

Agriculture Non-Point Source Pollution Control is part of the World Bank Working Paper series. These papers are published to communicate the results of the Bank's ongoing research and to stimulate public discussion.

Over the past few decades the quality of many international water bodies has deteriorated, resulting in economic losses from declines in the fishing industry and in tourism, as well as a loss of biodiversity and health impacts from contaminated water. This deterioration has been caused by many factors including nutrient run-off from agriculture, insufficiently treated sewage, drainage of wetlands, coastal erosion, introduction of exotic species, eutrophication and inadequate resource management. One of the most significant sources of degradation has been from excessive discharge of nitrogen and phosphorus compounds (nutrients), due to the poor management practices used in agricultural, domestic and industrial activities. This publication aims to draw the attention of professionals and practitioners working in agricultural and environmental sectors to the experiences and successes of the environmentally friendly good agricultural practices being used in the Chesapeake Bay Region of the United States to reduce nutrient loads in water.

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Agriculture Non-Point Source Pollution Control

*Good Management Practices
—The Chesapeake Bay Experience*

Rita Cestti
Jitendra Srivastava
Samira Jung



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FOREWORD

Over the last decades the quality of the Black Sea waters has deteriorated, resulting in economic losses from declines in the fishing industry and in tourism, loss of biodiversity and health impacts from contaminated water. This deterioration has been caused by many factors including nutrient run-off from agriculture, insufficiently treated sewage, conversion of wetlands, coastal erosion, introduction of exotic species, eutrophication and inadequate resource management. One of the most significant sources of degradation has been from run off of nitrogen and phosphorus compounds (nutrients), as a result of agricultural, domestic and industrial activities.

To address the problem of excessive nutrient discharge to the Black Sea, the Global Environment Fund (GEF) has established the “Strategic Partnership Program on the Black Sea and Danube Basin” with cooperation from the World Bank (WB), the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP), other financiers and the basin countries. Under this partnership, a number of Black Sea riparian countries are preparing or implementing projects that aim to reduce nutrient load to the Black Sea from agricultural sources. To assist them in their efforts the World Bank has developed this paper on good management practices to control non point source pollution from agriculture. The paper is based on U.S. experiences in the Chesapeake Bay watershed which faces similar problems.

I believe this document will be very useful for all who are concerned in the preparation and implementation of Agriculture Pollution Control Projects in the countries of the Europe and Central Asia region.

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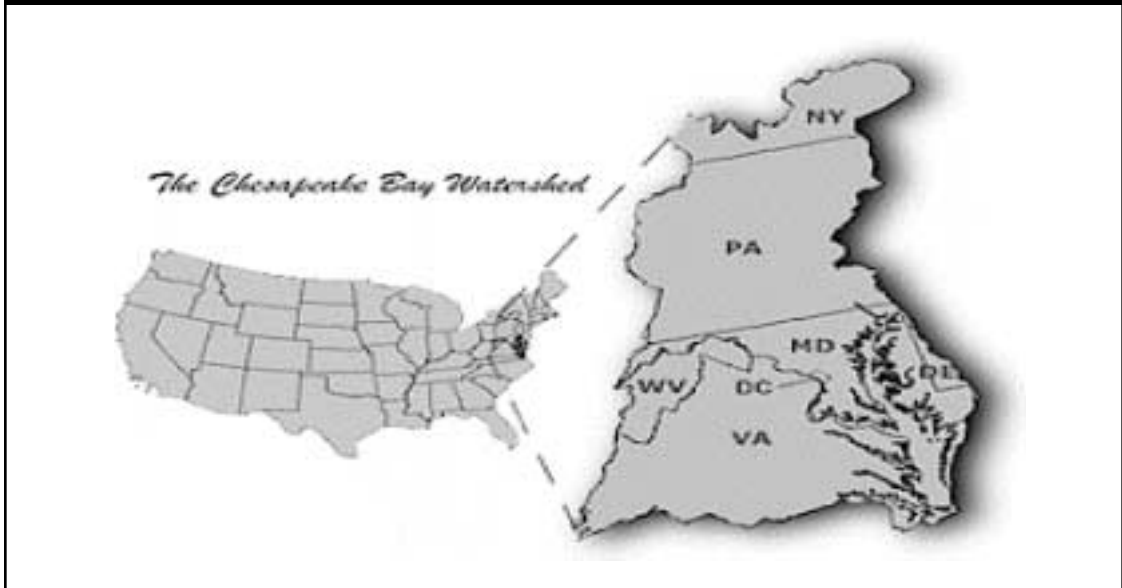
INTRODUCTION

The Chesapeake Bay is the largest and historically most productive estuary in the United States. It is approximately 200 miles long and 35 mile wide at it broadest point. The Bay's watershed includes parts of six states (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the entire District of Columbia. This area encompasses 64,000 square-miles, 150 major rivers and streams and has a population of 15.1 million people. It receives half of its water from the Atlantic Ocean; the rest from rivers, streams and groundwater sources. Fifty percent of the freshwater coming into the Bay comes from the Susquehanna River, which starts in New York State and flows through Pennsylvania and Maryland. The Chesapeake Bay supports 3,600 species of plants, fish and animals. It is home to 29 species of waterfowl, a major resting ground along the Atlantic Migratory Bird Flyway, and provides winter nesting for over one million waterfowl. After years of decline, the Bay still supports number of commercial and recreational fisheries, producing about 500 million pounds of seafood per annum.

Over the years as its population the watershed grew, use of agricultural chemicals became widespread and livestock numbers increased, the water quality in the Bay declined. Nutrients, sediments and toxic chemicals flowing into the Bay were decreasing dissolved oxygen, increasing turbidity, killing-off sea grasses and producing diseases in fish and shellfish. Research undertaken in the late 1970s and early 1980s determined that the major culprits responsible for the decline of the Chesapeake Bay's health were the excess nutrient loads from municipal wastewater plants and from agriculture and residential lands, the sediment runoff from agricultural and residential construction, and the high level of toxic chemicals coming from industry and agriculture. However, eutrophication is generally considered the main ecological threat to the Bay. Analyses indicate that non-point sources of pollution contribute with about 68 percent of the nitrogen that reaches the Bay, and about 77 percent of the phosphorous. Agricultural runoff has also been identified as the largest single polluter (Chesapeake Bay Program, 1997).

In 1983, the federal government and Maryland, Pennsylvania, Virginia, the District of Columbia and the Chesapeake Bay Commission agreed to establish a Chesapeake Executive Council to coordi-

FIGURE 1: MAP OF THE CHESAPEAKE BAY WATERSHED



Source: http://www.chesapeakebay.net/maps/thumbnails/pages/inset_huc.htm

nate the development and implementation of strategies for restoring the Bay. In 1987 the member governments agreed to the goal of reducing nutrients (total nitrogen and total phosphorus) reaching the Bay by 40% (from 1985 levels) by the year 2000. State and federal agencies were to work with farmers to develop and implement site specific “total resource management plans”, composed of Best Management Practices (BMPs) for preventing nutrients, sediments and pesticides from reaching the Bay. In an 1992 agreement a “tributary strategy” was adopted for meeting the 40% reduction goal . Specific limits for nitrogen and phosphorus were to be set for each of the Bay’s ten major tributaries (based on the 40 % reduction goal); then states were to develop strategies for achieving the assigned nutrient limits for each of those rivers. As it has evolved, each the jurisdictions has taken a somewhat different approach (Chesapeake Bay Program, 1994). But in general, these strategies consist of a mix point and non-point source programs and mechanisms for achieving the assigned nutrient targets. Where agricultural non-point sources are the problem reliance is placed on inducing the adoption of the appropriate mix of BMPs. The emphasis is on heavy stakeholder participation and, incentives for voluntary adoption, but within a general matrix of regulation.

The experience in the Chesapeake Bay Region of using BMPs for controlling on-farm non-point pollution sources is very relevant to the countries in Eastern Europe whose lands drain into the Black Sea, which is facing severe eutrophication problems. One key lesson that emerges from what has occurred in the Chesapeake Bay Region, is that farmers can indeed become part of the solution to reversing the ecological decline of the Black Sea even in the face of economic constraints. Over the medium to long run farmers can derive significant economic benefits from adoption of BMPs. Reluctance to address the environmental impacts of agriculture pollution may stem from initial lack of understanding of the economic and environmental potentials of agricultural best management practices,¹ and the fact that some of the BMPs take a few years before the farmers realize economic gains.

1. Adoption of “best management practices” is not only happening in the US agricultural sector. Several other developed and developing countries are also adopting alternative means for managing agricultural production, resulting in tremendous gain for the farmers and the society as a whole. Argentina, Paraguay, and Brazil are just few examples, where this phenomenon is also taking place.

The aim of this paper is to draw the attention of the professionals in the Black Sea countries working in the agricultural and environmental sectors to the wide number of management measures being used today in the Chesapeake Bay Region to address the challenges imposed by eutrophication and at the same time improve farmers' competitiveness. The specific objectives of the paper are:

- To document the wide range of on-farm measures currently used in the Chesapeake Bay Watershed to reduce nutrient loads from non-point source pollution.
- To discuss their benefits, from both the private (farmers) and social (Bay's health) points of view.
- To identify the factors that affect farmers' adoption of best management practices.

Apart from this introductory section, the paper is divided into four sections. The first section briefly stresses the importance of addressing both point and non-point sources when developing a strategy to managing nutrient inputs into water bodies. Often, non-point sources of pollution are considered difficult to control because of their diffuse nature and temporal and spatial variability; therefore quality control actions are often focused entirely on point source pollution. This approach, however, may not be cost effective and may lead to limited or no enhancement of the quality of receiving bodies.

The second section provides a brief description of the most commonly used best management practices in the Chesapeake Bay Region. It focuses on those on-farm best management practices that allow farmers to get the most beneficial use out of their lands while preserving the protecting the quality of water bodies. Whenever possible, direct impacts from each measure on the environment as well as on the financial effects on the farm are identified. In several instances, it was necessary to look at studies outside the Bay to quantify direct impacts of each measure.

The third section presents the relative effectiveness of these measures in terms of their impacts on water quality as well as their cost-effectiveness in terms of reducing soil erosion. It should be understood that farmers in the Chesapeake Bay Region are not looking at individual practices, but instead at systems of practices, aiming to economically optimize farm operations and minimize nutrient losses to the environment. A few case studies on the economics of systems BMPs are also presented in this section. The last section identifies those elements that influence farmers' adoption and implementation of best management practices.

IMPORTANCE OF ADDRESSING NON-POINT SOURCE POLLUTION

Early studies on the Chesapeake Bay did not identify any particular pollution source as the major threat to the health of the Bay. Moreover, their initial finding indicated that efforts should be directed to reduce all sources of pollution equally. Over time point sources have largely been addressed by regulatory mechanisms. Subsequent research, modeling and monitoring efforts in the Bay led to the conclusion that non-point source pollution involving animal wastes, cropland, pasture, urban runoff, forest and atmospheric deposition, contributed to 82 percent of the remaining nitrogen load and 68 percent of the remaining phosphorous load to the Bay.

The above findings triggered the refocusing of the Chesapeake Bay Program. Recognizing that a significant portion of the threats to the health and ecology of the Bay were caused by nutrient over-enrichment from non-point pollution sources led to better targeting of both limited financial resources and technical assistance provided under the Bay Program.

Table 1 provides an order of magnitude of the average total phosphorous and total nitrogen loads from various land use in the Chesapeake Bay on a per unit area basis.

**TABLE 1: AVERAGE PHOSPHOROUS AND NITROGEN LOADS BY LAND USE
IN THE CHESAPEAKE BAY**

Land Use	Total Phosphorous Loads (kg/ha)	Total Nitrogen Loads (kg/ha)
Forest	0.1	4.3
Pasture	0.4	7.9
Livestock Operations	460.0	2,302.0
Conventional Tillage	2.6	25.2
Conservation Tillage	2.0	20.5
Hay	1.7	11.0
Urban areas Business & Residential	0.9	11.1
Atmospheric Loads	0.7	16.2

Source: Adopted from Shuyler *et al.*, (1995)

ON FARM BEST MANAGEMENT PRACTICES

Best management practices (BMPs) are individual or combinations of management, cultural and structural practices that researchers (academic or governmental), have identified as the most effective and economical way of reducing damage to the environment. In general, these practices are designed to efficiently use agricultural chemicals; increase ground cover, decrease the velocity of surface runoff, and improve the management of livestock waste. Controlling erosion is an essential aspect of preventing nutrient non-point source pollution of surface waters as eroding soil particles will carry excess nutrients, particularly phosphorous, with into water bodies.

To address agriculture nutrient non-point source pollution, farmers can use either structural measures (i.e., waste containment tanks/lagoons, sediment basins, terraces, diversion, fencing, tree plantings) or managerial ones (i.e., nutrient budgeting, rotational grazing, conservation tillage,). In either case, good management is always a necessary condition for reducing farm pollution (Gale *et al.*, 1993).

There are several BMPs currently under implementation in the Chesapeake Bay Region, these include: conservation tillage, treatment of highly erodible land, streambank protection, nutrient management planning (budgeting), winter cover crops, waste management systems, forest and grass buffers (Chesapeake Bay Program, 1994) The provision of technical assistance, regulation, cost sharing and incentive payments have tremendously influenced farmers in the Bay Region to develop and implement comprehensive management plans (Total Resource Management Plans) that integrate individual BMPs. into a coherent system of practices to maximize all environmental outcome (e.g., terrestrial habitat as well as water quality)

Agriculture best management practices can be grouped according to their functions. The USEPA, 1993 guidelines identifies the following categories:

- Managing sedimentation. Measures to control the volume and flow rate of surface water runoff, keep the soil in place, and reduce soil transport.

- Managing nutrients. Measures to help to keep the nutrients in the soil, minimizing their movement into water bodies.
- Managing pesticides. Measures to reduce non-point source contamination from pesticides, by helping limiting pesticide use and managing its application.²
- Managing confined animal facility: Measures to reduce or limit the discharge from confined animal facilities.
- Managing livestock grazing. Measures to reduce impacts of grazing on water quality.
- Managing irrigation. Measures to help farmers to improve water use efficiency³.

Table 2 presents a list of the BMPs suggested by USEPA (1993) according to their functions. For details on the measures included under each BMP, the reader is referred to Annex 1. As seen from Table 2, these BMPs very often control more than one pollutant of concern. BMPs reinforce each other, and rarely the implementation of a single BMP is practiced. Farmers in the Bay have selected the best combination of BMPs for minimizing soil erosion, controlling emissions of nitrogen and phosphorous and protecting water quality, according to their specific agricultural and environmental needs. The most commonly used measures used in the Bay will be reviewed next.

TABLE 2: BEST MANAGEMENT PRACTICES AND THEIR FUNCTIONS

BMP	MS	MN	MP	MCAF	MLG
Permanent vegetative cover	X	X			X
Animal waste management system		X		X	
Strip cropping systems	X	X	X		
Terrace system	X	X	X		
Diversion systems	X				X
Grazing land protection system	X	X			X
Waterway system	X				X
Cropland protection system	X	X			
Conservation tillage systems	X	X			X
Stream protection system	X				X
Sediment retention and erosion	X				
Tree planting	X	X			X
Fertilizer management		X			
Pesticide management			X		

Notes:

MS: Managing sedimentation

MN: Managing nutrients

MP: Managing pesticides

MCAF: Managing confined animal facility

MLG: Managing livestock grazing

Source: Adapted from Chesapeake Bay Advisor Committee (1997) and USEPA (1993a).

Before describing each of BMPs methods (beginning below) used in the Bay, it is important to note that alternative financial incentives and technical resources are being offered to farmers on the Bay to voluntarily install agriculture BMPs to protect the environment. In the case of the State of Maryland, for example, the Maryland Agriculture Water Quality Cost-Share Program (MACS)

2. Pesticide management is not directly related to nutrients and/or eutrophication, consequently, will not be discussed further in this paper.

3. Irrigation management measures will not be covered in this review, since irrigation is not being practiced in the Bay Region.

provides farmers with up to 87.5 percent of the cost to install eligible BMPs. Use of labor as “in-kind” match for funding is allowed. Maximum cost-share assistance levels are as follows:

- Animal waste treatment and containment projects: Up to \$50,000 per farm, with a maximum of \$65,000 per farm when combined with other BMPs; or up to \$50,000 per project under a pooling agreement to solve a pollution problem on two or more farms.
- All other BMPs: Up to \$10,000 per project, with a maximum of \$35,000 per farm; or up to \$20,000 per project under a pooling agreement to solve a pollution problem on two or more farms.

In the case of the State of Virginia, cost-share funding for BMPs is available for 75 percent of the cost to purchase or construct BMPs. The agricultural BMP Cost Share Program requires a 25 percent match with a restriction on annual total of \$50,000 to a given landowner. Farmers can use their labor as “in-kind” match contribution for the funding. In addition, the State of Virginia is also offering the Agriculture BMP tax credit to encourage farmers to install conservation practices. Under this program, farmers can claim a tax credit equivalent to 25 percent of BMP installation costs. The maximum credit to be claimed on 1998 state income tax forms is limited to \$17,500 per year.

Nutrient Management

Nutrient management utilizes farm practices that permit efficient crop production while controlling non-point source water pollutants. A nutrient management plan is a written, site-specific plan that addresses these issues. The plan must be tailored to specific soils and crop production systems. The goal of the plan is to minimize detrimental environmental effects (primarily on water quality), while optimizing farm profits. Nutrient losses will occur with the plan but will be controlled to an environmentally acceptable level. Nutrient management programs emphasize how proper planning and implementation will improve water quality and enhance farm profitability through reduced input costs. These plans incorporate soil test results, manure test results, yield goals and estimates of residual N to generate field-by-field recommendations. (Alfera and Weismiller, 2002 p6).

The efficient use of nutrients in agricultural production systems has important environmental implications. Crops are not efficient at removing fertilizer and manure nitrogen from the soil during the growing cycle. Unused or residual nitrogen is vulnerable to leaching prior to the start of the next cropping year especially during the fall and winter months if precipitation occurs when fields lay fallow. The potential exists for accelerated nutrient loss when essential nutrient amounts exceed crop uptake needs. Nutrient reactions and pathways in the soil-water system are complex. Nutrient flow to surface water and groundwater vary from nutrient to nutrient as do the threats to water quality. Potential surface water impacts include sedimentation, eutrophication and overall water quality degradation. Groundwater concerns center around the potential migration of pesticides and nitrates in recharge waters, and the resulting degradation to drinking water quality. Groundwater can also be a source of surface water recharge, extending its detrimental ramifications. (Alfera and Weismiller, 2002 p7).

The potential for plant nutrients (N and P) to migrate to surface and groundwater is largely dependent on soil and site conditions. Therefore, an important aspect of nutrient management planning is the recognition and delineation of these sites and conditions and the development of best management practices (BMPs) to control these losses. It is known that a number of particular soil/landscape features and properties are environmentally sensitive and particularly conducive to the loss of nutrients. The following include the major types of land with these concerns. Appropriate setback or buffer zones should be established between these areas and any field receiving nutrient applications. Intensive nutrient management practices should be used on land adjacent to sensitive areas.

- Soils with high leaching potentials: This includes soils with very coarse textures and water tables at or near the surface during the winter
- Shallow soils (< 100 cm) over fractured bedrock: These soils should be managed like soils with a high leaching index. Once the soil water percolates to the fractured rock, the continued move to the groundwater can be rapid. Nutrient management practices should include split-applications of N on crops and the use of winter cover crops.
- Tile drained lands: There is a direct connection of the tile outlets to surface watersheds. These lands typically have high seasonal water tables and therefore have the potential to pollute surface water and local water tables.
- Irrigated lands: These fields are prone to runoff and leaching of water and nutrients. Irrigation scheduling methods including the use of gypsum blocks, tensiometers or computerized systems. Rates should be applied according to soil type and water holding capacities.
- Excessively sloping lands: Slopes greater than 12% to 15% are prone to loss of surface applied N and P. If nutrients are incorporated through tillage practices, sediment loss can be significant in cases of heavy rainfall. If using manure, applications should be limited by P soil test needs or crop uptake estimates. Injection would be the preferred manure application method.
- Floodplains and other lands near surface waters: Surface flow of runoff water has little chance to be filtered before discharge into adjacent waters if channeled flow develops. Sub-surface flow in groundwater can also seep directly into adjacent surface water. If nitrate contaminated water flows into the area, significant N can be denitrified and lost to the atmosphere. Manure and bio-solid use is not recommended. If there use is necessary, incorporation or injection application methods are preferred.⁴

Conservation Tillage Systems

Conservation tillage is a tillage system that leaves at least 30 percent of the soil surface covered with crop residue to protect the soil from erosion. When wind plays a major role in soil erosion, conservation tillage consists of any system that maintains at least 1,000 pounds per acre of crop residue through the wind erosion period. Conservation tillage systems include no-till, wherein the soil is left undisturbed from harvest to seeding and seeding to harvest; ridge-till, wherein the soil is left undisturbed from harvest to planting, except for creation of the ridges (or birms) and nutrient injection; and mulch-till where the soil is disturbed prior to planting. The latter is one of a number of minimum-tillage techniques scarify the soil, but do not turn it over, with no disturbance of the soil occurring between harvest and planting.

Currently, almost 50 percent of the total cropland in the States of Virginia and Maryland is under conservation tillage (Dillaha, 1990, p. 4). In some watersheds of the State of Maryland, the share of cropland using conservation tillage and no-till systems is even higher. For example, in the Pocomoke Watershed, with 543 farmers managing 70,000 hectares, 71 percent of the cultivated land uses some form of conservation tillage for the crops (MDA, 1997).

There are many benefits associated with conservation tillage systems. They can reduce wind erosion by 50 percent to 90 percent compared to conventional tillage (CTIC, 1998)⁵. In addition, conservation tillage systems increase water filtration and moisture retention and reduce surface sediment and water runoff by about 25 percent (Dillaha, 1990, p. 4). High residue systems also tend to improve long-term soil productivity and reduce release of carbon gases, sequester carbon and particulate air pollution (MDA, 1997, p. 155–158). They do, however, generally require more use of herbicides than conventional tillage and mechanical weeding

Conservation tillage systems offer farmers prospects for improved economic returns. Although impacts on farm's profitability take a few years, and are site specific, conservation tillage can benefit

4. U.S. Experiences with Nutrient Management, 2002. p 8–9).

5. Dillaha (1990) indicates that wind erosion is halved for every 9 to 16 percent increase in residue cover.

TABLE 3: CONVENTIONAL TILLAGE VIS-À-VIS CONSERVATION TILLAGE

Dimension	Difference between conservation tillage and conventional tillage
Production cost	Lower by \$135 per hectare
Yield	Higher by 150 kilos per hectare
Net return	Higher \$320 per hectare

Source: Smart et al. 1998.

farmers in several ways. USDA (1998), CTIC (1998a), CTIC (1998b), and Srivastava *et al.* (1998) cite the following potential benefits that can be derived from practicing conservation tillage:

- Increasing yields. In areas under dry conditions, conservation tillage improves moisture retention of at least 100 mm in the root zone as a result of reduced runoff, increased infiltration and suppressed evaporation from the soil surface, translating into increased crop yields. Increases of up to 15 percent in crop yields have been reported with minimum-till operations accompanied by crop rotation and integrated pest management.
- Reducing production costs. Adoption of conservation tillage systems has a direct impact on the amount of inputs, i.e., labor, machinery, fuel and chemical. High residue tillage operations can significantly reduce the amount of hired labor. Savings can be as great as 1.1 hour-labor per hectare. Fewer number of needed trips over the field can also save an estimated \$10 per hectare on both machinery wear and maintenance costs. Fewer trips also mean reduced fuel consumption. Conservation tillage can save an average of 3.5 gallons of fuel per acre.
- Reducing land preparation time. Conservation tillage can drastically diminish the amount of time required in field preparation and planting. This offers an opportunity for early planting date and even for increasing the number of crops per year.

The results of a study on the economics of conservation tillage undertaken by the University of Minnesota reveal that indeed crop residue management through reduced tillage is a cost-effective practice. The main finding of the study is that with appropriate tillage systems, farmers do not sacrifice profitability. On the contrary, the practice offers potential for reducing production costs and increasing net profits. For 800-acre farm evenly divided between corn and other crops, switching from using a moldboard plow to using a chisel plow would represent a net private gain of \$25 per hectare⁶.

Smart *et al.* (1998) compared the effects of conservation tillage and moldboard tillage systems on cotton crop yield and production costs in six producer fields in Cameron County, Texas. Table 3 illustrates the differences on production costs, yields and net returns between the conservation tillage and the conventional moldboard tillage systems.

The effects of conventional and conservation tillage on corn yield and production costs were also studied by Smart and Bradford (1997). The findings of the study reveal that the pre-plant⁷ no-tillage corn yields were 9 and 20 percent lower than conventional moldboard plow tillage in the spring and fall during the first year of the study. Yields for pre-plant no-tillage were equivalent or up to 12 percent greater than conventional tillage in the spring and fall during the second and third year of the study. The overall net returns for the three years for spring and fall were \$106 per hectare greater for the pre-plant no-tillage than the conventional tillage treatments.

6. It does not take into account the benefits derived from a cleaner river.

7. "Pre-plant" refers to the application of herbicides just prior to planting.

Crop Rotation

Crop rotation consists of a planned sequence of growing different crops (annual or perennial) in the same field. Apart from improving the quality of the soil, this practice. It may also help to reduce the use of fertilizers by naturally breaking the cycles of weeds, insects and other pest diseases. The inclusion of a grass crop or a legume in a rotation is highly effective in reducing erosion and improving soil structure. A legume can further eliminate the need for chemical nitrogen fertilizer since legumes supply their own nitrogen needs and add nitrogen to the soil by “fixation” (USDA, 1993).

This practice of crop rotation with legumes offers farmers the possibility of reducing commercial nitrogen fertilizer needs as well as fertilizer costs for the subsequent crop, since rotation crops such alfalfa and other legumes crops (e.g. soy beans, etc) can replace some of the nitrogen. In addition, pesticide costs can also be considerably reduced.

Studies have found that crop rotations, particularly those involving fall planted crops for spring harvesting, can improve surface water quality by reducing sediment loss, reducing application of chemical pesticides, and reducing losses of dissolved and sediment-attached nutrients and pesticides. Crop rotations also tend to encourage healthy root systems, which are effective at retrieving nutrients from the soil, thus reducing the potential for pesticide leaching to groundwater.

Economic factors cause some farmers to choose not to rotate their crops because it means planting crops that are less profitable, but crop rotation has many economic and environmental benefits including the following: The most effective crops for soil improvement are fibrous rooted, high residue producing crops such as grass and small grain.

Perennial, deep-rooted forages like alfalfa increase the soil organic matter improving soil tilth and reducing soil erosion. Water is absorbed more quickly in fields under a crop rotation than fields continually planted with row crops. Moisture efficiency improves due to the improvements in soil organic matter and soil structure. Continuous cropping of row crops such as corn cause the greatest decline in organic matter. Rotations help to control diseases and insects that are limited by their plant hosts. For example, soybean cyst nematode feeds on soybean roots. When soybeans are rotated with corn, the nematode population decreases. Yields can increase due to a resulting decrease in soil pathogens. Alternating crops can suppress species that grow best in one certain crop type. Some rotations supply allelopathy, the emission of chemicals from plant roots that suppress the growth of other plants. For example, wheat’s allelopathic effects reduce the number of weeds in soybeans planted into wheat residue. Legume plants such as alfalfa can reduce the amount of fertilizer needed by sequential crops. (Alfera and Weismiller, 2002 p 35.)

Strip Cropping System

Under this technique, alternate strips of different crops are planted in the same plot along contours or across the main direction of the wind. By growing crops together in alternating strips it is possible to obtain higher total system yields and higher economic returns, as a result of the improved biological stability in the system. There are three main types of this practice:

- Contour strip cropping. The layout is such that the crops follow a definite rotational sequence. Tillage should closely follow the exact contour of the field.
- Field strip cropping. Under this practice, strips of the same width are placed across the general slope of the plot. It can be used in irregular topography if combined with grassed waterways.
- Buffer strip cropping. Under this practice, strips of grass or close-planted legume crops are laid out between contour strips of crops in irregular rotations. Short-rotation woody plants can also be used. These strips may be even or irregular in width, and placed on critical slope areas of the field.

This management practice is used to control wind erosion and the amount of sediment and related substance delivered to water bodies. Planting strips along contours can minimized water

damage in dry regions. Planting strips crosswise to the contours can minimize wind damage. One potential pitfall of strip cropping is that it may increase leaching of soluble substances (e.g., nitrogen) into the groundwater.

Strip cropping has the potential to reduce erosion on hilly lands, to allow a crop rotation in the field if strips are changes from one season to the next, and to increase total system yields. Results from several experiments in the U.S. East and Midwest show considerable variation in production among years and locations. An interesting finding is that total yield in a strip cropping system rarely falls below the average monoculture system. In years of adequate rainfall, production of strip crops may be 10 percent to 20 percent higher than sole crops (Francis *et al.*, 1986, p. 1)

The 4-year study of alternative strips of corn and soybeans conducted in the Land Laboratory at Parkland College in Champaign, Illinois, shows that corn yields increased from 22 percent to 41 percent and soybeans yields decreased from 18 to 20 percent in the strip crops. The study, however, also shows that strip cropping is economically superior to sole cropping. The average gross income advantage was reported at \$83 per hectare over the 4 years (Francis *et al.*, 1986, p. 7).

When strip cropping is combined with other conservation practices, such as conservation tillage, cover crops, crop rotation, the impacts on reduction of topsoil erosion on hillsides are high. Relative impacts of strip cropping and alternative conservation practices are presented in Table 4.

TABLE 4: IMPACTS OF STRIP-CROPPING PRACTICES ON SOIL EROSION

Crop Rotation	Strip Cropping and Conservation Practice	Residue Management*		
		0 percent	30 percent	60 percent
Corn-soybean	None	100	78	33
	Contour	50	39	17
	Contour-strip with small grain cover	40	31	13
	Contour-strip with meadow	25	20	8
Corn-corn	None	76	63	26
	Contour	38	32	13
	Contour-strip with small grain cover	31	25	10
	Contour-strip with meadow	19	16	6

Note:

*Measure as a percentage of maximum erosion calculated at 47 tons per acre per year for a corn-soybean notation with tillage practice leaving no residue on the soil, and no conservation practice.

(Source: Francis et al 1986).

A recent survey conducted in the State of Maryland revealed that the percentage of farmers using strip cropping has steadily increased since 1986, from 10 percent to 38 percent in 1995. It was also found that this practice was suitable for crop farmers operating in lands with at least 3 percent slope (Lichtenberg, 1996, pp. 6–7).

Cover Crops

This practice is designed to absorb excess nitrogen after crop harvest and to prevent erosion during winter months. There are two types of cover crops: those used to decrease runoff, erosion and leaching between cropping seasons; and those that provide nitrogen to succeeding crops. The latter type is also called green manure. Legumes are usually used as green manure (Michigan State University, 1998, p. 38).

Technically speaking, a cover crop is a crop that is not harvested but is grown to benefit the topsoil and or other crops, but if the length of the growing season permits, they can be harvested prior to planting a summer crop Crops such as cereal rye, oats, sweet clover, winter barley and winter

wheat are planted to temporarily protect the ground from wind and water erosion during times when cropland is not adequately protected against soil erosion. They may also be used to use up surplus nutrients. Cover cropping is short-term practices, not exceeding one crop-year.

The crop cover keeps the ground covered, adds organic matter to the soil, traps nutrients, improves the soil tilth, and reduces weed competition. When properly grown, cover crops or green manure may contain 1–2 percent nitrogen, 0.5–0.75 percent of phosphorus, and 3–5 percent potassium, which is equivalent to low-analysis fertilizing materials. In addition, cover crops are used to decrease erosion, runoff, and leaching between cropping seasons as well as pest problems. Crop covers can reduce soil erosion by 70 percent and runoff by 11 to 96 percent (Dillaha, 1990, p. 6).

This practice is used extensively by farmers in the Bay. In the State of Maryland, about 40 percent of farmers plant cover crops in their fields. The benefits to the farmers are the same as those discussed in crop rotation, as essentially they serve a parallel function. Research at the Biological Station in Michigan that compared continuous corn to corn following frost seeded red clover in wheat shows a \$40 per acre per year incremental net return when cover crops were incorporated into a crop rotation (Michigan State University Extension, 1998, p. 52).

TABLE 5: COVER CROPS, BENEFITS AND CONSIDERATIONS

Cover Crops		
Pure Legume Stand	Pure Grass Stand	Grass/Legume Mixtures
Benefits		
Provides nitrogen for the crop that follows it.	Excellent nitrogen scavenging ability Tolerant of low temperatures	Good strategy for combining a reduced level of nitrogen conservation with some nitrogen contribution to following crop Summer moisture conservation is greater than grass alone Immobilization is less than grass alone
Provides substantial mulch	Variable mulch cover depending on residual nitrogen	
Considerations		
Less effective than grasses as a nitrogen scavenger Kill date is important	Provides little nitrogen to the following crop Kill date is important Typically requires 11.3 to 22.6 kg of starter nitrogen for subsequent crop due to immobilization	Does not provide as much nitrogen as pure legume stand or conserve as much nitrogen as pure grass stand

Source: Nutrient Manager, University of Maryland, College Park, Eastern Shore, Vol. 2, Issue 2, Winter 1995.

Terraces

Terraces consist of an earthen embankment, a channel, or a combined ridge and channel built across the slope of the field (USEPA, 1993, p. 2–24). They may reduce topsoil erosion rate, sediment and the associated pollutants content in surface water runoff. They have been reported to reduce soil loss by 94 to 95 percent, nutrient losses by 56 to 92 percent and runoff by 73 to 88 percent (Dillaha, 1990, p. 7). Terraces intercept and store surface runoff, trapping sediments and pollutants. Underground drainage outlets are used to collect soluble nutrient and pesticide leachates, reducing the risk of movements of pollutants into the groundwater and improving field drainage.

This is not a very popular practice among farmers in the Bay, because of its high capital costs. The latest survey of farm practices in the State of Maryland revealed that in 1995 only 10 percent of farmers have installed terraces in their field. The above survey also revealed that installation of

terrace systems was only appropriate for farmers operating fields with at least 8 percent slope (Lichtemberg, 1997, p. 7).

Topography and equipment size must be adjusted to fit terrace spacing. Slope, soil erodibility, crop type, management and rainfall also determine spacing. See table 6 for recommended terrace spacing with and without a conservation management system.

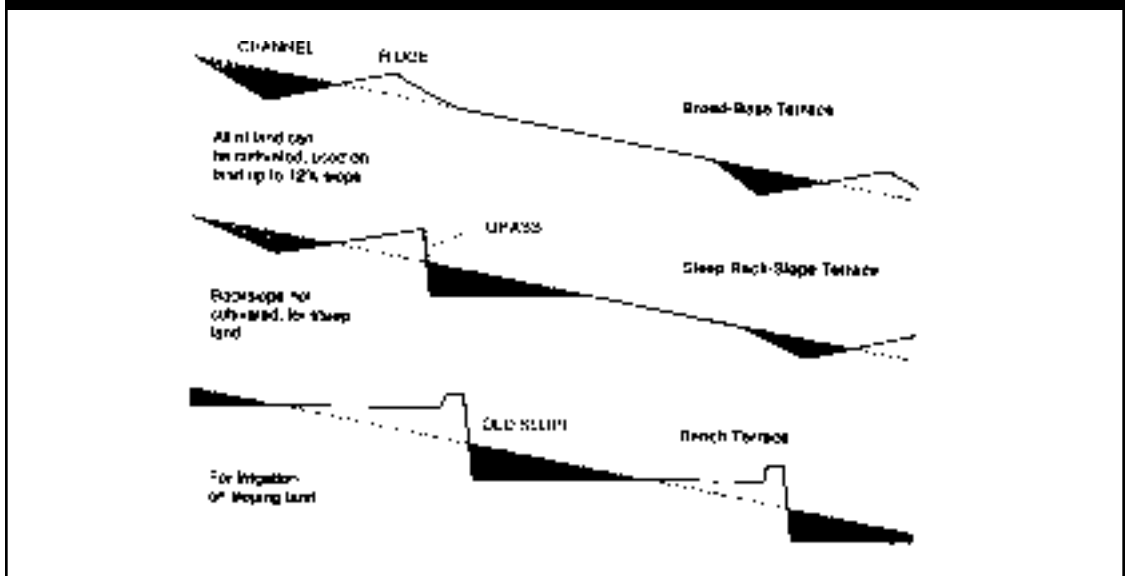
TABLE 6: RECOMMENDED TERRACE SPACING WITH AND WITHOUT A CONSERVATION MANAGEMENT SYSTEM

Field Slope (%)	Without Conservation Management		With Conservation Management	
	Meters	Feet	Meters	Feet
0-1	90	300	120	400
2-3	75	250	110	350
4-5	55	180	90	300
6-8	45	150	75	250
9-12	35	120	60	200

Source: Best Management Practices, Field Crop Production, Agriculture Canada

There are three terrace design choices including broad base, grassed back slope and narrow base. When using the broad base terrace, the entire terrace is farmed and slopes must be less than 8%. Ridges can be easily destroyed if not properly maintained. Grassed back slope terraces have permanent vegetation seeded on the back slopes and are better suited to steeper slopes. The narrow base terrace is used when both front and back slopes are steep and seeded to permanent vegetation. Narrow base terraces are often half the price of the broad base. (Alfera and Weismiller 2002, p38) Figure 2 illustrates the various terraces.

FIGURE 2



SCALE IS EXAGGERATED. BROKEN LINES SHOW THE OLD GRADE. SOURCE: (ALFERA AND WEISMILLER, 2002).

Diversions

A diversion is very similar to a terrace, but its purpose is to direct or divert surface water runoff away from an area, or to collect and direct water to a pond. When built at the base of a slope, the diversion diverts runoff away from the bottomlands. Filter strips should be installed above the diversion channel in order to trap sediments and protect the diversion. Similarly, vegetative cover should be maintained in the diversion ridge. The outlet should be kept clear of debris and animals.

This practice assist in the stabilization of the watershed reduces soil erosion on lowlands by catching runoff water and preventing it from reaching farmland. In addition the vegetation in the diversion channel filters runoff water, therefore improving the water quality. The diversion also serves to provide cover for small birds and animals. Furthermore the vegetation allows better crop growth on bottomlands soils.

Grassed Waterways

A grassed waterway is a natural or constructed channel, usually broad and shallow, that is shaped or graded to required dimensions and covered with suitable perennial vegetation. Waterways can serve to convey runoff from terraces, diversions, and other water concentrated flow areas as well as for transporting storm water without causing erosion or flooding and to improve water quality. Farmers must avoid inundating the waterways with sediments and ensure that waterways are not used as a roadway. Consequently, they require periodic maintenance. (USEPA, 1993, p. 2–23).

Waterways may reduce gully erosion in those areas of concentrated flow, thereby reducing sediment movement downstream and improving water quality. The vegetation in a grassed waterway also acts as a filter to remove sediment-attached pollutants, chemicals and nutrients from the runoff. An additional advantage to grassed waterways is that they provide cover for small animals and birds.

In the State of Maryland, the percentage of farmers using grassed waterways has declined since 1991. In 1991, 43 percent of all farmers used waterways; by 1995, about 36 percent reported following such practice (Linchtenberg, 1997, p. 7).

Waste Management Systems

Controlling the runoff from animal production facilities is a very important component of the total program to control pollution from animal production. Within the Chesapeake Bay basin, there are a large number of livestock equivalent to over 3.25 million animal units⁸ housed in over 6,000 livestock production facilities, most of which are under 1,000 animal units [(Shuyler, 1992, p. 103). To put things into perspective, a single dairy farm with only 200 cows can produce as much nitrogen as is in the sewage from a community of 5,000–10,000 people; and an annual litter from a typical broiler housing 22,000 birds contains as much phosphorus as is in the sewage from a community of 6,000 people (USDA, 1995).

Animal waste management is a complex undertaking that must take account of rainfall, temperature, and soil characteristics; structural features such as ponds and waterways; and is a comprehensive management strategy for protecting or enhancing the ecological setting of the animal production facility. It basically entails a planned system that has the necessary components installed to manage liquid and solid waste, including runoff from concentrated waste areas, in a manner that does not degrade air, soil or water resources. Such systems are planned to avoid the discharge of pollutants to surface and groundwater and to facilitate the recycling of waste through soil and plants to the maximum extent possible (USEPA, 1993). Animal waste storage structures are discussed separately in the next section and the use of animal manure is discussed under Fertilizer Management.

An efficient barnyard runoff control system provides collection, channeling, storage and treatment of the runoff, while minimizing discharge by diverting clean water sources away from the barnyard. Barnyard runoff management practices that protect natural resources have two primary goals: reduce barnyard runoff volume and contain and treat barnyard runoff. These two goals can

8. One animal unit is 1000 pounds of live weight, approximately equivalent to a beef cow.

be achieved through a variety of practices, but only some of the common practices are briefly summarized in Table 7.

TABLE 7: COST AND BENEFITS OF BARNYARD RUNOFF PRACTICES

Management Practice	Description	Cost* (1993 prices)	Benefits
Terrace gradient storage	Grassed earthen channels constructed perpendicular to a slope, with a supporting ridge on the lower side.	\$4.5–7.2 per m	<ul style="list-style-type: none"> • Slows runoff speed to allow sediment deposition. • Reduces volume of runoff • Assists in collection of runoff.
Reduce barnyard surface area	Involves moving the containing fencing. Depends on animal age, surface type, lot usage, and confinement time.	Move fencing	<ul style="list-style-type: none"> • Reduces volume of effluent by minimizing the barnyard surface area. • Enables runoff contaminant with curbing and basins.
Roof barnyard	Collects the rainwater before contamination. Areas to cover include feed bunks and watering facilities.	\$59.2 per m ²	<ul style="list-style-type: none"> • Diverts clean roof water from contamination. • Reduces the amount of waste to be treated
Diversion	Earthen channels of parabolic shape with a ridge on the lower side (upslope of the barnyard).	\$5.2 per m	<ul style="list-style-type: none"> • Protects clean water from barnyard contact. • Reduces volume of polluted runoff.
Grassed waterways	Serve to direct water away from contaminant sources or to channel wastewater to a storage or treatment facility.	\$0.5 per m ²	<ul style="list-style-type: none"> • Allows transport of clean or contaminated water.
Subsurface till drainage	Used in unpaved barnyard. Drains enable a barnyard surface to absorb rainfall by reducing the saturation from upslope groundwater seepage.	\$4.7 per m	<ul style="list-style-type: none"> • Improves absorption of rainwater at barnyard surface. • Helps contain barnyard runoff.
Roof runoff management system	Collect and divert clean rainwater prior to its contamination.	\$15.2 per m	<ul style="list-style-type: none"> • Diverts clean roof water. • Prevents contamination. • Reduces amount of barnyard waste.
Downsprout (4" diameter)	Piping installed in roof gutters to direct clean water away from barnyard contamination.	\$4.6 per m	<ul style="list-style-type: none"> • Diverts clean roof water. • Prevents contamination. • Reduces the amount of barnyard waste to be treated.
Curbing (concrete)	Beneficial when installed along the barnyard perimeter.	\$24.2 per m	<ul style="list-style-type: none"> • Provides containment of barnyard wastes. • Collects all effluent and solids.
Barnyard paving	Paving material is usually concrete or asphalt.	\$139.0 per m ³	<ul style="list-style-type: none"> • Enables better cleaning of the barnyard surface. • Improves the herd health due to cleaner animals

Note:

*Cost figures represent the Pennsylvania State averages, compiled by the Bureau of Land and Water management of the Department of Environmental Resources in 1993.

Source: Adapted from Evans and Sandman (1997).

Managing manure and waste can improve the overall farming operation while improving the environment and reducing fertilizer cost. Proper animal waste management improves water quality by preventing pollutants from migrating to surface and ground waters. Soil quality is also improved through the addition of organic materials that improve soil tilth and increasing soil's water-holding capacity. Apart from reduced odors, air quality may also benefit from reduced emissions of methane and ammonia compounds.

Waste management systems can benefit the farmer in several ways. Covered lagoon offers the opportunity to capture and use methane and other gases and to reduce energy expenditures. Composting solid wastes stabilizes the nutrient content, destroys undigested seeds kills harmful microbial contaminants and make the manure easier to handle. Application of manure to the land at the proper time allows recycling nutrients through the soil profile, reducing the purchase of commercial fertilizers and the need to add organic matter. This in turn can increase crop yields. In addition, certain types of manure, generally poultry litter can be processed into ruminant feed.

Animal Waste Storage Structures

Animal waste storage structures are made of concrete, wood, or other fabricated material and are used to store solid or liquid wastes during the non-growing season. Those structures that store liquid manure, flush water, or polluted runoff are usually located below ground so they can operate by gravity. In case of storing dry wastes, these structures are usually covered to protect the material from rainwater. These storage systems allow farmers to apply manure in the spring or fall, when both weather and soil conditions are suitable for land application. They provide flexibility in managing animal waste and allow farmers to achieve better utilization of nutrients.

Two important aspects on the economics of animal waste storage structure in the Holmes *et al.* (1996) study are that "the need for government cost sharing declines with increases in farm size, and that the construction of above ground manure storage tanks should be avoided whenever possible". Switch to waste storage can be a costly proposition to small farms of less than 60 cows. Instead of building their own storage facilities, small farms should contract out their manure storage and spreading. Building an above ground facility can cost more than twice than alternative belowground storage on a 60-cow farm, and 66 percent more on a 240-cow farm.

Animal manure can be used as a source of energy, protein, and nutrients. The value of manure as plant nutrient or any other purpose depends on the way it is handled, which is turn is determined by the operator's needs and capabilities. Liquid waste in holding ponds or anaerobic lagoons can be covered and anaerobically digested (decomposed in the absence of oxygen) to capture biogas (principally methane a potent greenhouse gas) for energy production. When the digestion process occurs uncovered, it releases biogas into the atmosphere, adding to global warming and loses nitrogen through ammonia volatilization. By keeping dry manure dry in stack houses, the opportunity for anaerobic digestion to occur is reduced and the opportunity for using the waste as an animal feed supplement (such as poultry litter) is increased (NRCS, 1995).

NRCS (1995) reports a case where alternative use of animal manure resulted in increased farm profits. "In 1980, the owner of a 1,000-head sow farrow-to-finish operation in the West covered a portion of his existing lagoon to collect methane for on-farm energy application. The collected methane fuels a 75 kilowatt engine generator, and waste heat is used for space heat and grain drying. The investment reduced annual operating costs at the facility by \$36,000, providing a 34 percent annual rate of return."

Maryland University (1994) also reports that the benefits from processed broiler litter for ruminant feed can exceed the costs. Because of the high nutritional value of broiler litter its value when used as a feedstuff can be as high as \$80 to \$120 per ton, which was five times greater than its cost.

Poultry Mortality Composting

Proper disposal of dead birds is one of the daily management responsibilities of a poultry producer. At normal mortality rates for commercial chicken or turkey flocks, producers need to dispose of

large quantities of birds. The weight and volume of carcasses that growers must deal with increases dramatically as poultry reach maturity (for example, 4 pounds each for broilers and 25 pounds for tom turkeys).

This practice is of particular interest to poultry producers, who have to ensure proper disposal of mortality. Until very recently, the common methods for disposing of mortality included disposal pits, trench burial, incineration, and rendering. Burial of birds poses a nutrient and microbial contamination treat to ground water. Recently, composting of dead poultry has been added to the list of available disposal options, which is in line with the agricultural environmental protection legislation. The composting can be done separately or with poultry litter.

The resulting compost has chemical and physical characteristics similar to poultry litter and can be used as a nutrient source for crops much like fresh poultry litter or manure. Recent studies have found that compost releases nitrogen more slowly and over a longer period of time than fresh litter.

Fertilizer or Nutrient Management

In the past, farmers in the Bay did not account for the nutrient value of manure. The most common practice was to spread manure and apply commercial fertilizers despite the fact that nutrient in the manure could have supplied crop requirements. For many years, the general belief was that “if a little fertilizer were good a lot would be even better.” Excessive application of fertilizers resulted in nutrient contamination of water bodies. Recently, farmers attitudes about the use of chemical fertilizers and the value of manure have been changing. By 1997, in Maryland, about 40 percent of the farmers were crediting manure in their management of nutrients (Lichtenberg, 1997, p. 6). More recent rates are undoubtedly higher

Nutrient plans or budgets are an essential component of nutrient management. These involve establishing realistic yield goals for crops; translating those goals into nutrient requirements; testing soils to determine how much additional nitrogen phosphorous potassium, etc. are needed; crediting the nutrient content of manure to the totals needed; and timing application of nutrients to the plants growth requirements. The latter may involve split applications of nitrogen fertilizer where that is feasible.

The Maryland Nutrient Management Act of 1998 requires is that all agricultural operations with annual incomes greater than \$2,500 or more than eight animal units (one animal unit equals 1,000 pounds live weight using standard weights for different animals) must have and implement a nitrogen and phosphorus based nutrient management plan by a prescribed date (Simpson, 1998). Pennsylvania and Virginia have similar legal requirements for nutrient management planning.

In these states farmers must prepare and implement a nutrient management plan with the assistance of a Certified Specialist. The plan is to help farmers to use nutrients (mainly nitrogen and phosphorus) efficiently for optimum economic benefit to the farmer, while minimizing impact on the environment.

The Certified Specialists (either a government employee or a private consultant), after taking a soil test, set realistic yield goals, and take credit for contributions from previous years' crops and manure applications, and finally determine the crop nutrient required. Average testing and consulting fee is about US\$13 per hectare. Plans must be approved by the state's department of agriculture. Maryland requires that soil testing be done at least once every three years.

Implementation of nutrient management plan is a “win-win” proposition for many crop growing farmers and livestock producers in the Bay. It allows them to cut potential nitrogen and phosphorous losses to streams and groundwater while increasing farm's profits (Pease and Bosch, 1997). In 1990, the State of Maryland estimated that if nutrient management plan recommendations were followed by farmers, these farmers would experience average savings of \$55 per hectare (USEPA, 1993, p. 2-60).

Research conducted by the Division of Soil and Water Conservation of Virginia Polytechnic and State University in four Virginia livestock farms shows that, after the implementation of nutrient management plans crediting the nutrient content of manure applied to the fields, these farmers

were able to reduce nitrogen fertilizer applications by an average of 37 to 106 kilos per hectare and increase farm profits by \$400 (\$12/ha) to \$7,300 (\$160/ha). In addition, nitrogen losses were reduced by 23 to 45 percent. Changes in each individual farm are reported in Table 8.

TABLE 8: IMPACTS ON LIVESTOCK FARMS AFTER IMPLEMENTING NUTRIENT MANAGEMENT PLANS

Farm	Nitrogen Available (kg/ha)	Nitrogen Losses (%)	Annual Farm Profit Increase (US\$)
Dairy farm in Southwest	37	27	400
Dairy farm in Shenandoah Valley	106	33	4,600
Swine farm in Southeast	44	45	3,000
Poultry farm in Piedmont	57	23	7,300

Source: Pease (1998).

Similar results are also reported by the University of Maryland. The case of the Cullen Farm, Maryland, illustrates that poultry manure can indeed be a profitable proposition for farmers. This farm has used chicken manure exclusively as a fertilizer, saving the farm between \$120 to \$145 per hectare without causing detrimental on crop yields (Maryland University, 1994).

For soils that have a high phosphorous content, application of manure, however, may become a problem. Recent research have shown farms where poultry manure is the major or only fertilizer source may be suffering from excessive application of phosphorous, especially in those where their soils have extremely high phosphorous content caused by previous application of manure⁹. In these cases, use of poultry manure increases the chances of phosphorous runoff, especially in those lands under reduced-till.

Switching from poultry litter nitrogen-based application rates to those driven by phosphorous may negatively impacts on the farmers' "bottom line." Phosphorous rapidly reaches "saturation" levels from the perspective of run-off potential, consequently it must be applied to a greater land area. This often exceeds the farmers land holdings, involving haulage and disposal costs. A 1998 study by Virginia Polytechnic and State University concludes that limiting application of poultry litter by phosphorus content would reduce potential nitrogen and phosphorous losses by 21–56 percent and 28–43 percent, respectively, but would decrease farm's net income by 11–23 percent (Pease, 1998).

Research is still underway to determine alternative methods for controlling either available phosphorous content of the poultry litter or the phosphorous holding capacity of the soil. A study has found that adding aluminum sulfate to poultry litter provides benefits for both the farmer and the environment. The chemical process is such, that the presence of alum in the poultry litter allows it to trap nitrogen in the fertilizer and reduce nitrogen losses through ammonia volatilization. Alum when added to poultry litter, reduces phosphorous runoff, increases the level of nitrogen available to plants, decreases energy requirements for ventilation of chicken-houses, and adds weight to birds (EPA, 1996). There are multiple benefits of using alum in poultry litter:

- Crop farmers using poultry litter can produce runoff with less than 87 percent phosphorous content.
- By limiting the amount of ammonia in chicken houses, chicken producers can decrease their propane use by 11 percent and their use of electricity by 13 percent. In addition, they can get increase birds' weight gain by 50 grams.

9. This is a serious problem for certain regions of the State of Maryland.

The state in the Bay Region offer several financial incentives to ease the burden on farmers for implementing nutrient management plans. The type and size of incentives vary with the State. In Maryland for example, the State offers tax credit to those farmers that will have to switch fertilizer source to dispose of surplus manure (i.e., from animal manure to purchased commercial fertilizer). The state tax credit is equal to 50% of the additional cost of fertilizer or \$4,500 per year for up to three consecutive years, whichever is less. In case the tax credit exceeds the total tax for the year, the excess may be carried over and applied to five subsequent tax years (Simpson, 1998, p.8).

In the Virginia nutrient management program, the State offers a tax incentive to farmers to encourage them to participate in the program. State tax credits are available to farmers who have nutrient management plans and need to purchase qualifying nutrient application equipment. The state tax credit is equal to 25% of the purchase price of the equipment or \$3,750, whichever is less (Faverno, 1997).

Since application of nutrient management plans based on phosphorous are expected to have a potential expensive impact on farmers that generate or use animal manure, the State of Maryland is offering a cost-share program for the transport and disposal of poultry litter. Under this program, farmers with excess poultry litter receive up to \$20 per ton for the removal and transport of the manure from their fields to lands with additional carrying capacity of phosphorous or to composting sites (Simpson, 1998, p.8). Delaware has recently launched a program to provide low interest rate loans to poultry growers for litter storage, poultry composter, or any other poultry-related BMP.

Tree Planting or Riparian Forest Buffer

Riparian buffer strips consist on an area of trees, usually accompanied by shrubs and other vegetation that is Down slope of crop fields and adjacent to a body of water. They reduce the impact of non-point pollution sources by trapping and filtering sediments, nutrients, and other chemicals. When vegetated buffers are located at the edges of the crop fields, they absorb nutrients and trap phosphorus-laden sediments that otherwise would runoff of the fields. Direct benefits of riparian forest buffers on the environment, as reported in NRCS (1998), are as follows:

- **Filtering runoff.** Rain water that runs off the land can be slowed and filtered by the forest, settling out sediment, nutrients and pesticides before they reach streams. Infiltration rates 10–15 times higher than grass turf and 40 times higher than a plowed field are common in forested areas.
- **Nutrient uptake.** Fertilizers and other pollutants that originate on the land are taken up by tree roots. Nutrients are then stored in leaves, limbs and roots instead of reaching the stream. Through a process called “denitrification”, bacteria in the forest floor convert harmful nitrate to nitrogen gas, which is released into the air. Forest buffer strip can remove up to 50 percent or more of nutrients and pesticides, 60 percent or more of certain pathogens and as much as 75 percent of sediment.
- **Canopy and shade:** The leaf canopy provides shade that keeps the water cool, retaining more dissolved oxygen, and encourages the growth of diatoms, nutritious algae and aquatic insects. The canopy improves air quality by filtering dust from wind erosion, construction or farm machinery.
- **Leaf food:** Leaves fall into a stream and are trapped on woody debris (fallen trees and limbs) and rocks where they provide food and habitat for small bottom-dwelling creatures (i.e. crustaceans, amphibians, insects and small fish), organisms that are critical to the aquatic food chain.
- **Habitat:** Streams that travel through woodlands provide more habitats for fish and wildlife. Woody debris serves as cover for fish while stabilizing stream bottoms, thereby preserving habitat over time.

- Reduction of soil erosion: Buffer strips reduce erosion by slowing water flow and increasing water infiltration.
- Reduction of noise and odor.

Studies on the impacts of riparian forest in the Bay show dramatic reductions of 30 to 98 percent in nutrients (nitrogen and phosphorus), sediment, pesticides, and other pollutants in surface and groundwater after passing through a riparian forest. The trees apart from protecting water quality, they provide deep root systems, which help to keep soil in place. Thus, stabilization of stream banks and reduction of erosion are also achieved.

The Paired Watershed Study in Iowa reveals the benefits of the riparian buffers. As shown in Table 9, the watershed with riparian buffer and poplar trees on each side of the stream has lower rates of sedimentation and nitrate nitrogen concentration. Farmers in this watershed would also be able to benefit from harvesting planted trees as a cash crop after 5 years (USEPA, 1996a).

TABLE 9: ENVIRONMENTAL BENEFITS OF RIPARIAN BUFFERS IN IOWA

Watershed Type	Sediment Rate	Nitrate Nitrogen Concentration
A 42-hectare watershed with 32 hectares of cropland without riparian buffer	3,830 kg per hectare	Greater than 10 mg per liter
A 114-hectare watershed with 70 hectares of crop land with riparian buffer	640 kg per hectare	3.1 mg per liter

Source: (USEPA, 1996a)

In the Bay, there are a number of existing federal, states and local programs to help protect and restore the lands adjacent to the tributaries of the Chesapeake Bay including wetlands. One of these programs is the Conservation Enhancement Reserve Program (CERP). This is an enhancement of the regular federal Conservation Reserve Program (CRP) That allows states using their own funds to offer landowners better terms for converting their land into buffer strips. Under the program, landowners receive incentive payments for stopping production in those portions of their lands that are suitable for riparian buffers. Landowners sign a contract with the local government indicating the enrolled hectares. Length of the contract varies from 10 to 15 years.

Annual incentives to participating landowners are similar to those under the regular Conservation Reserve Program but a premium is added depending on the type of riparian buffer practice use. If the land is covered with trees, landowners receive a 70 percent premium on the normal USDA rental payment 70 percent, but if only grass is planted the premium is 50 percent. For example, if the CRP rental rate is \$70 per hectare, the CERP pays up to \$120 per hectare per year for a riparian buffer. Additional payments of up to \$12 per hectare are also made for maintenance of the buffer. Together USDA and the State of Maryland pay up to 87.5 percent of the investment cost of the practice, while landowners contribute the remaining 12.5 percent (Progressive Farmer, 1997).

Controlled Grazing

Controlled grazing may simply involve protecting streams and stream banks by fencing livestock out of water bodies and providing alternative watering facilities, or more complex rotational grazing systems which can be an alternative to confined feedlot-type operations.

Rotational grazing allows the herdsman to achieve a balance between fully utilizing available forage while encouraging vigorous plant growth. Uncontrolled grazing may lead to an

extreme situation in which animals are left on the pasture until there is nothing left to graze. The result is often low output from livestock production (measured by tons of livestock or their products per hectare).

A rotational grazing system involves two basic components:

- Dividing the pasture with one fence to provide two areas or paddocks . Additional areas can be providing by continuing to subdivide the pasture area. A commonly used technique is a single strand of temporary wire to limit the grazing animals to the areas that can be grazed in the allotted time, i.e., forage in each paddock needs to be utilized within 5–7 days.
- Providing access to a water supply. A supply of water needs to be available within 150–180 meters for milking cows and 300–360 meters for other livestock.

Improved grazing management offers a great opportunity for making livestock farming more profitable by reducing production costs. Direct benefits of controlled grazing accruing to farmers are as follows:

- Number of animals in the grazing system can increase by 30 to 50 percent.
- Vigor of the pasture sod is improved.
- Standing forage feeding directly by animals is cheaper than harvested forage.
- Handling and checking grazing animals is easier.

The possible environmental benefits of grazing management consist of: keeping livestock and their wastes out of water bodies; preserving stream banks thereby avoiding stream-bank erosions; reducing the contamination risks from large accumulations of waste in confinement operations; providing vigorous ground cover that absorbs nutrients, slows runoff and traps sediments.

EFFECTIVENESS OF BEST MANAGEMENT PRACTICES

This section presents information on the financial cost effectiveness and nutrient removal effectiveness of the BMPs to control agriculture non-point pollution sources. It draws extensively on the “Chesapeake Bay Program Nutrient Reduction Strategy Reevaluation” study conducted by USEPA (1993). This information can help to obtain a rough idea of the best mix of individual BMPs.

It is very difficult to categorize the effectiveness of any given BMP for several reasons. Effectiveness is often a function of local conditions: topography, climate, cropping systems, maintenance, proper site selection and proper installation. In addition, most BMPs are used not alone, but in conjunction with either one or more complimentary BMPs. For instance, a grassed waterway will require appropriate inlet and outlet structures and proper cultivation practices just to name a few. An effective nutrient management plan will also require proper cultivation practices, proper water management techniques as well as other BMPs. Thus BMP effectiveness can vary from 5% to 95% depending upon those factors previously mentioned. Poorly sited, poorly maintained and improperly selected BMPs will be nearly useless, while those that are appropriately selected and properly sited, implemented and maintained may be highly effective to control soil erosion and nutrient losses and to increase water quality. (Alfera and Weismiller, 2002 p39).

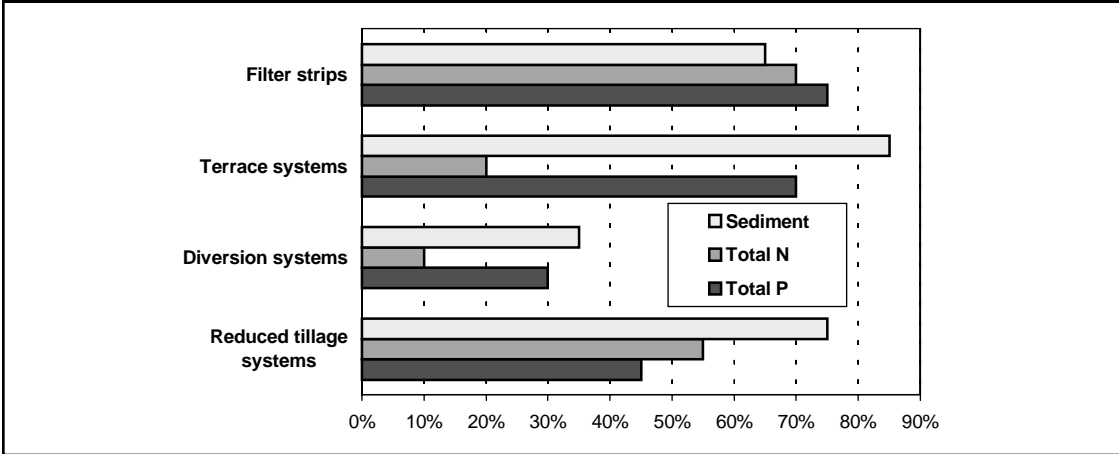
Anecdotal information shows that as a result of implementing a nutrient management plan reductions in nitrogen, phosphorus (P_2O_5) and potassium (K_2O) inputs were reduced in all crops; corn, soybeans, small grains, pasture, alfalfa and hay. When combined together for all these crops the estimated reductions in fertilizer use were 17 kg/ha, 15 kg/ha and 15 kg/ha for nitrogen, phosphorus (P_2O_5) and potassium (K_2O) respectively. (Alfera and Weismiller, 2002 p39–40).

As stated earlier in the paper, unlike other conservation measures, the installation of one agriculture BMP can rarely be sufficient to control non-point pollution from agriculture sources. The experience gained in the Chesapeake Bay reveals that a combination of BMPs is often a most cost-effective proposition. The identification of the best combination of BMPs, however, requires a “resource management systems” analysis approach.

Nutrient and Sediment Removal Effectiveness

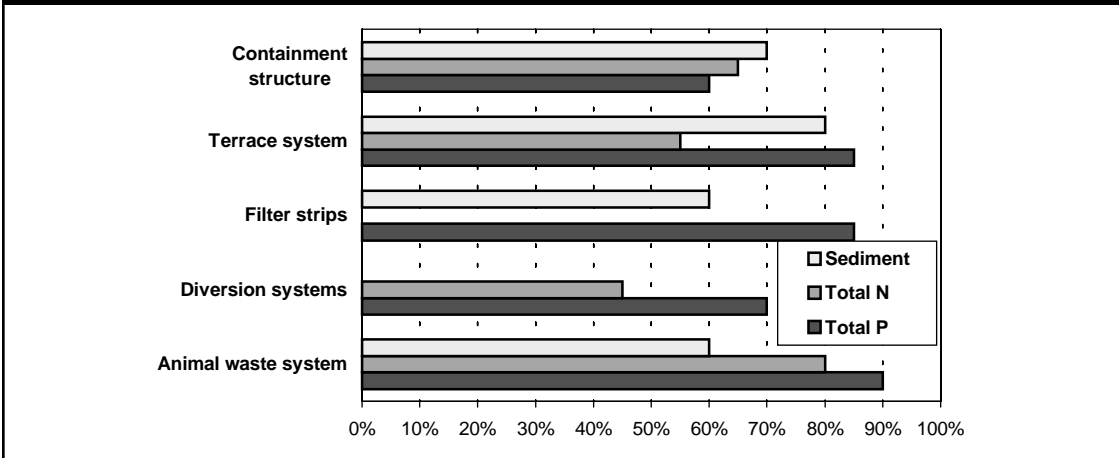
Figure 3, Figure 4 and Table 10 illustrate the relative efficiency of alternative BMPs used in the Chesapeake Bay in terms of reducing total nitrogen, total phosphorous and sediment from non-point pollution sources.

FIGURE 3: RELATIVE EFFECTIVENESS OF SEDIMENT CONTROL BMPs IN TERMS OF REDUCING NUTRIENT RUN-OFF



Source: Adapted from USEPA (1993a), p. 2–15.

FIGURE 4: RELATIVE EFFECTIVENESS OF CONFINED CONTROL LIVESTOCK BMPs IN TERMS OF REDUCING NUTRIENT RUN-OFF



Source: Adapted from USEPA (1993a), p. 2–37

TABLE 10: RELATIVE EFFECTIVENESS OF NUTRIENT MANAGEMENT BMPs

Percentage Change of Total Phosphorous Loads	Percentage Change of Total Nitrogen Loads
-35%	-15%

Source: Adapted from USEPA (1993a), p. 2–55.

Since reducing pesticide runoff is often an ancillary benefit of practices for controlling nutrient contamination, various practices are compared for their effectiveness at reducing pesticide runoff. Table 11 presents the estimates of potential reductions in pesticide loss reductions as a result of alternative best management practices applied to cotton fields.

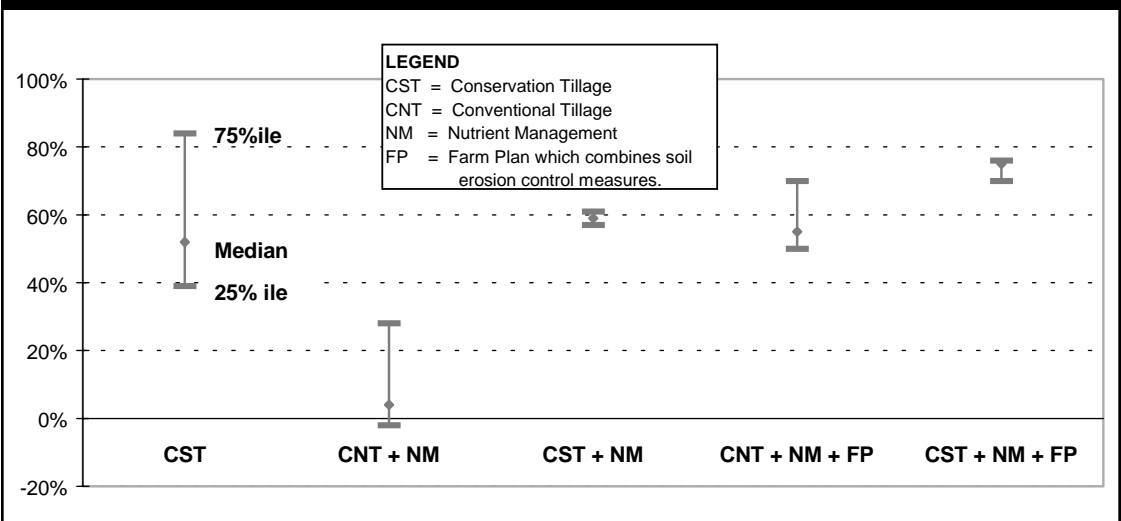
TABLE 11: POTENTIAL REDUCTIONS IN PESTICIDES LOSS IN COTTON FIELDS

Best Management Practice	Pesticide Loss Reduction
Terrace	0–20%
Contouring	0–20%
Conservation tillage	–40%–20%
Grassed waterways	0–10%
Sediment basins	0–10%
Filter strips	0–10%
Cover crops	–20%–10%
Optimal application techniques	40%–80%
Scouting economic thresholds	40%–65%
Crop rotation	0–20%

Source: Adapted from USEPA (1993b), p. 2–66.

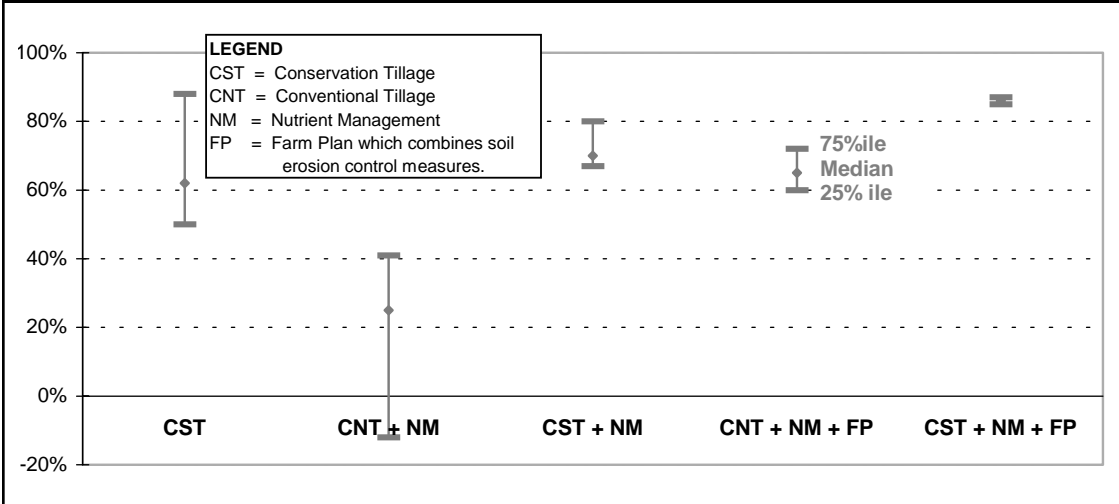
Two remarks are in order with regard to the effectiveness values presented above. First, actual effectiveness of a BMP or systems of BMPs depends on site-specific conditions. Second, these values are not cumulative. Figure 5 and Figure 6 present typical nutrient effectiveness of a combination of BMPs or resource management systems in the Chesapeake Bay.

FIGURE 5: NUTRIENT REMOVAL EFFICIENCY OF BMPs IN TERMS OF REMOVAL OF NITROGEN FROM CULTIVATED LANDS



Source: USEPA 1995a

FIGURE 6: NUTRIENT REMOVAL EFFICIENCY OF BMPs IN TERMS OF REMOVAL OF PHOSPHOROUS FROM CULTIVATED LANDS

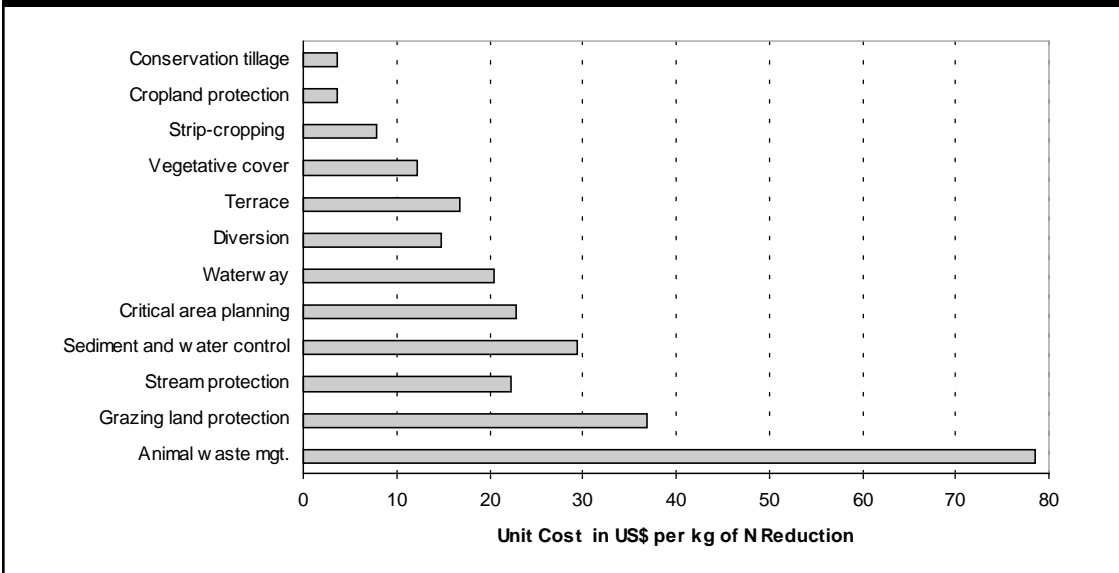


Source: USEPA 1995a

Cost-Effectiveness

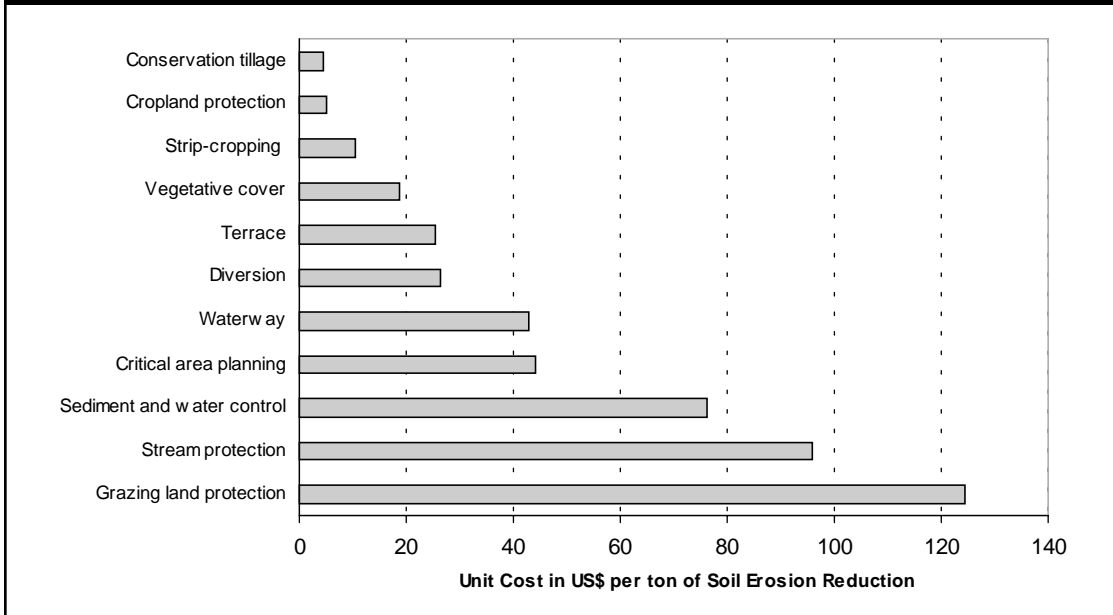
The cost effectiveness, defined as the ratio of the cost per ton of pollutant removed per year, of alternative BMPs in terms of nitrogen removed, reduction of soil erosion and soil sedimentation are presented in Figure Figure 7, Figure 8 and Figure 9.

FIGURE 7: COST EFFECTIVENESS OF BMPs IN REDUCING NUTRIENTS



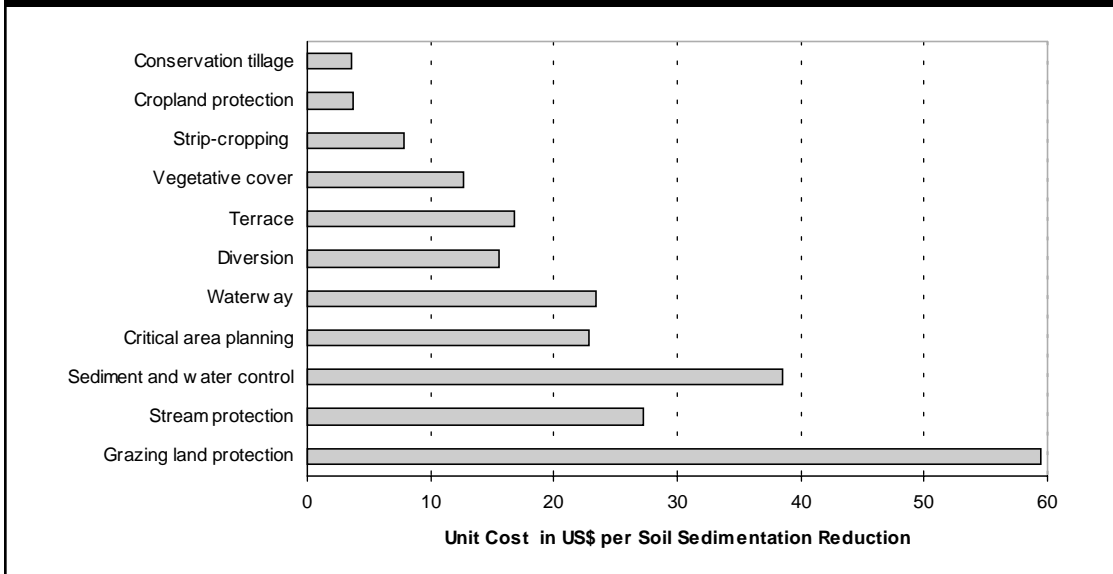
Source: USEPA 1996a

FIGURE 8: COST EFFECTIVENESS OF BMPs IN REDUCING SOIL EROSION



Source: USEPA 1996a

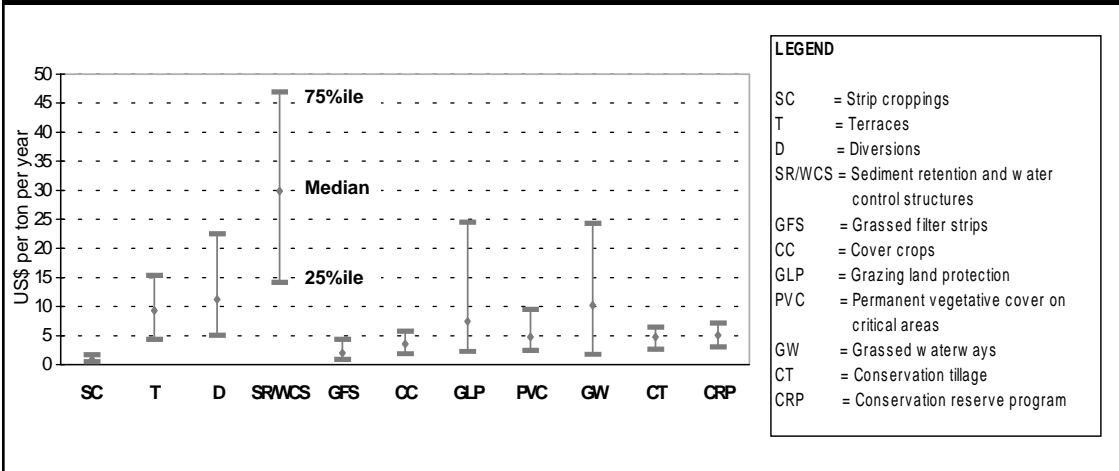
FIGURE 9: COST EFFECTIVENESS OF BMPs IN REDUCING SEDIMENTS



Source: USEPA 1996a

Figure 10 shows the cost effectiveness of soil conservation erosion control BMPs, calculated as the ratio of the annual cost (capital and O&M costs) to the tons of soil saved. The figure shows a wide range of values for some of the structural measures.

FIGURE 10: RANGE OF COST EFFECTIVENESS OF BMPs IN THE CHESAPEAKE BAY



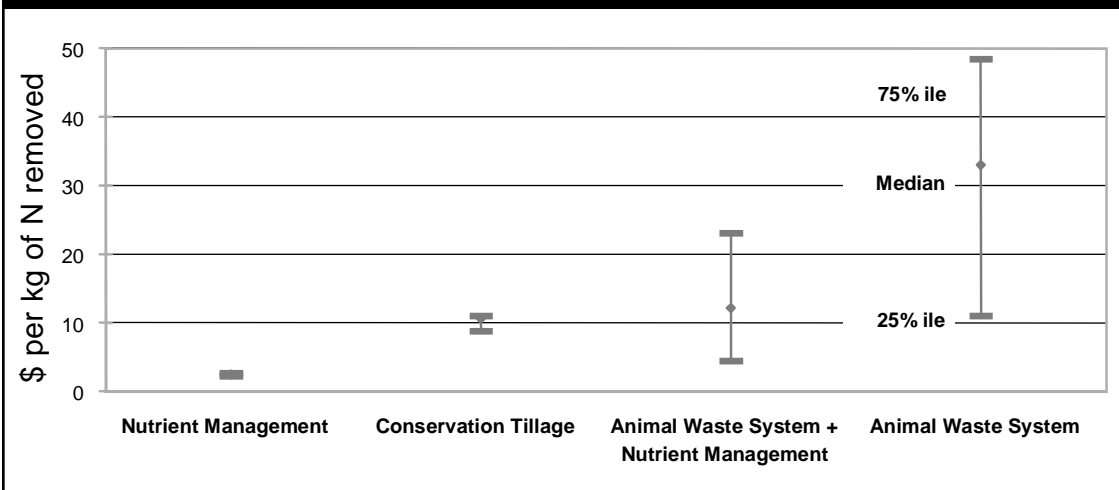
Source: USEPA (1993b)

Figure 11 and Figure 12 present the cost-effectiveness of a typical combination of BMPs or a resource management system in the Chesapeake Bay. These figures are taken from USEPA (1993). The results shows that nutrient management is the most cost effective BMP. However, it should be mentioned that although Animal Waste Systems can be relatively more expensive to initiate, animal waste is one of the major sources of pollution and its control can have a dramatic and positive effect on the environment and lead to a reduction in fertilizer costs. The figures below demonstrate the importance of combining nutrient management with animal waste management system.

Case Studies

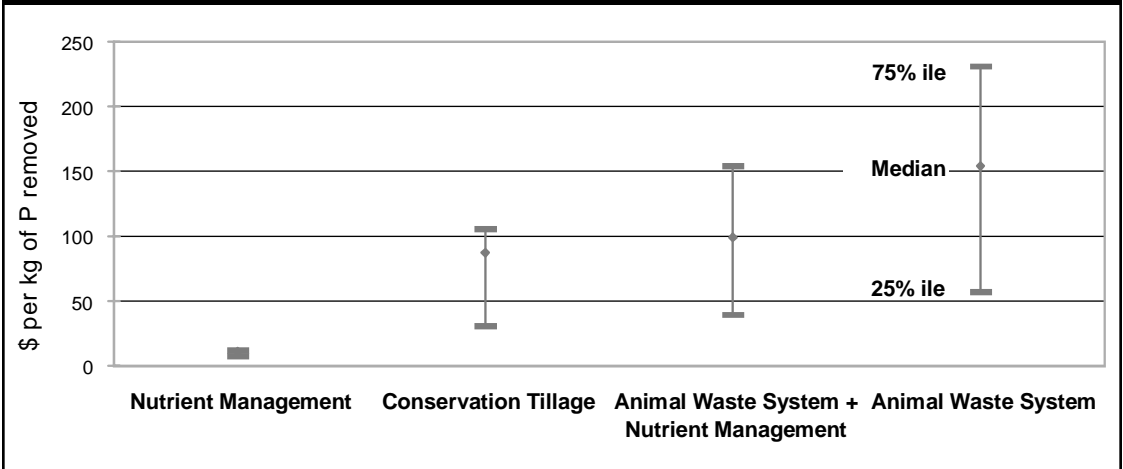
A recent study conducted by the National Resources Conservation Service of the U.S. Department of Agriculture reveals that Virginia farmers can profit from implementing systems best management

FIGURE 11: COST EFFECTIVENESS OF SYSTEMS BMPs - NITROGEN REMOVAL



(Source: USEPA 1993a).

FIGURE 12: COST EFFECTIVENESS OF SYSTEMS OF BMPs - PHOSPHOROUS REMOVAL



(Source: USEPA 1993a).

practices to prevent and control non-point pollution. None of the three cases investigated reported negative impacts (USEPA, 1995a).

A combined dairy and poultry farm (110-head dairy and 50,000 broilers) in the Shenandoah Valley needed rotational pasture grazing and barnyard system including diversion, filter strip and fencing. After implementing all these practices with a 50 percent cost sharing, the farm benefited from an increased annual profit of \$4,200. Reduced labor costs were excluded from the calculations. In the absence of cost-sharing arrangement the increase in annual profits would have been reduced by \$3,000.

A 575-acre cash grain operation needed additional nutrient management practices and improved pesticide management. The net economic gain after implementing the needed best management practices was \$1,050 per year, resulting from the reduction of purchases of commercial fertilizer.

A combination cash grain/vegetable crops operation (500 acres of small grains and 350 acres of vegetables) on the Eastern Shore needed a nutrient management plan for the vegetable crop area. After implementing the BMP, the farm achieved a net positive gain of \$3,950 per year, resulting from savings on purchases commercial fertilizer.

Maryland’s Nutrient Management Program

Prior to the 1987 Chesapeake Bay Agreement, programs existed to implement some aspects of water quality improvement, but no program was in place to specifically address nutrient management planning. However, it was known that implementation of nutrient management planning could play a key role in reducing the amount of nutrients from agricultural non-point sources. In 1989, the Maryland Department of Agriculture (MDA) and the University of Maryland/Maryland Cooperative Extension (MCE) established the Maryland Nutrient Management Program (MNMP). The primary focus of this program was to place 0.54 million hectares of Maryland’s 0.91 million hectares of farmland under nutrient management plans by the year 2000 . (Alfera and Weismiller, 2002 p40)

To facilitate nutrient management planning MDA administers a mandatory certification exam to those who want to write nutrient management plans. After becoming certified and licensed, private consultants and firms are required to report their planning progress to the MNMP annually. These advisors provide nutrient management planning services to clients and also emphasize how such planning enhances farm profitability and improves water quality. In addition to writing plans, advisors perform other free services such as yield checks; pre-side dress nitrate tests (PSNT) for

corn, collecting manure samples to be tested by the University of Maryland Soil Test Laboratory and manure spreader calibrations. Manure testing procedures are also provided free of charge by the MNMP through a grant from the Maryland Department of Agriculture. (Alfera and Weismiller, 2002 p40)

A range of other initiatives compliments the MNMP. These initiatives (Table 12) are provided by the Maryland Agricultural Water Quality Cost-Share Program (MACS) to help farmers install BMPs.

TABLE 12: BMPs ELIGIBLE UNDER THE MACS PROGRAM

Animal Waste Management Systems	Field Borders/Windbreaks	Roof Runoff Management
Conservation Cover	Filter Strips	Sediment Basins
Contour Farming/Orchards	Grade Stabilization Structures	Spring Developments
Cover Crops	Grassed Waterways	Stream Crossings
Critical Area Plantings	Lined Waterways/Outlets	Stream Fencing
Dead Bird Composting Facilities	Nutrient Management Services	Strip Cropping
Diversions	Riparian Buffers	Terrace Systems

Source: Maryland Department of Agriculture Website (<http://www.mda.state.md.us/resource/mawqcs10.htm>)

The purpose of the MACS Program is to provide cost-share assistance (up to 87.5 percent of cost) to farmers for the installation of eligible BMPs. Since BMPs help reduce soil erosion and protect water quality, their use in certain situations is mandated under the WQIA and the Chesapeake Bay Critical Area Law. For all BMPs, except animal waste treatment and containment projects, the MACS Program will pay up to \$20,000 per project and a maximum of \$50,000 (when combined with other BMPs). For animal waste treatment and containment projects, MACS will pay up to \$75,000 per project and a maximum of \$100,000 (when combined with other BMPs). To be eligible for the MACS Program, an individual, or business must be operating a farm in Maryland and must have excessive levels of soil, nutrients or pollution running off into Maryland’s waters. (Alfera and Weismiller, 2002 p41).

Two other cost-share programs not listed in Table 8 are the Manure Transport (5) and Poultry Litter Transport (6) Programs. These programs were established in 1999 as four year, \$750,000 pilot projects, with the purpose of providing cost-share assistance (up to \$20 per ton) to animal producers for transporting excess manure off of their farms. The programs were designed to help producers make the transition to phosphorus-based nutrient management plans (as mandated by the WQIA), and are open to those who have high soil phosphorus levels or inadequate land to fully use their manure. Farmers on the receiving end of the transport programs are eligible to accept manure and poultry litter only if these wastes can be safely land-applied according to an agronomic and environmentally sound nutrient management plan. (Alfera and Weismiller, 2002 p42).

FACTORS AFFECTING FARMERS' PARTICIPATION AND ADOPTION OF BMPs

According to a recent study conducted by USDA on “Voluntary Incentives for Reducing Agriculture Non-Point Source Water Pollution” (Feather and Cooper, 1995), increased farm profitability is the most important factor influencing farmers’ decisions to participate and adopt BMPs. The adoption of less polluting management practices is driven by the farmer’s perception of their effect on profitability. On-farm water quality benefits, farmer knowledge and familiarity with the practices also influence farmers’ decision to adopt improved management practices.¹¹

Research findings indicate that the success of programs to control agriculture non-point sources pollution depends on how targeted the programs are at promoting inexpensive changes in existing agricultural practices that are already familiar to the farmers, and on the tangibility (visibility and immediacy) of derived environmental benefits.

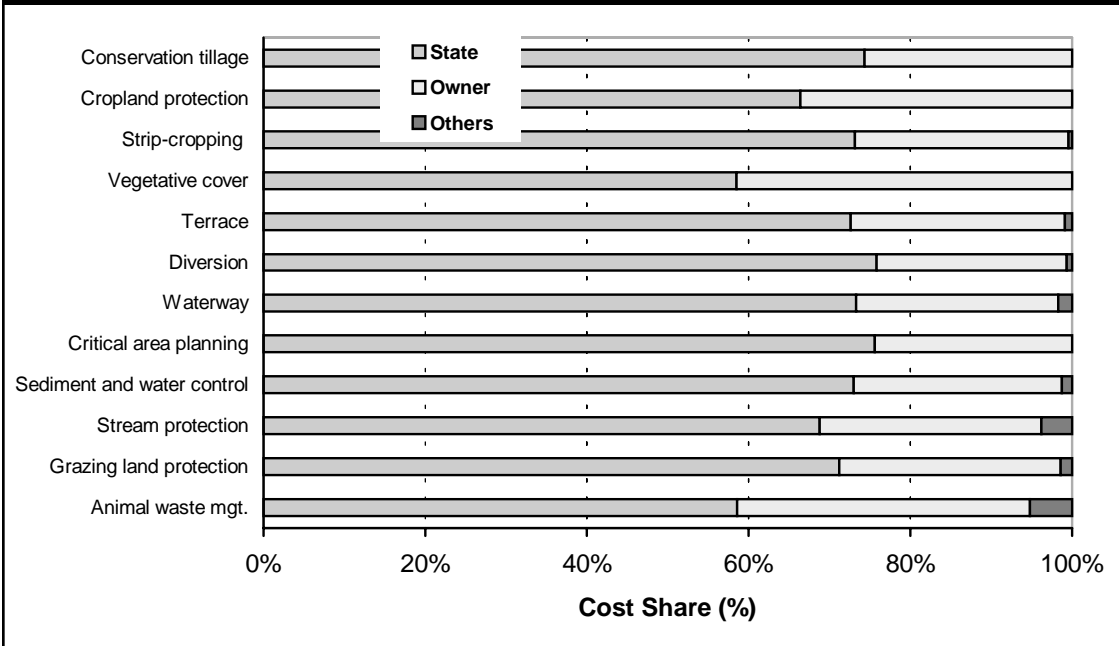
Currently, the clean-up effort of the Chesapeake Bay Program relies primarily on voluntary policies to control non-point source pollution. Financial incentives in the form of cost-sharing, tax credits and incentive payments transfers, as well as technical assistance and educational programs are used to encourage voluntary adoption of BMPs.

However, it has also been found that introducing economic incentives has increased the numbers of farmers adopting environmentally friendly BMPs. Incentives offset the initial incremental costs involved in introducing the BMPs. When the benefits of the BMPs have been realized an incentive program is usually phased out.

The Chesapeake Bay experience reveals that special attention should be given to the design of cost-sharing programs. As seen in Figure 13, not all BMPs received the same level of support from the State. There are some BMPs for which adoption does not seem to be influenced by the by the

10. Recent studies on cost-share programs have found that the potential for deriving water quality benefits can influence farmer’s decision to adopt a BMP; however, the impacts of the BMP on the farm’s profitability was found to be the most determinant factor.

FIGURE 13: CHESAPEAKE BAY COST-SHARING PROGRAM FOR BMPs



Source: Gale et al., 1993.

level of cost sharing available, i.e., fertilizer management and nutrient management planning. Cost-sharing programs should reflect the impacts on the farm production cost as a result of adoption of BMPs. Use of benefit cost analysis techniques in the design of financial incentive programs is likely to improve their effectiveness.

Some important lessons from a recent study on the effectiveness of the Rural Clean Water Program in the US (Gale et al., 1993), that are relevant to non-point source pollution control programs and efforts, are as follows:

- “High awareness about water quality issues and the impacts of agriculture on water quality do not necessarily translate into ownership of water quality problems by farm operators. Educational programs must be initiated to encourage farm operators to deepen their understanding of NPS pollution causes and water quality impacts...”
- Farmers must be informed about water quality and aware that their own farms contribute to water quality degradation. Ownership of water quality problems by farmers is essential to successful NPS control programs...
- Well-targeted effective educational efforts can alter farmer behavior. Education and availability of cost-share assistance are key components of voluntary projects.”

GLOSSARY

Best Management Practice (BMP). A practice or combination of practices that are determined to be the most effective economically practical means of controlling point and non-point pollutant levels compatible with environmental quality goals.

Buffer area. An area of natural or established vegetation managed to protect critical resource areas such as, wetlands, water bodies from significant degradation due to land disturbance and nutrient chemical runoff.

Conservation Reserve Program. A federal government program for retiring environmentally sensitive farmland, normally highly erodable land but also land suitable for buffer strips and shelter belts, converting it from crops to permanent vegetative cover. It makes use of long-term leases and cost-sharing for the establishment of the vegetative cover

Conservation tillage. Any tillage system that leaves at least 30% of the soil surface covered with crop residue after planting.

Conventional tillage. Any tillage practice that involve the complete inversion of the soil incor-

porating all residues with a moldboard plow, leaving less than 30% surface residue.

Cost effectiveness. Measures the costs per physical unit of control achieved by a BMP or systems of BMPs. Costs (both capital and operation and maintenance) are measured in dollars per year, and outcomes are measured in terms of the effectiveness in removing tons or kg. of pollutants per year. It is particular useful for comparing the performance of different BMPs relative to a particular pollutant

Cost-sharing. Direct financial assistance offered to farmers in order to induce them to adopt BMPs involving large capital investment. Generally, covering a specified percentage of the capital cost.

Erosion. The process by which the topsoil and land's surface are worn away by the action of wind, water, ice and gravity.

Eutrophication. It refers to the nutrient enrichment (particularly by nitrogen and phosphorous compounds of waters. Excessive nutrient loads promote the growth of algae, leading to oxygen depletion and reduction in

the depth through which light penetration is sufficient for primary production.

Integrated pest management. Consists of pest control strategies involving establishment of pest population thresholds above which application of pesticides will increase net returns, monitoring of pest populations, rotations, use of pheromones, all aimed at reducing total pesticide use.

Non-point source pollution (NPS). Pollution consisting of constituents such as sediment, nutrients, and organic and toxic substances from diffuse sources, such as runoff from agricultural and urban land development and use. Generally having a high variability associated with weather conditions.

No-Till. A form of conservation tillage with no soil preparation, where seeds, fertilizer, and herbicides are inserted through the residue from the last crop into the soil in a single planting operation

Nutrient Management. A system of management measures, which provides recommendations on optimum rates, times, and application methods of nutrients based on soil and manure analysis results and expected crop yields.

Ridge-Till. A form of conservation tillage in which the crop is planted in ridges that follow the contour of the land and in which nutrients and pesticides are only applied to the ridge.

Strip-Cropping. Alternating close grown crops such as alfalfa or grass with row crops in strips. Strips generally follow the contour of the land.

Tributary strategy. A strategy involving allocation watershed goals to sub-watersheds, relying on stakeholder participation in each sub-watershed to develop a unique approach (with respect to appropriate BMPs, incentives, modes of implementation) for meeting the sub-watersheds assigned goals

BEST MANAGEMENT PRACTICES

Pasture and hayland management	x			
Pasture and hayland planting	x			
Pesticide management				x
Planned grazing systems	x			
Pond		x		
Proper grazing use	x			
Range seeding	x			
Sediment basin				x
Sinkhole treatment			x	
Soilbank spreading			x	
Streambank protection		x		
Structure for water control				x
Stubble mulching		x		
Terrace			x	
Tree planting			x	x
Trough or tank				
Waste management system			x	
Waste storage ponds and structures				x
Waste treatment lagoon				x
Waste utilization				x
Water and sediment control basin				x
Waterways				x
Well				x
Wind stripcropping			x	
Woodland grazing				x

Legend:

- BMP 1: Permanent vegetative cover. Improves water quality by establishing permanent vegetative cover on farm or ranch land to prevent excessive runoff of water quality or soil loss.
- BMP 2: Animal waste management system. Improves water quality by providing facilities for the storage and handling of livestock and poultry waste.
- BMP 3: Stripcropping systems. Improve water quality by providing enduring protection to cropland causing pollution.
- BMP 4: Terrace system. Improves water quality through the installation of terrace systems on farmland to prevent excessive runoff of water or soil.
- BMP 5: Diversion system. Improve water quality by installing diversion on farm and ranch land where excess surface or subsurface water runoff contributes to a water pollution problem.
- BMP 6: Grazing land protection system. Improves water quality through better grazing distribution and better grassland management.
- BMP 7: Waterway system. Improves water quality by installing a waterway to safely convey excess surface runoff water across fields at non-erosion velocities into watercourses or impoundments.
- BMP 8: Cropland protection system. Improves water quality by providing needed protection from severe erosion on cropland between crops or pending establishment of enduring protective vegetative cover.
- BMP 9: Conservation tillage systems. Improves water quality by use of reduced tillage operations in producing a crop. The reduced tillage operations and crop residue management need to be performed annually.
- BMP 10: Stream protection system. Improves water quality by protecting streams from sediment or chemicals through the installation of vegetative filter strips, protective fencing, livestock water facilities, etc.
- BMP 11: Permanent vegetative cover on critical areas. Improves water quality by installing measures to stabilize source of sediment such as gullies, banks, field borders, or similar problem areas contributing to water pollution.
- BMP 12: Sediment retention, erosion and water control. Improves water quality through the control of erosion, including sediment and chemical runoff from a specific problem area.
- BMP 13: Improving an irrigation and or water management system. Improves water quality on farmland that is currently under irrigation by installing tailwater return system, converting to a different system to reduce pollutants, or reorganizing existing system to also reduce pollutants.
- BMP 14: Tree planting. Improves water quality by planting trees to treat critical areas or sources contributing to water pollution.
- BMP 15: Fertilizer management. Improves water pollution through needed changes in the fertilizer rate, time or method of application to achieve desired degree of control of nutrient in critical areas contributing to water pollution.
- BMP 16: Pesticide management. Improves water quality by reducing use of pesticides to a minimum and manage pests in critical areas to achieve the desired level of chemical contributing to water pollution.

SIMPLIFIED BMPs

BMPs to reduce phosphorus losses

- Use soil erosion control practices.
- Test soils on a regular basis and avoid applications of manure or fertilizer that would result in soil levels above an optimum range.
- Obtain nutrient analysis of manure sources and use soil test recommendations and yield goals when calculating application amounts.
- Adopt phosphorus based management plants for areas vulnerable to phosphorus runoff or leaching.
- Do not spread manure on frozen ground.
- Inject or incorporate applications of manure or fertilizer whenever possible.
- Using P-rich organic sources like manure and sludge on soils with lower soil test rates for phosphorus.

BMPs to reduce nitrogen leaching include the following

- Apply only recommended rates of nitrogen fertilizer, manure or sludge.
- Know the accumulated levels of nitrogen collected from rotated legume crops, and past fertilizer, manure and bio-solid applications.
- Proper application timings including split-applications when appropriate
- Realistic yield goals.
- Correctly calibrate application equipment.
- Use of cover crops to utilize the residual nitrate in the soil at the end of the growing season.

Guidelines for Soil Sampling

1. Try to sample in the fall.
2. Take representative cores from 15 to 20 spots in the field. One spot should represent one management unit.
3. Sample between rows. Avoid old fencerows, dead furrows and other spots that are not representative of the whole field.
4. Take separate samples from areas that differ significantly if they can and will be managed as different units.
5. In cultivated fields, sample to plow depth.
6. In no-till fields some labs will recommend a 5 to 10 cm deep sample while others recommend taking two samples: one to plow depth for lime and fertilizer recommendations, and one to a 2.5 to 5 cm depth to monitor surface acidity.
7. Sample permanent pastures to a 5 to 10 cm depth.
8. Collect the samples in a clean container. Do not use a galvanized bucket.
9. Mix the core samples, allow to air dry and remove roots and stones.
10. Fill a soil test container.
11. Complete any information sheets that accompany the sample to the lab. Recommendations can only be as good as the sample collected and the information supplied.

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