In One End and Out the Other
Scientific and Historical Information for Teacher

Agricultural lands comprise 22% of the Chesapeake Bay watershed (Chesapeake Bay Program, 2009). In order to meet the nation's increasing demand for food, farmers must be as efficient as possible, often by intensifying production. Farmers primarily achieve this in one of two ways: by increasing the number of animals raised and/ or the crop yield per acre. Both methods require intensive use of commercial fertilizers, supplemental feeds, pesticides, and irrigation (Chesapeake Bay Program, 2009), Rotz et al., 2011a). Intensified agricultural production has contributed to a variety of existing challenges within the watershed including increased nutrient buildup in the soil; pollution of ground and surface waters by excess nutrients, pesticides and fine sediment; and increased runoff from fields (US Environmental Protection Agency, 2003; Cheaspeake Bay Program, 2009).

Nonpoint pollution from agriculture is a major source of nitrogen and phosphorus in the Chesapeake Bay watershed. Fertilizer and manure applications of *nitrogen* (N) and *phosphorus* (P) typically exceed outputs. This results in a surplus of phosphorus buildup in the soil. In addition, excess nitrogen moves not only through the soil, but also volatilizing into the air, eventually depositing in aquatic systems. Fortunately, many alternative technologies are available today that allow farmers to both increase profitability and reduce environmental impacts. This overview provides a summary of the latest best management practices (BMP) in agricultural production designed to reduce runoff and erosion, maintain soil organic matter, minimize phosphorus (P) and nitrogen (N) leaching and runoff from farm fields, and properly manage livestock waste.

Cover Crops

Cover crops provide permanent soil cover which decreases soil compaction and creates organic matter that provides food for soil organisms and increases biological activity, thereby increasing nutrient availability to crops (SAN 2007, CTIC 2011, Hoorman et al., 2011). Cover crops from the *legume family* convert nitrogen (N) gas in the atmosphere to a useable form for plants, thereby reducing the need for N fertilizer applications (SAN, 2007). Cover crops are also important for reducing nutrient and sediment loss in runoff, reducing greenhouse gas levels through carbon dioxide uptake for photosynthesis, protecting against wind and rain erosion, and increasing water infiltration (SAN 2007, CTIC 2011). Reduction in soil erosion due to cover crops is proportional to the amount of cover on the soil-- 40% cover by winter is sufficient to reduce soil erosion until spring (SAN, 2007).

Conservation Tillage

Sediment from erosion and runoff is a widespread source of agricultural water pollution (US Environmental Protection Agency, 2005). As fine sediment fills the bottoms of waterways, it blocks sunlight from reaching aquatic plants. This is a major cause of sea bed grass declines in the Chesapeake Bay (Chesapeake Bay Program, 2011).

Many farmers have adopted *conservation tillage* in an effort to reduce soil erosion and sediment loss through runoff. Conservation tillage is designed to minimize soil losses by leaving at least one-third of the soil covered with crop residue after planting and includes the following practices: no-till, ridge-till, and mulch-till. *No-till* planting disturbs only the minimum amount of soil needed to ensure a good stand and yield. Holes are drilled in the soil, seeds are inserted, and the holes are covered with soil. *Ridge-till* involves building ridges with heights of 4 to 6 inches when cultivating and scraping off the upper 1 to 2 inches during planting. *Mulch-till* disturbs 100% of the soil surface and uses implements such as chisel plows, disks, and field cultivators (CTIC, 2011). The previous crop residue is turned over and mixed into the soil just before planting.

Nutrient Management

The steady flow of nitrogen and phosphorus into the Bay has resulted in uncontrollable *algal blooms* there (Carpenter et al., 1998; Galloway et al., 2003). As algae die and decompose, the bacterial decomposers remove oxygen from the water, resulting in "dead zones" that are unable to support other aquatic life (US EPA, 2005). The Chesapeake Bay Agreement of 2000 set a goal of reducing the amount of nitrogen entering the Bay by 110 million pounds by 2010, but by 2007 only 17.5% of that goal had been reached (Sutphin, 2008).

Nitrogen and phosphorus can originate from different sources and enter our waterways via different pathways (Crops and Soils, 2008). Over half of the nitrogen inputs to the Bay come from agricultural sources: animal manure, ammonium fertilizers, crop residues, and the root nodules of leguminous plants (Castro et al., 2003; Fields, 2004; Whitall et al., 2004; Crop and Soils, 2008). Nitrogen in its reactive forms is continuously cycled through the air, soil, and water. A nitrogen (N) molecule that enters the air via NH_3 volatilization can easily end up in the soil as *nitrate* molecules. While the nitrogen (N) from nitrate and nitrite molecules is necessary for plant growth, nitrate is the form of nitrogen most often associated with water quality problems. This is partially due to nitrogen's high solubility, which causes it to enter streams and rivers primarily through leaching and subsurface pathways such as groundwater (Carpenter et al., 1998; US EPA, 2003; Crop and Soils, 2008).

Although a major source of phosphorus pollution is human waste, the EPA has identified agriculture (mainly animal manure) as the major nonpoint source of this nutrient. Phosphorus pollution occurs primarily (>90%) via surface water pathways such as runoff and *tile drains* (Crops and Soils, 2008).

Fertilizers

Historically, farmers have determined the amount of nutrients present in the soil, compared that to the amounts needed for their crops, and applied the difference as either manure or a commercial fertilizer. However, there are multiple factors which determine a plant's ability to uptake nutrients and the soil's ability to hold these nutrients. Some researchers (Galloway et al., 2003) estimate that only 12% of the reactive nitrogen form available for plants and animals created for global food production actually reaches our plates. The rest is lost to the environment. Today's best nutrient management plans are designed to maximize plant uptake and yield while minimizing environmental impact (Crop and Soils, 2008).

Manure Management

Field Application of Manure:

Proper recycling of manure is critical for sustainable management. Spreading manure on fields is economically beneficial, because it provides nutrients (nitrogen and phosphorus) for crops and utilizes an accumulating waste product, thereby cutting costs for both commercial fertilizers and manure storage/disposal (Rotz et al., 2011). Problems arise when losses occur, primarily in the form of gaseous emissions of nitrogen through NH_3 volatilization, nitrate leaching to groundwater, and surface runoff of phosphorus (Rotz et al., 2011). Traditionally, farmers spread manure onto fields via broad surface application just prior to tilling the soil. However, it is difficult to incorporate manure into the soil when practicing no-till management, thus increasing NH3 volatilization and nutrient leaching in runoff (Rotz et al., 2011). As a result, alternative methods have been developed for applying manure to fields.

Manure Storage:

Concentrated Animal Feeding Operations (CAFOs) can be found throughout the Chesapeake Bay watershed. Large numbers of animals generating significant amounts of waste may result in an inability of the available cropland to absorb the manure produced. This excess manure may lead to contamination of surface and ground water with nutrients and pathogens (US EPA, 2005). Thus, it is imperative that appropriate waste management techniques are employed.

Integrated Farm System Model

Computer simulation can provide a useful tool for integrating the complex physical and biological factors involved in farm management affecting the farm's performance, environmental impact, and economic viability. The Integrated Farm System Model (IFSM) simulates crop production, feed use, and the return of manure nutrients back to the land over a period of 25 years and takes into consideration average weather conditions throughout that time. Comparing simulation results for different production systems allows one to determine differences in resource use, production efficiency, environmental impact, production costs, and net return. Farm simulation models can help determine not only the environmental effects of varying agricultural practices but also their projected short and long-term economic viability.

Glossary

Algal blooms: Increased growth of algae and water plants, sometimes the result of an excess of nutrients (particularly phosphorus and nitrogen) into fresh and marine waters.

Conservation tillage: Any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop, to reduce soil erosion and runoff.

Legume: Member of a family of plants whose characteristic fruit is a seed pod (beans, peas, etc.). Legumes live in a symbiotic relationship with bacteria in structures called root nodules. These bacteria are able to take nitrogen from the air, which is in a form that plants cannot use, and convert it into compounds that the plants can use.

Nitrate: A salt of nitric acid; found in most fertilizer; becomes a pollutant when in high concentrations in runoff water and leachate into ground water

Nitrogen (N): An element that occurs as a colorless, odorless gas that is essential for the life and growth of all living cells. It is found in several forms throughout the nitrogen cycle.

Nitrogen Cycle: A biogeochemical cycle that describes the movement of nitrogen atoms in several molecular forms through an ecosystem
Nonpoint source pollution: Pollution discharged over a wide area or from several sources, not from one specific location, such as air pollution from motorized vehicles and pollutants washed off of farm fields in rainwater.

Phosphate: A salt of phosphoric acid; often found in fertilizers; becomes a pollutant when in high concentrations in runoff water

Phosphorus (P): An element that occurs as a white, red or black powder; essential for the normal growth and functioning of living cells.
Point source pollution: Any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack

Tile drains: A subsurface system of pipes installed in farm fields to drain off excess water

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