.nrcs.usda.gov/technical/ECS/nutrient/documents.html).

[USDA] United States Department of Agriculture. 2004. Farm Service Agency. [Brochure].

[USDA] United States Department of Agriculture. 2005a. (29 October 2005; http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?navtype=_MA&navid=HOME).

[USDA] United States Department of Agriculture: Economic Research Service. 2005b. Maryland state fact sheet. (21 September 2005; http://www.ers.usda.gov/statefacts/MD.HTM).

[USDA] United States Department of Agriculture. 2005c. About USDA (9 October 2005; http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?navtype= MA&navid=ABOUT_USDA).

U.S. Department of State. American Agriculture: It's Changing Significance. (24 November 2005; http://usinfo.state.gov/products/pubs/oecon/chap9.htm).

University of Maryland & University of Maryland Eastern Shore. 1999. Project/Program Plan for 2000 – 2004. (25 November 2005; http://www.agnr.umd.edu/intranet/plan99/goal1.htm).

[USGS] United States Geological Survey. 2003. Agricultural History Patuxent River Watershed. (30 October 2005; http://landcover.usgs.gov/urban/cbay/ag/aghist.asp).

Vanderwel D., Abday S. 2001. Agriculture, food and rural development: an introduction to water erosion control. (11 November 2005; http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2074).

Vasilikiotis C. Undated. Can organic farming "feed the world"?. (21 October 2005; http://www.cnr.berkeley.edu/~christos/articles/cv_organic_farming.html).

Vitosh M. 1995. Selecting forms of fertilizer. Michigan State University. (17 October 2005; http://www.msue.msu.edu/portal/).

Weaver B. 2002: Master Plan 2010 Highlights (12 October 2005; http://www.co.ba.md.us/Agencies/planning/master_planning/master_ an_2010.html).

Webber G. 1995. Insect-resistant crops through genetic engineering. Biotechnology Information Series. (10 October 2005; http://www.ag.uiuc.edu/~vista/html_pubs/biotech/insect.htm).

Wood mulching. 2003. California Stormwater BMP Handbook. (10 October 2005; http://www.cabmphandbooks.com/Documents/Construction/EC-8.pdf).

Yancy C. 2004. Buyout brings changes to Maryland farm landscape. (7 November 2005; http://southeastfarmpress.com/news/maryland-buyout/index.html).

Appendix 1: Resources for Sustainable Farming Practices

Introduction to low-input sustainable agriculture.
http://www.ibiblio.org/intergarden/permaculture/mailarchives/2/msg00293.html

Watershed conservation on Northfield Farms.
http://www.stolaf.edu/depts/environmental-studies/courses/es-399%20home/es-399-04/Projects/Gregory_Project/Web%20Pages/ Watershed_Conservation_on_ Northfield_Farms.html

Making the transition to sustainable agriculture: fundamentals of sustainable agriculture.
http://www.resourcesaver.org/file/ toolmanager / O16F21724.pdf

Moving toward sustainable farming practices.
http://www.metrokc.gov/WSU-CE/Agriculture/PDFs/SustFrming.pdf#search='moving %20toward%20sustainable%20farming%20practices'

Farming systems for sustainable agriculture.
http://www.oecdobserver.org/news/printpage.php/aid/508/Farming_systems_ for_sustainable_agriculture.html

Effects of alternative and conventional farming systems on agricultural sustainability.
http://www.fftc.agnet.org/library/article/bc44001.html#0

Is organic farming sustainable?
http://www.sustainablefarming.info

Applying the principles of sustainable farming.
http://www.attra.org/attra-pub/trans.html

What is sustainable agriculture?
http://www.sarep.ucdavis.edu/concept.htm

Appendix 2: Technical Methods

Total Extractable Nitrogen Analysis (C/N analyzer);

Total extractable nitrogen (TN) was determined for soils using a Shimadzu TOC-V equipped with a TN analyzer. Wet soil samples were extracted with 30 mol high purity water overnight on an orbital shaker table. Samples were centrifuged and the supernatant was retained for analysis of TN (including organic N, ammonia, nitrite and nitrate). Wet soil weights were normalized for water content and all results are reported in terms of dry weight (mg N per kg dry soil).

Determination of Nitrate, Nitrite and Phosphate Concentrations using Ion Chromatography:

The same soil extracts, along with surface and groundwater samples, were also analyzed for nitrite and nitrate concentrations using a Dionne DX-320 ion chromatograph. All samples were filtered through 0.45 μm PÂTÉ syringe filters prior to analysis. Calibration was based on commercially prepared standard solutions. For soil extracts, NO_2-N and NO_3-N are reported in terms of dry weight (mg N or P per kg dry soil).

Appendix 3: **Soil Sample Analyses**

These are the complete set of results from the soil samples obtained on September 25 analyzed for nitrate, nitrite and phosphate with an ion chromatograph. See Chapter IV for description of sampling sites.

Soil Samples	Percent Solids	Total Extractable Nitrogen (mgN/kgSoil)	mg NO_2^- Nitrogen per K soil	mg NO_3^- Nitrogen per K soil	mg PO_4^{-3} P per K soil
Pumpkin top of hill 1"	92.4	88.8		96.9	21.8
Pumpkin top of hill 4”	89	23.2	6.9	14.4	8
Pumplin mid-slope 1”	93.5	26.3	8.6	24.7	20.3
Pumpkin mid-slope 4”	91.1	27.2		26.5	11.8
Corn harvested 1"	94	72.1		84.2	12.4
Corn harvested 4"	90.1	27.4		17.4	22.8
Corn growing 1”	92.3	121.4			
Corn growing 4"	90.1	23.8		17.6	11
Cuke harvested 1"	94.6	226.8	7.9	276.3	15.5
Cuke harvested 4"	86.1	12.7		24.7	19.5
Grass strip below tomatoes 1"	98.9	34.4	8.3	31	26.3
Grass strip below tomatoes 4"	97.3	22.9	7.4	25.2	22.4
Tomatoes growing 1"	92.5	14.4		16.6	21.1
Tomatoes growing 4"	84.5			10.2	19.6
Above top pumpkins 1"	89.2			20.7	
Above top pumpkin 4"	87			16	
Compost Light1	59	2425.0		10.3	1002.8
Compost Light 2	72.3	2957.7			
Compost Med.1	52.4	2580.5		12.1	
Compost Med. 2	43.3	3856.3		14.1	1605.8
Compost Dark 1	44.2	952.7		309.1	92
Compost Dark 2	45.9	1052.9		282.8	96
Pasture top of hill	32.2	40.2		347.4	64.5
Pasture bottom of hill	88.1	5.9		15.8	10
Corn growing core dup	88.2	9.7		12.4	8.4
Corn growing core	88.1	30.6		10.9	8.9

Appendix 3 (continued):

Result of soil testing from November 6. Ion chromatograph data presented first and total extractable nitrogen from the C/N analyzer below.

Ion Chromatograph Data

Sampling Sites	**nitrite**	**nitrate**	**mg/L Nitrate**	**mg/L NO_3-N**	**mg NO_3-N/kg soil**
	n.a.	0.2926	3.517	0.794842	8.643
	n.a.	0.3174	3.814	0.861964	10.054
Harvested corn 1"	n.a.	0.1754	2.11	0.47686	5.521
Harvested corn 4"	n.a.	0.1328	1.599	0.361374	4.185
Corn growing 1"					
Corn growing 4"	n.a.	0.1777	2.138	0.483188	5.622
	n.a.	0.1508	1.815	0.41019	4.989
Pasture top of hill	n.a.	0.4426	5.316	1.201416	14.33
Pasture bottom hill	n.a.	0.248	2.981	0.673706	7.194
Pump. top of hill 1"	n.a.	0.1119	1.348	0.304648	3.345
Pump. top of hill 4"	n.a.	0.1097	1.322	0.298772	3.214
Pump. mid-slope 1"	n.a.	0.275	3.305	0.74693	8.708
Pump. mid-slope 4"	n.a.	0.1284	1.546	0.349396	3.376

Total Extractable Nitrogen Data

Sampling Sites	**Percent Solids**	**Mean Conc.**	**Total Nitrogen (mg/kgSoil)**
Harvested corn 1"	83.7	2.936	32
Harvested corn 4"	82.3	2.604	30.28
Corn growing 1"	76.47	3.437	39.65
Corn growing 4"	80.15	3.324	38.63
Pasture top of hill	79.55	2.03	23.63
Pasture bottom hill	78.26	3.711	45.26
Pump. top of hill 1"	79	3.529	42.19
Pump. top of hill 4"	80.8	2.942	31.03
Pump. mid-slope 1"	81.78	2.6	28.99
Pump. mid-slope 4"	83.6	2.509	26.89
Growing corn core	78.46	4.29	50.94
Pump. mid-slope 4”dup	87.6	3.042	29.56

<u>Appendix 4</u>: Stream Water Quality Data Set 1.

The results from our first round of chemical monitoring for three sites. The first site was upstream from interstate 795 (W-1), the second site was just downstream from interstate 795, but upstream from the farm (W-2), and the third site was slightly downstream from the farm (W-3).

Date sampled (analyzed)	**9/25/2005** (9/26/2005)	**10/8/2005** (10/8/2005)
Site Sampled	**<u>W - 1</u>**	**<u>W - 1</u>**
Temp. Analyzed	25C +/- 1C	25C +/- 1C
Recent Precipitation	Drought	Flood
pH	7.1	7
Cond.	439µs	86.6µs
D.O.	11.1mg/L	8.1mg/L
Ammonia	0.03mg/L	0.05mg/L
Chlorine	0.03mg/L	0.09mg/L
Alkalinity	38mg/L	22mg/L
Hardness	138mg/L	36mg/L
Site Sampled	**<u>W - 2</u>**	**<u>W - 2</u>**
Temp. Analyzed	25C +/- 1C	25C +/- 1C
Recent Precipitation	Drought	Flood
pH	7.5	7.1
Cond.	475µs	89.9µs
D.O.	11.5mg/L	8.3mg/L
Ammonia	0.04mg/L	0.08mg/L
Chlorine	0.04mg/L	0.10mg/L
Alkalinity	98mg/L	26mg/L
Hardness	170mg/L	30mg/L
Site Sampled	**<u>W - 3</u>**	**<u>W - 3</u>**
Temp. Analyzed	25C +/- 1C	25C +/- 1C
Recent Precipitation	Drought	Flood
pH	7.5	7.1
Cond.	282µs	107.2µs
D.O.	11.3mg/L	8.5mg/L
Ammonia	0.04mg/L	0.08mg/L
Chlorine	0.06mg/L	0.05mg/L
Alkalinity	50mg/L	28mg/L
Hardness	96mg/L	32mg/L

Appendix 5: Stream Water Quality Data Set 2.

The results from our second series of chemical monitoring for two sites. The first sample site is just past interstate 795, and upstream from the farm (W-2'), and the second site was slightly downstream from the farm (W-3'). Nitrate and Phosphate levels measured with LaMott test kits.

Date sampled (analyzed)	**10/23/2005** (10/24/2005)	**11/6/2005** (11/8/2005)
	W - 2'	**W - 2'**
Temp. Sampled	9.0C	11C
Temp. Analyzed	25C +/- 1C	25C +/- 1C
Recent Precipitation	Moderate Rain	Moderate - Dry
pH	7.3	7.1
Cond.	343µs	416µs
D.O.	8.4mg/L	12.2mg/L
Ammonia	0mg/L	0.03mg/L
Chlorine	0.01mg/L	0.01mg/L
Alkalinity	60mg/L	74mg/L
Hardness	120mg/L	148mg/L
Nitrate	0.8mg/L	0.7mg/L
Phosphate	0mg/L	0mg/L
Discharge	0.129cfs	0.156cfs
Total Nitrate Load	0.56lb/day	0.59Ib/day
	W - 3'	**W - 3'**
Temp. Sampled	8.5C	10C
Temp. Analyzed	25C +/- 1C	25C +/- 1C
Recent Precipitation	Moderate Rain	Moderate - Dry
pH	7.4	7.1
Cond.	246µs	293µs
D.O.	9.0mg/L	12.3mg/L
Ammonia	0mg/L	0.01mg/L
Chlorine	0.02mg/L	0.02mg/L
Alkalinity	54mg/L	52mg/L
Hardness	96mg/L	100mg/L
Nitrate	2.75mg/L	2.0mg/L
Phosphate	0mg/L	0mg/L
Discharge	0.322cfs	.0293cfs
Total Nitrate Load	4.77Ib/day	3.16Ib/day

<u>Appendix 6</u>: Benthic Macroinvertebrate Data.
The benthic macroinvertebrate data for Norris Run at two sample sites. The first sample site is just past interstate 795 and upstream from the farm (W-2'), while the second site was slightly downstream from the farm (W-3').

Families	W-2' (# of orgs.)	W-3 (# of orgs.) '	Pollution score
Tipulidae	25	0	3
Veliidae	1	0	NA
Hydropsychidae	34	15	4
Corydalidae	4	0	0
Nemouridae	1	1	2
Philpotamidae	5	0	3
Elmidae	5	2	4
Chironomidae	13	3	6
Perlidae	4	1	1
Heptageniidae	0	3	4
# organisms/m^2	989.92	269	
# of organisms	92	25	
# of Families	9	6	
Family Biotic Index	3.63	4.04	
E.P.T.	0.478	0.8	

Appendix 7: Water Nutrient Analysis.

An ion chromatograph (IC) (see Appendix 2 for technical information on the IC) was used to analyze water samples. Stream samples are W-1, W-2, W-2', W-3, and W-3'. Ground water samples (from a shallow well used for irrigation) are labelled GW. RO samples were obtained from different sites on the farm during a heavy rain event (see page 116 for details). As a result of being moved over the summer, the IC did not initially function. Therefore samples from 9/25 and 10/8 were refrigerated for several weeks prior to analysis. The remaining samples were put on ice in the field and then frozen until being thawed and promptly analyzed.

Date	Site	Nitrite (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
9/25/2005*	W-1	n.a.	0.36	n.a.
	W-2	n.a.	0.29	n.a.
	W-3	n.a.	0.56	n.a.
10/8/2005*	W-1	n.a.	0.32	n.a.
	W-2	n.a.	0.24	n.a.
	W-3	n.a.	0.25	n.a.
10/9/2005	RO 1	n.a.	0.62	n.a.
	RO 2	0.14	5.05	1.52
	RO 3	0.26	9.24	12.71
	RO 4	0.49	8.36	1.45
	RO 5	0.13	2.44	1.15
	RO 6	0.28	3.19	6.50
	RO 7	0.32	2.70	8.30
10/23/2005	W-2'	n.a.	5.07	n.a.
	W-3'	n.a.	8.41	n.a.
11/6/2005	W-2'	n.a.	5.08	n.a.
	W-3'	n.a.	11.01	n.a.
11/6/2005	GW-1**	n.a	n.a	n.a
	GW-2	n.a	n.a	n.a

n.a. = not applicable which refers concentrations too low for the I.C. to pick up.

*These samples were refrigerated for several weeks before being analyzed due to technical problems with the I.C. unit.

** Ground water samples were taken as follows: A simple plastic tube containing a ball bearing, known as a bailer, was lowered into the well and allowed to fill with water. The filled bailer was pulled up, and the well water was dumped. This process was repeated several times, in an attempt to flush the well (to remove stagnant water). A sample of water was then collected from the well by repeating this process but retaining the water in 2 sample containers. The water was kept on ice until it could be frozen several hours after sampling. The groundwater samples were then analyzed for nitrate and nitrite using ion chromotography.