Chapter 6. Soil Management

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Introduction

The importance of soil management

The quality of many soils in the Mid-Atlantic region can be improved with good management. Some practices that are part of nutrient management plans may have unintended consequences that degrade instead of improve soil quality. For example, it is often recommended that manure be incorporated with tillage. However, tillage exposes the soil to erosion, reduces organic matter content and can increase runoff. Facilities that store large amounts of manure may require heavy manure spreading equipment, and often have a smaller time window for spreading, both of which increase the risk of soil compaction. If nutrient management specialists can design plans that meet soil conservation and soil quality considerations as well as nutrient management requirements, they will do a great service to agricultural producers, other citizens, and the quality of natural resources in the Mid-Atlantic.

Soil quality

Defining soil quality

Soil quality is defined as “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health, and promote plant and animal health” (Doran and Parkin, 1994). Soil quality became a widely accepted concept after a symposium was held by the Soil Science Society of America and the American Society of Agronomy in 1992 (Doran et al, 1994). There is widespread concern among soil scientists that the quality of many soils in the U.S. has declined significantly since the beginning of cultivation.

Soil quality indicators

Soil scientists are working to develop quantitative indicators of soil quality, similar to those used to measure air and water quality. The following minimum dataset has been proposed by Doran and Parkin (1996) for soil quality measurement:

- texture
- depth of soil
- infiltration
- bulk density
- water holding capacity
- soil organic matter
- pH
- electrical conductivity
• microbial biomass C and N
• potentially mineralizable N
• soil respiration

Collecting such data requires a substantial investment in time and resources, especially because some of the soil quality parameters change over time and with management. Therefore, a less scientific, but nonetheless valuable, approach has been to use readily observable, but subjective, ratings of soil quality. For example, the Pennsylvania Soil Quality Assessment scorecard (available at http://pubs.cas.psu.edu/FreePubs/pdfs/uc170.pdf) has been developed as a tool to rate soil quality quickly in the field. This scorecard gives guidance to judge soil structure, compaction, water movement, erosion, and different biological indicators. It can be used to evaluate and compare fields and then suggest changes to improve or maintain soil quality.

Soil erosion

Effects of erosion

In the Mid-Atlantic region, soil erosion is one of the major contributors to degradation of water quality. It is closely linked to phosphorus pollution because most phosphorus transported into the Chesapeake Bay is attached to soil particles. In practice, this means that soil erosion control practices will also decrease phosphorus movement in the landscape. Soil erosion also causes increased turbidity and sedimentation in the Bay. Other effects of soil erosion on the Chesapeake Bay and associated waterways are:

• Increased need for channel dredging.
• Adverse impacts on the recovery of underwater grass beds because the sediment reduces the amount of light reaching plants.
• Benthic (bottom-dwelling) organisms suffer increased mortality and reduced reproduction.
• Fish may be affected as increased sediment affects their feeding, clogs gill tissues, and smothers eggs.
• Siltation can alter the habitat of aquatic organisms.
• Increased turbidity may change the abundance of plankton, a prey which is important for larval and juvenile fish.
• Phosphorus is carried with the sediment, contributing to eutrophication.

Soil erosion also seriously reduces soil quality. The loss of productive topsoil by erosion exposes the subsoil, which usually is less productive, and has undesirable physical characteristics for field work and plant growth. Degraded soils are visible throughout the undulating parts of the Mid-Atlantic region in higher spots in fields where clay knobs or stone outcrops come to the surface. Crop establishment is poor on these knobs because of coarse
seedbeds and poor seed-to-soil contact. Drought stress because of reduced water-holding capacity is also common on these knobs and outcrops.

**Water erosion**

Soil erosion can be caused by wind, water, or tillage. Water and tillage erosion are of most concern in the Mid-Atlantic region.

There are four types of water erosion:

- *Inter-rill erosion*: the movement of soil by rain splash and its transport by thin surface flow. The erosive capacity of inter-rill surface flow is increased by turbulence generated by raindrop impact.
- *Gully erosion*: erosion by runoff scouring large channels (deeper than 1 foot).
- *Streambank erosion*: erosion by rivers or streams cutting into banks.

The term *sheet erosion* is still frequently used, but omits the concept of rainsplash (Figure 6.1), and conveys the erroneous concept that runoff commonly occurs as a uniform sheet.

Figure 6.1. Raindrop impact on bare soil initiates the erosion process. (Photo courtesy of USDA-NRCS)
The Revised Universal Soil Loss Equation

The Natural Resources Conservation Service (NRCS) uses the *Revised Universal Soil Loss Equation* (RUSLE) to calculate soil loss by erosion as a function of 5 factors:

$$A = R \times K \times LS \times C \times P$$

Where:
- $A$ = annual soil loss (tons/A/yr)
- $R$ = erosivity of rainfall
- $K$ = erodibility of the soil
- $LS$ = slope length/steepness
- $C$ = cropping and management factors
- $P$ = erosion control practices

Rainfall erosivity

The impact of raindrops on the soil surface is the beginning, and most important part, of the erosion process. The extent of erosion caused by rainfall (erosivity) depends on the size and velocity of raindrops and the amount of precipitation. Gentle, drizzly rain is not very erosive, whereas fierce thunderstorms and hurricanes are very erosive. High-intensity storms produce larger drops that fall faster than those of low-intensity storms and therefore have greater potential to destroy aggregates and dislodge particles from the soil matrix. Although the same total amount of rain may fall, a short, high-intensity rainfall event causes much more erosion than a long, low-intensity storm.

The erosivity of annual precipitation is calculated from the intensity of rainfall and the total energy of storms. Erosivity increases from the north to the south in the Mid-Atlantic region because convectional storms (usually taking place as thunderstorms in summer) are more common in the southern U.S. Most erosive precipitation events usually occur in the late summer and early fall (Figure 6.2). Soils that are bare during this period are under extreme risk of soil erosion. Bare soil (especially if planted to wide-spaced crops such as corn) is also extremely vulnerable to erosion before canopy closure in the spring.
Figure 6.2. An example of rainfall erosivity in the eastern part of the Chesapeake Bay watershed (calculated from Renard et al., 1997). Erosive storms are most frequent in the late summer/early fall.

Soil erodibility  
Soils differ in their susceptibility to erosion (erodibility) depending on natural and human factors. Erodibility is influenced by many factors, some of which vary during the year and/or vary with soil management:

- The erodibility of a soil increases with a decrease in aggregate stability. Clay and organic matter help improve aggregate stability and reduce erodibility.
- Living or dead roots also increase aggregate stability and decrease erodibility.
- Erodibility decreases with an increase of large sand grains and rock fragments because these large particles are not easily moved with water.

Soil conservation personnel use standard erodibility values published for each soil series in a particular county.

Tillage erosion  
Tillage erosion is a form of erosion that is receiving increased attention. Tillage erosion is limited to movement of soil within a field. It causes topsoil to be removed from the high points of fields and exposes subsoil. Research suggests that the total amount of soil that is moved with tillage erosion exceeds that of water erosion. Tillage erosion is probably the main cause of increased yield variability due to in-field soil movement.
Tilling up-and-down the slope causes more soil to move downslope than upslope (Figure 6.3). Tillage along the contour also moves soil downslope. More soil is moved if a moldboard throws soil downslope, which is usually preferred because better inversion is obtained this way.

Figure 6.3. Three causes of erosion resulting from tilling soils on slopes. Reprinted from Magdoff and van Es, 2000, with permission from the Sustainable Agriculture Network (SAN). (For more information about sustainable agriculture, see www.sare.org.)

Since soils are continuously formed from parent material, it is commonly accepted that a low level of erosion will not compromise soil productivity. NRCS personnel use tolerable soil loss levels (T), which vary per soil type, to indicate the maximum rate of soil erosion that can be allowed while still permitting crop productivity to be sustained indefinitely. Levels of T are a function of root development, gully prevention, on-field sediment problems, seeding losses, reduction of soil organic matter, and loss of plant nutrients. The level of T varies from 3 to 5 tons/acre/year for most soils in the Mid-
Atlantic region. Deep soils with subsoil characteristics favorable for plant growth have greater T levels than soils with shallow root zones or high percentages of shale at the surface.

**Controlling soil erosion**

The two types of water erosion that can be controlled by soil management practices are inter-rill and rill erosion. Engineering structures such as grassed waterways and streambank reinforcement are usually needed to limit other types of water erosion.

Cropping and management practices to control erosion include previous management and cropping, the protection offered the soil surface by vegetative canopy, and surface cover and surface roughness. Generally, the most important crop management practices that will help decrease erosion are:

- maintaining crop residue cover above 30% until crop canopy closure
- alternating summer crops with winter crops and perennial crops
- using cover crops during periods when the soil would have insufficient residue

Additional erosion protection is provided by contour farming and contour strip cropping:

- **Contour farming** implies that crops are planted nearly on the contour. The benefit of this practice is greatest on moderate slopes (2-6%) when crops are planted in tilled soil where ridge height is 2-3 inches. However, even with no-till, contour farming can reduce erosion if residue cover is marginal and ridge height is 2 inches or more.

- **Contour strip-cropping** involves alternating strips with high-residue cover or perennial crops with strips with low residue cover. The strips should be laid out close to the contour, something that is not always possible in rolling landscapes. Strip width is usually between 75 and 120 feet. The soil that erodes from the bare or low residue strips is deposited in the strips with high residue or dense vegetation because runoff velocity is decreased. This practice is most useful if the soil is tilled or if the soil is left bare during part of the year in no-till. In today’s cropping systems, the difference in cover between strips is frequently minimal, which reduces the effectiveness of this practice.

If high residue cover (greater than 30% at all times) is maintained in no-till
As slope length and steepness increase, runoff and soil loss also increase. Slope steepness can be changed by the construction of level terraces as is common in Southeast Asia. However, in the United States it is relatively uncommon to change slope steepness with management practices.

Slope length can be changed by installing terraces and diversions that divert runoff:

- **Terraces** are cross-slope channels that control erosion on cropland and are built so that crops can be grown on the terrace.
  - *Storage terraces* store water until it can be absorbed by the soil or released to stable outlet channels or through underground outlets. Storage terraces are usually designed to drain completely in 48 hours to avoid waterlogging within the terrace.
  - *Gradient terraces* are channels designed almost perpendicular to the natural field slope that collect runoff water and carry it to a stable outlet like a waterway.

- **Diversions** are similar to terraces, except that they are permanently vegetated with grass. They are used on steeper slopes where a terrace would be too expensive or difficult to build, maintain, or farm. They can also be used to protect barnyards or farmsteads from runoff.

Erosion control practices that help protect water quality

There are other erosion control practices that help maintain water quality but are not immediately relevant to maintain soil productivity on working cropland. The following practices are very helpful in reducing sediment and nutrient load in surface waters even though they do not directly improve soil quality:

- **Contour buffer strips**: permanently vegetated strips located between larger crop strips on sloping land.

- **Field borders**: bands or strips of permanent vegetation at the edge of a field.

- **Filter strips**: strips or areas of permanent vegetation used to reduce sediment, organic materials, nutrients, pesticides, and other contaminants from runoff.
• **Riparian forest buffers**: areas of trees and/or shrubs along streams, lakes, ponds, or wetlands.

• **Vegetative barriers**: narrow permanent strips of stiff-stemmed, tall, dense perennial vegetation established in parallel rows perpendicular to the dominant field slope.

• **Grassed waterways**: natural or constructed swales where water usually concentrates as it runs off a field.

• **Streambank protection**: structures such as fences and stable crossings to keep livestock out of the streams as well as streambank stabilization with rocks, grass, trees, shrubs, riprap, or gabions.

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### Soil compaction

<table>
<thead>
<tr>
<th>Yield loss</th>
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<tbody>
<tr>
<td>Soil compaction is the reduction of soil volume due to external factors. The risk of soil compaction is greater today than in the past due to an increase in the size of farm equipment.</td>
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Soil compaction reduces soil productivity. Research in tilled soils showed average first-year yield losses due to compaction of approximately 15% (Figure 6.4). Yield loss in the first year after compaction is mostly due to residual effects of surface compaction. In this summary of many studies in different countries, yield losses decreased to approximately 3% by 10 years after the compaction event (in the absence of re-compaction). The final yield loss was assumed to be due to subsoil compaction and can be considered permanent.
Figure 6.4. Relative crop yield on compacted soil compared to non-compacted soil with moldboard plowing. The fields were wheeled four times with 10-ton axle load, 40 psi (pounds per square inch) inflated tires. The letters a, b, and c indicate yield losses due to compaction of the topsoil, upper part of the subsoil, and lower subsoil (Hakansson and Reeder, 1994).

Other effects of compaction

Soil compaction also reduces both soil quality and environmental quality:

- Compacted soil is dense and has low porosity. Compaction preferentially compresses large pores, which are very important for water and air movement in the soil. Infiltration is then reduced and erosion is increased.

- Compaction causes the penetration resistance of the soil to increase. There is little root penetration in soil above 300 psi, except if there are cracks and macropores in the soil that can be followed by plant roots. More energy is expended when tilling compacted soil.

- Compacted soil is a harsher environment for soil organisms (especially earthworms) to live in.

- Compaction affects nutrient uptake. Denitrification rates can increase in compacted soil due to limited aeration. Manure ammonia volatilization losses have been found to increase when liquid manure is surface applied to compacted soils because of reduced infiltration. Phosphorus and potassium uptake can be reduced if root growth is inhibited.

Causes of compaction

Compaction is caused by wheel or foot traffic on the soil and by soil tillage. Soil is most compactable at a moisture content approximating field capacity.
Surface compaction (Figure 6.5) is caused by contact pressure (expressed in psi). A pick-up truck tire can cause as much surface compaction as a manure spreader at the same contact pressure. Contact pressure is approximately similar to tire pressure in flexible tires.

Figure 6.5. Surface compaction is caused by high contact pressures. Using flotation tires instead of narrow tires reduces surface contact pressure, but does not reduce subsoil compaction.
Subsoil compaction (Figure 6.6) is caused by axle load (expressed in tons). The higher the axle (or wheel) load, the deeper the stress will be transmitted into the soil.

Figure 6.6. Axle load determines subsoil compaction. Reduction of axle load reduces subsoil compaction.
Plow pans

*Plow pans* are caused just below the tillage tool, if that layer of the soil has a moisture content conducive to compaction at the time of tillage. The moldboard plow (Figure 6.7) is renowned for causing a plow pan, but the disk plow and harrow have also been found to cause plow pans.

Figure 6.7. The moldboard plow is infamous for causing a plow pan just below the depth of plowing.

Not all compaction is caused by humans. Some glaciated soils have been compacted by glaciers in the past and are still compacted at depth. Other soils have fragipans, which are naturally compacted subsoils high in silt content. Finally, some sandy coastal plain soils have such poor structure in the subsoil that root growth is negatively affected.

Controlling compaction

Avoiding soil compaction

An understanding of the causes of soil compaction makes it possible to develop management strategies that either avoid or remediate its effects. It is easier to avoid compaction because remediation strategies can be costly and will likely not correct the problem entirely.
The aim of compaction management should be to avoid subsoil compaction altogether and to limit surface compaction as much as possible. Soil compaction is not likely to cause much damage if traffic is limited to dry soil conditions. If soil is moist, however, the following is important:

- To avoid subsoil compaction, reduce axle load at least below 10 tons by:
  - reducing load
  - increasing number of axles

- To avoid surface compaction, reduce contact pressure (should be no higher than 35 psi), by:
  - reducing tire pressures to minimal allowable pressures
  - using flotation tires
  - using tracks or duals to replace singles
  - using radial-ply instead of bias-ply tires
  - installing larger diameter tires to increase length of footprint
  - properly ballasting tractor for each field operation

It is also advisable to reduce the number of passes over the field and to limit the area of the field that is impacted by traffic. This can be done by increasing swath width of spreading and spraying equipment and reducing width of tracks.

- To avoid plow pans:
  - do not drive a tractor wheel in the furrow
  - use no-tillage
  - use a chisel instead of moldboard plow
  - use a field cultivator instead of disk harrow

A producer can make the soil more resistant to compaction by increasing its organic matter content and by building a soil ecosystem that has a permanent macro-pore system. There is now much interest in using cover crops with root systems that serve to reduce or remediate the effects of soil compaction.

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Choosing equipment for remediating compaction

If the diagnosis has determined that tillage is justified, it becomes necessary to select the best tillage tool to remediate compaction. Leaving 30% residue cover after planting is recommended to reduce erosion and increase soil quality, so the tillage tool selected should not reduce residue cover below this level.

The moldboard plow is not recommended for remediation of soil compaction because it buries most residue and can actually lead to the formation of a plow pan. Chisel plows are better suited than moldboard plows for alleviating compaction if they can penetrate the compacted soil, but the tension springs on the chisel plows are not often heavy enough to penetrate the compacted
layer. In this situation, subsoilers are often used.

Traditional subsoiler shanks are heavy, wide, and have curved shanks and large points. These subsoilers were designed to cause maximum fracturing and disturbance of the soil. At the same time, however, they bury much residue and leave a rough surface that necessitates secondary tillage. Clearly, residue conservation and reduction of secondary tillage were not considerations at the time these subsoilers were designed.

Modern subsoilers are designed differently. They usually have narrow shanks, have coulters to cut through residue in front of the shank, and have some type of attachment to leave the soil in a condition that is ready to be planted. These subsoilers leave most residues at the soil surface and do not create much surface disturbance. They vary in subsoil disturbance according to their design. Two examples of these modern subsoilers are shown in Figure 6.8.

Using cover crops to ameliorate compaction

Cover crops are increasingly used to correct compaction. These cover crops are planted in the fall and grow when soil moisture contents are high and soil is easy to penetrate. Some cover crops have a taproot that can create channels into the subsoil. Other cover crops have a massive, fine root system that intermeshes with soil particles, stabilizing aggregation and creating many small channels. Roots of summer crops can take advantage of the channels created by the cover crop roots at a time when soil moisture content is typically lower than in the winter. More research is needed to further substantiate the benefits of cover crops for soil compaction alleviation and to enable better recommendations for cover crop selection and management for this purpose.
Figure 6.8. Two types of modern subsoilers that break through subsoil compaction while conserving surface residue cover.
Residue management and conservation tillage

Crop residue management

*Crop Residue Management (CRM)* is a year-round process that begins with the selection of crops that produce sufficient quantities of residue and may also include the use of cover crops after low residue producing crops. CRM will influence all field operations that affect residue amounts, orientation, and distribution throughout the period requiring protection. Residue cover amounts are usually expressed in percentage but may also be expressed in pounds. CRM is an “umbrella” term encompassing several tillage systems including no-till, ridge-till, mulch-till, and reduced-till.

Conservation tillage

*Conservation tillage* is a generic term that includes many varied tillage systems that leave more than 30% crop residue cover after planting. Conservation tillage can include no-till, minimum tillage systems, zone tillage, strip tillage, and ridge tillage, as long as these systems leave more than the required residue cover after planting. The residue limit of 30% was established as a result of the relationship between residue cover and inter-rill erosion (Figure 6.9), because an increase from 0 to 30% residue cover results in a 70% reduction of inter-rill soil loss.

Figure 6.9. The 30% residue cover limit that defines conservation tillage is based on the relationship between residue cover and inter-rill erosion.
The following definitions were adapted from those given by the Conservation Technology Information Center (2005):

- **No-till/strip-till (>30% residue):**
  - Soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width. These strips may involve only residue disturbance or may include soil disturbance.
  - Planting or drilling is accomplished using disc openers, coulters, row cleaners, in-row chisels or roto-tillers.
  - Weed control is accomplished primarily with herbicides. Cultivation may be used for emergency weed control.
  - Other common terms used to describe no-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

- **Ridge-till (>30% residue):**
  - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width.
  - Planting is completed on the ridge with sweeps, disk openers, coulters, or row cleaners, and usually involves the removal of the top of the ridge.
  - Residue is left on the surface between ridges.
  - Weed control is accomplished with herbicides (frequently banded) or cultivation.
  - Ridges are rebuilt during row cultivation.

- **Mulch-till (>30% residue):**
  - Full-width tillage involving one or more tillage trips which disturb the entire soil surface. Tillage tools such as chisels, field cultivators, disks, sweeps, or blades are used.
  - Done prior to and/or during planting.
  - Weed control is accomplished with herbicides or cultivation.

- **Reduced-till (15-30% residue):**
  - Full-width tillage involving one or more tillage trips which disturb the entire soil surface.
  - Done prior to planting. There is 15-30% residue cover after planting or 500 to 1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period.
  - Weed control is accomplished with herbicides or row cultivation.

- **Conventional-till or intensive-till (<30% residue):**
  - Full width tillage which disturbs the entire soil surface and is performed prior to and/or during planting. There is less than 15% residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period.
  - Generally involves plowing or intensive (numerous) tillage trips.
Weed control is accomplished with herbicides or row cultivation.

- **Stale seedbed:**
  - Not an official tillage category.
  - Fields are tilled full-width soon after harvest. The seedbed “settles” until planting is performed in the undisturbed (settled) seedbed or in re-formed beds (minimum disturbance).
  - Weeds and/or cover crops are controlled with herbicides or row cultivation.

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**Tillage systems in the Mid-Atlantic**

The adoption of conservation tillage virtually stagnated in the Mid-Atlantic and Northeast U.S. between 1990 and 2004 (Figure 6.10). This does not mean that no changes in tillage practices have taken place, but, rather, it means that, in many cases, the residue cover requirements for conservation tillage are not met.

Over the past two decades there has been a gradual shift by farmers away from the moldboard plow to the chisel plow as the primary tillage tool. Because of low residue cover left by the preceding crop or because of secondary tillage operations, however, the level of residue cover left after chisel plowing and secondary tillage operations is usually less than 30% residue cover. The only two common field crops that leave enough residue to enable chisel plowing and still maintain 30% residue cover after planting are high-yielding corn or small grains harvested for grain.

Another change in tillage practices has been within the conservation tillage class. There has been a steady increase in no-tillage, but this increase has been at the expense of other conservation tillage practices such as chisel plowing and disking.
Figure 6.10. Tillage systems in the Northeast, including Mid-Atlantic states (Conservation Technology Information Center, 2005).

No-tillage

In recent years there has been an increasing realization of the negative aspects of soil tillage:

- takes time
- costs money (fuel, equipment, maintenance)
- increases erosion
- reduces organic matter content
- destroys soil tilth
- promotes soil crusting
- increases runoff
- increases evaporation losses
- reduces biological activity (e.g. earthworms)
- brings rocks to surface

These negative attributes of tillage explain the increased adoption of no-tillage. However, a major concern of producers that may have slowed the adoption of no-till is whether they can produce the same yields as with tillage. No-tillage is most challenging on poorly drained soils. In addition, the northern sections of the Mid-Atlantic region have a short growing season for corn, so slower warming of no-till soils may sometimes reduce corn yields there. On most soils in the region, however, no-till yields should be similar to
yields obtained with tillage, and no-till should out-yield tilled crops in areas where drought stress is a problem, due to the water conserved by the mulch cover.

As the adoption of no-till increases, we continue to learn more about it. There is now an increasing realization that:

• No-till without or with little mulch is not a sustainable practice. Almost all environmental benefits of no-tillage are due to the mulch cover at the soil surface.

• Soil improvement with no-till takes years. Continuous no-till is recommended because rotating tillage and no-till destroys the soil-building benefits of no-till.

• No-till affects many other aspects of crop production (nutrient, weed and pest dynamics; residue distribution) that need to be integrated into a systems approach. Crop rotations and cover crops are central to this systems approach.

Cover crops

Cover crops can provide many benefits, including:

• erosion control
• organic matter increase
• soil structure improvement
• atmospheric nitrogen fixation
• nitrate recapture
• soil water management
• weed control

The reason for using a cover crop will determine which cover crop should be used and how it should be managed. A cover crop should provide quick cover, have an extensive root system, and preferably survive the winter. If the cover crops are killed without tillage and the main crop established with no-till methods, additional erosion protection will be provided by the resulting mulch.

Small grains such as rye, wheat, and oats are excellent cover crops that protect soil from erosion, improve its organic matter content and structure and capture nitrates after summer crop harvest. Erosion protection is especially critical after low residue crops such as corn silage, soybeans, and vegetables. Small grain cover crops are also preferred to increase organic matter content because of their large biomass production and high C:N ratio after boot stage. Their fine and extensive root system helps improve soil structure and take up nitrate, thus preventing this mobile nutrient from leaching to groundwater.
Rye is the most winter hardy of the winter cereal cover crops. It produces a heavy cover in the spring. Rye takes up much moisture once its stem extension begins. This can help dry up wet soils, providing earlier field access. Some rye varieties have *allelopathic* properties, which means they can suppress weeds.

Wheat is also winter hardy in most of the region. It does not grow as fast as rye in the spring and is, therefore, easier to manage.

Spring oats winter-kill in December in most of the Mid-Atlantic region and should be established early to allow enough biomass accumulation. Although oats are easy to manage, they provide fewer benefits than rye and wheat because of their early winter-kill in many areas.

Leguminous cover crops such as hairy vetch, crimson clover, red clover, white clover, and winter pea are used to fix nitrogen (see Chapter 4 for N-supplying capacity of legume cover crops). To achieve successful results with these cover crops, they need to be established in a timely manner and allowed to accumulate enough biomass.

*Brassica* cover crops such as radish and mustards are receiving increased attention because of their taproots, which can create large pore spaces in the subsoil. These pores can later be occupied by summer crop roots. *Brassica* species also have allelopathic properties that can help with weed control.
References cited


