Soils and Water Quality

NC STATE EXTENSION

SoilFacts

Erosion and Sedimentation

When a soil is well managed, it can be an efficient receiver of rainwater. If the soil is improperly managed, however, the water may run off the surface, carrying soil particles with it. This process, called soil erosion, has been a major cause of soil degradation in North Carolina for many years (Figure 1). Damage to water quality occurs when this eroded soil enters surface waters.

Sedimentation occurs when water carrying eroded soil particles slows long enough to allow soil particles to settle out. The smaller the particle, the longer it stays in suspension. Larger, heavier particles such as gravel and sand settle out sooner than smaller, lighter particles such as clay. Clay may stay in suspension for very long periods, contributing significantly to water turbidity.

Sediment comes from many sources: agricultural fields, woodlands, highway road banks, construction sites, and mining operations. By volume, sediment is the largest water pollutant in North Carolina. It affects water quality physically, chemically, and biologically. Damage from sediment is expensive, both economically and environmentally. Sedimentation destroys fish spawning beds, reduces useful storage volume in reservoirs, clogs streams, and makes costly filtration necessary for municipal water supplies. Suspended sediment can reduce aquatic plant life and alter a stream's ecology. Because the environmental damage from sediment is often additive, the ultimate effects and costs may not be evident for years. The consequences of off-site sedimentation can be severe, both for those immediately affected and for those who must cope with subsequent problems.

Sediment often carries organic matter, animal or industrial wastes, nutrients, and chemicals. The most troublesome nutrient element is phosphorus. In freshwater ecosystems developed under very low phosphorus conditions, large additions of phosphorus can stimulate the production of algae blooms. As the algae die, organisms in the aquatic system decompose the algae to use as a food source. In the process, they also use significant amounts of oxygen. If the oxygen level is initially low, the decomposition process can further reduce it to a point that "fish kills" can occur. Phosphorus may come from such sources as fertilizers, organic matter, and animal manure. Phosphorus is very immobile in most soils and concentrates in the top few inches of soil. It is very susceptible to erosion and likely to be present in sediment.

Sediment also may carry pesticides—such as herbicides and insecticides—that may be toxic to aquatic plants and animals. The varying chemical properties of pesticides—for example, their solubility, toxicity, and chemical breakdown rate—determine the potential damage to water quality.

Figure 1. Runoff water can transport chemicals and remove uniform amounts of soil from a wide area.

Attribution: U.S. Department of Agriculture, Natural Resources Conservation Service

Runoff and Leaching

Runoff water also can transport potentially harmful dissolved chemicals from fields to bodies of water (Figure 1). Nitrogen, in the form of nitrate, NO_3, may cause human and animal health problems when concentrations exceed 10 milligrams of nitrogen per liter (44 mg of NO_3). In waters where nitrogen deficiency limits growth of the ecosystem, added nitrogen stimulates algae growth in the manner described earlier for phosphorus.

Certain dissolved nutrients and pesticides can reach the groundwater by moving down through the soil (leaching). Nitrogen in the nitrate form can move in this way. Results from a North Carolina Cooperative Extension Service and EPA well testing program indicate that the levels of nitrate nitrogen in groundwater are generally well below the critical level of 10 mg of nitrogen per liter, or 10 parts per million (ppm). Fewer than 3 percent of the wells sampled had nitrogen levels exceeding 10 ppm. Certain pesticides are highly mobile and have been detected in the groundwater of other states.

Household Waste Disposal

About half of the citizens of North Carolina depend on septic tanks (and hence on soil absorption) for the treatment and disposal of their household wastewaters. More than one million housing units in the state use on-site systems to dispose of their wastewater. At least 30,000 additional septic tank systems are installed each year. Each day, septic tanks discharge more than 100 million gallons of sewage into the soils of North Carolina.

Septic tanks should be used only in soils that can filter, absorb, and treat waste constituents. Key soil properties to consider include depth, texture, structure, drainage, color, and the presence of restrictive layers. These properties should be evaluated to a depth of at least 6 feet to reveal any limitations.

Each region of North Carolina poses potential problems for septic tank installation. In the piedmont, problems occur with thin, shallow soils over bedrock and with clayey soils whose mineral content causes them to swell extensively when wet. In the coastal plain, problems result from a seasonally high water table close to the soil surface. In the mountains, major soil problems occur on steep slopes, in shallow soils, and at the base of long slopes where subsurface water can accumulate. Alternatives to conventional septic systems need to be considered in these problem areas.

Land Application of Nutrient Containing Organic Materials

Municipalities and industries are increasingly interested in applying sludges from wastewater treatment plants to agricultural land. (See Extension Service publication AG-439-3, *Land Application of Municipal Sludge—Advantages and Concerns.*) Applications of livestock and poultry manure also have shown renewed popularity because of an increase in production and new regulations governing manure management. Land application is an appropriate technology to use for these products, provided their nutrient characteristics are known and matched with an appropriate cropping system that will use these nutrients.

For land application, the characteristics of the wastes determine the amounts to use. Each waste will contain one constituent that limits the amount that can be safely applied to land. This limiting constituent may be one of the plant nutrients such as nitrogen or phosphorus, one of the heavy metals such as cadmium, lead, or other constituents such as sodium or calcium carbonate. Waste regulations administered by the state and recommendations developed by North Carolina State University provide information on correct loading rates. With most wastes generated in North Carolina and applied to supply the nitrogen and phosphorus needs of a crop, health hazards and crop toxicities will not be a problem if recommendations are followed.

The soil's capacity to use, retain, or reduce the undesirable effects of waste varies significantly according to the physical, chemical, and biological properties of the soil and the characteristics of the wastes. Thus, the development of a land treatment system must be tailored to the characteristics of the specific site and the specific waste. The following are among the characteristics that may disqualify a site: steep slopes; very clayey or sandy soils; nearby streams, wells, and property lines; a likelihood of flooding; and shallow depth to bedrock or the water table. Because each site has a finite capacity to accept certain waste constituents (for example, heavy metals such as zinc, copper, and cadmium), a threshold may be reached beyond which land application of wastes is no longer acceptable.

Importance of Good Soil Management

An understanding of soil properties and how these interact with common management practices is essential for reducing the movement of pollutants from the land to our waters. These factors determine the types and amounts of water pollution risks in each situation.

Reducing soil erosion is the key to reducing the damaging effects of sedimentation. Fortunately, with current technology, erosion can be reduced to acceptable levels. The challenge is to match the appropriate technology to each situation.

The Natural Resources Conservation Service has developed a variety of practices that improve surface water quality. Crops themselves as well as crop residues and structures are used alone or in combination to hold the soil in place and allow water to move into it rather than to run off the surface. Agricultural practices such as strip-cropping, contour cultivation, and filter strips are both beneficial and economical (see Figure 2). Sometimes more costly structures such as grassed waterways and terraces are required to provide the necessary control. Conservation tillage, which reduces soil disturbance and preserves residue cover on the land, is another effective way to reduce erosion.

The benefits to water quality of several widely used conservation practices are shown in Table 1. Various practices enhance surface water quality by controlling erosion. Some of these have little effect on groundwater. The careful use of fertilizers, animal wastes and pesticides is a widely applicable approach that benefits our groundwater. It is essential to apply management practices that protect both surface and groundwater quality.

Soil properties and crop needs determine the proper amounts of fertilizers and pesticides to apply and the timing and method of their application. For example, sandy soils cannot hold as large a quantity of nutrient elements and other absorbed materials as can more clayey soils. Thus, the amount, frequency, and timing of nutrient applications need to be adjusted for each situation. Furthermore, inputs should be based on realistic crop yield expectations that vary with soil properties. Proper management helps avoid excessive levels of elements such as nitrogen and phosphorus that then become harmful.

Table 1. Effects of selected conservation practices on water quality.

Practice	SurfaceWater	Groundwater
Conservation tillage	+	N
Contour farming	+	N
Cover crop	+	N
Crop residue management	+	+
Field border	+	N
Filter strip	+	N
Grassed waterway	+*	N
Strip-cropping (contour)	+	N/+
Subsurface drainage	+/-**	+/N
Subsurface drainage, controlled	+	+
Terracing	+	N

Note: The plus sign (+) denotes a positive effect; the N denotes a neutral or possibly unfavorable effect.
*Maintenance fertilization of vegetation may lower the quality of runoff water.
** A negative effect occurs where nitrogen can move through a porous soil to the tile system and then into streams. Controlled subsurface drainage, properly installed and managed, greatly reduces this risk.

Contamination from home waste disposal systems can be prevented. This requires careful selection of soils for home sites and the installation of septic systems appropriate to the soil's characteristics.

The land application of wastes is now an essential part of soil management programs. The composition and properties of the waste need to be known before it is applied. When applying municipal sludge, compost, or any other form of organic wastes to the land, match the loading rate to the soil's capacity to safely accept the material and the crop's ability to use the nutrients. Manure must be thoroughly mixed into the soil to maximize the effectiveness of the nitrogen. Manure exposed on the field's surface loses up to 25 percent of its ammonia nitrogen within two days. Sixty percent or more can be lost within one month.

Manure application rates should be based on the available portion of the nutrients and should not exceed the nutrient requirements of the crop. Excessive loading may result in surface water and groundwater pollution. For more information on livestock and poultry manure, see Extension Service publications AG-439-4, *Swine Manure as a Fertilizer Source*, AG-439-5, *Poultry Manure as a Fertilizer Source*, AG-439-28, *Dairy Manure as a Fertilizer Source*, and also the *North Carolina Agricultural Chemicals Manual*. Soil testing also should be conducted to determine proper loading rates. Examples of how to compute manure application rates are outlined in these publications.

Figure 2. Strip-cropping provides an efficient means of controlling runoff problems.

Attribution: U.S. Department of Agriculture, Natural Resources Conservation Service

Conclusion

Many agricultural and industrial practices can threaten our water quality if soil properties and capabilities are poorly understood or are ignored. These threats are serious, but they also are manageable. Water quality can be improved while protecting the productivity and value of the soil for agricultural, industrial, and recreational uses. We can have both healthy soil and clean water by applying good soil management practices.

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