10

# Soil Management and Tillage

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Soil is one of our most precious natural resources. Proper soil management is a key to sustainable agricultural production. Soil management involves six essential practices: proper amount and type of tillage, maintenance of soil organic matter, maintenance of a proper nutrient supply for plants, avoidance of soil contamination, maintenance of the correct soil acidity, and control of soil loss (erosion). In Illinois, the greatest concern for soil degradation is erosion caused by water. All of these practices depend on soil type, soil texture, and slope as well as on the crops that are grown.

The potential for erosion of a specific soil type largely depends on the severity of the slope, the crops grown, and the number and types of tillage operations. Several techniques are available to reduce soil erosion, including residue management, crop rotation, contour tillage, grass waterways, terraces, and conservation structures. The techniques adopted must ensure the long-term productivity of the land, be environmentally sound, and, of course, be profitable. Conservation tillage and crop residue management are recognized as cost-effective ways to reduce soil erosion and maintain productivity.

## Conservation Compliance

A dramatic step taken to encourage the adoption of techniques to control soil erosion was the passage of the 1985 Food Security Act. Provisions of this act require farmers producing agricultural commodities on *highly erodible land* (HEL) to fully implement an approved conservation plan to remain eligible for certain farm program benefits. This program, known as "conservation compliance," was amended in subsequent versions of the Farm Bill. Conservation systems must meet specifications or guidelines of the *Natural Resources Conservation Service Field Office Technical Guide* and must be approved by the local conservation district. Most conservation compliance systems include use of mulch-till or no-till. The goal of conservation compliance is to reduce soil erosion to levels that will maintain the long-term productivity of the land. Even though conservation compliance pertains only to HEL fields, many farmers are adopting conservation tillage systems not only to reduce soil erosion but also to reduce labor and equipment costs.

Federal conservation provisions focus on reducing soil erosion, both to maintain soil productivity and to limit the amount of sediment that enters streams and rivers. Concerns about water quality are likely to continue to be an issue in legislation. Conservation practices such as conservation tillage, terraces, strip cropping, contour tillage, grass waterways, and filter strips all help reduce water runoff and soil erosion and thus help preserve water quality.

As indicated earlier, the tillage system selected to produce a crop has a significant effect on soil erosion, water quality, and profitability. Profitability, of course, is determined from crop yield (net income) and costs. But it is useful to include considerations of long-term effects on soil loss and productivity, not simply on yields in the short term. Selecting a tillage system is thus an important management decision. Before the factors are discussed in detail, several tillage systems will be defined.

Nationwide there has been a slight recent increase in the amount of no-till acreage that coincides with rapid adoption of glyphosate-tolerant soybeans (**Table 10.1**). In Illinois, the percentage of glyphosate-tolerant soybean has risen to more than 90% within 12 years of the introduction of this trait, and the percentage of no-till soybean now exceeds 50%. By comparison, no-till corn production accounts for less than 17% of Illinois corn acreage.

## Conservation Tillage

The objective of conservation tillage is to provide a means of profitable crop production while minimizing soil erosion due to wind and/or water. The emphasis is on soil conservation, but conserving soil moisture, energy, labor, and even equipment provides additional benefits. To be considered conservation tillage, the system must provide conditions that resist erosion by wind, rain, and flowing water. Such resistance is achieved either by protecting the soil surface with crop residues or growing plants or by maintaining sufficient surface roughness or soil permeability to increase water filtration and thus reduce soil erosion.

Conservation tillage is often defined as any crop production system that provides either a residue cover of at least 30% after planting to reduce soil erosion due to water or at least 1,000 pounds per acre of flat, small-grain residues (or the equivalent) on the soil surface during the critical erosion period to reduce soil erosion due to wind.

The term *conservation tillage* represents a broad spectrum of tillage systems. However, maintaining an effective amount of plant residue on the soil surface is the crucial issue, which is why the Natural Resources Conservation Service (NRCS) has replaced conservation tillage with the term *crop residue management*. This term refers to a philosophy of year-round management of residue to maintain the level of cover needed for adequate control of erosion. Adequate erosion control often requires more than 30% residue cover after planting. Other conservation practices or structures may also be required. Some of the conservation tillage systems are described here.

**Table 10.1.** Trends in tillage types in the United States from 1992 through 2007.

| | % of all planted U.S. acres | | | |
|---|---|---|---|---|
| Year | No-till | Mulch-till | Reduced-till | Conventional tillage |
| 1992 | 9.9 | 20.2 | 25.9 | 42.7 |
| 1996 | 14.8 | 19.8 | 25.8 | 38.5 |
| 2000 | 17.5 | 18.0 | 26.2 | 42.7 |
| 2004 | 22.6 | 17.4 | 21.5 | 37.7 |
| 2007* | 23.7 | 17.2 | 21.4 | 36.8 |

Percentages are of all planted acres. Data from the Conservation Tillage Information Center.

*Data from 2004 supplemented by additional sampling.

### No-Till

With no-till, the soil is left undisturbed from harvest to seeding and from seeding to harvest. The only "tillage" is the soil disturbance in a narrow band created by a row cleaner, coulter, seed furrow opener, or other device attached to the planter or drill. Many no-till planters are now equipped with row cleaners to clear row areas of residue. No-till planters and drills must be able to cut residue and penetrate undisturbed soil. In practice, a tillage system that leaves more than 70% of the surface covered by crop residue is considered to be a no-till system.

### Strip-Till

Strictly speaking, a no-till system allows no operations that disturb the soil other than planting or drilling. On some soils, including poorly drained ones, the no-till system is sometimes modified by the use of a strip tillage operation, typically in the fall, to aid soil drying and warming in the spring. This system is called strip-till. It is considered a category of no-till, as long as it leaves the necessary amount of surface residue after planting.

Strip-till is sometimes done along with the fall application of anhydrous ammonia, dry fertilizer, or both. This usually involves using a mole knife, which is designed to shatter and lift soil as it places fertilizer. A closing apparatus, usually disk blades run parallel to the row, pulls soil into the row. In some cases a rolling cage is used to firm the strip and break up clods. This process creates a small, elevated strip called a berm.

One benefit of strip-till, compared to no-till, is accelerated soil warming that results from removing residue and disturbing the soil in the berm. Planting takes place as close as possible to the center of the berm, which has usually "melted down" by spring to be little higher than the soil between the rows. The width of the strip-till implement is usually matched to the planter width, and the use of RTK-directed autosteer greatly assists the strip-till and planting processes. Maintenance of interrow residue helps to provide the benefits of a no-till system, while the uncovered soil near the seed row reduces the negative effects of cold, wet soils often found in no-till. The advantages of strip-till over no-till are thus most likely to be seen in cold, wet springs.

Disadvantages of strip-till include difficulty in getting the process completed in a wet fall, and washing out of the soil in the berm by heavy rainfall in the spring. Failure to complete strip-tilling in the fall raises the question of whether or not to strip-till in the spring. In many cases, soils are too wet to do effective soil shattering and tillage in the spring until near planting time. When this happens, the amount of soil warming in strips will be limited, and it may be better to use row cleaners to improve seed placement and to plant instead of forming strips first. Placement of fertilizer with the strip-till knife is generally safe for dry fertilizer, but ammonia needs to be placed quite deep beneath the row in order to prevent damage to the seedlings, and even then ammonia can move up if the soil dries after planting.

### Ridge-Till

Ridge-till is also known as ridge-plant or till-plant. With ridge-till, the soil is left undisturbed from harvest to planting except for possible fertilizer application. Crops are planted and grown on ridges formed in the previous growing season. Typically, ridges are built and reformed annually during row cultivation. A planter equipped with sweeps, disk row cleaners, coulters, or horizontal disks is used in most ridge-till systems. These row-cleaning attachments remove 0.5 to 2 inches of soil, surface residue, and weed seeds from the row area. Ideally, this process leaves a residue-free strip of moist soil on top of the ridges into which the seed is planted. Special heavy-duty row cultivators are used to reform the ridges. Corn and grain sorghum stalks are sometimes shredded before planting. The use of ridge-till has decreased considerably in the past decade, and it is currently practiced on small acreage. Reasons for its decline include the inconvenience related to driving across ridges during harvest, the difficulty in forming and maintaining ridges, especially on slopes, and the requirements for specialized equipment and row cultivation during the season.

### Mulch-Till

Mulch-till includes any conservation tillage system other than no-till and ridge-till. Deep tillage might be performed with a subsoiler or chisel plow; tillage before planting might include one or more passes with a disk harrow, field cultivator, or combination tool. Herbicides and row cultivation control weeds. The tillage tools must be equipped, adjusted, and operated to ensure that adequate residue cover remains for erosion control, and the number of operations must also be limited. At least 30% of the soil surface must be covered with plant residue after planting.

## Conventional Tillage

Conventional tillage is the sequence of operations traditionally or most commonly used in a given geographic area to produce a given crop. The operations used vary considerably for different crops and in different regions. In the past, conventional tillage in Illinois included moldboard plowing, usually in the fall. Spring operations included one or more passes with a disk harrow or field cultivator before planting. More recently, conventional tillage has changed to include the use of a chisel plow instead of a moldboard plow, and newer combination tools are replacing chisel plows. These implements leave more residue than traditional moldboard plows, but often not enough to qualify as conservation tillage.

The soil surface following conventional tillage as practiced in the past was essentially free of plant residue. This was helpful with older planting equipment that had limited ability to plant into residue. It also buried weed seed and disease-bearing crop and weed residue, thereby helping to reduce problems with weeds and plant diseases before the advent of modern chemical control.

The term *clean tillage* is used for any system that leaves the soil surface more or less free of residue. A soil surface essentially free of residues can also be achieved with other implements, especially following a crop such as soybean that produces fragile, easy-to-cover residue. Removing all residue from the soil surface and disturbing the soil surface greatly increase the potential for soil erosion. The potential for water erosion is less in flat fields, but the potential for wind erosion is high. Improved planters, seed quality, and herbicides have largely eliminated the need to practice clean tillage.

## Effects of Tillage on Soil Erosion

The primary advantages of conservation tillage systems, particularly no-till, are less soil erosion due to water on sloping soils and conservation of soil water for later crop use. Residue absorbs the impact of raindrops, thereby reducing the amount of soil dislodged. It also intercepts water as it moves down the slope, which allows soil particles to settle. Although wind erosion in Illinois is not as great a problem as water erosion, the residue left on the surface by conservation tillage systems slows the wind near the soil surface, thereby reducing the movement of soil particles into the air.

A bare, tillage-disturbed (or smooth) soil surface is extremely susceptible to erosion. Many Illinois soils have subsurface layers that are not favorable for root growth and development. Soil erosion slowly but continually removes the topsoil that is most favorable for root development, resulting in gradually decreasing soil productivity. Even on soils without root-restricting subsurface layers, erosion removes nutrients that must be replaced with additional fertilizers to maintain yields.

An additional problem related to soil erosion is sedimentation. Sediment and other materials (such as pesticides and nutrients) from eroding fields increase water pollution, reduce storage capacities of lakes and reservoirs, and decrease the effectiveness of surface drainage systems.

Surface residues effectively reduce soil erosion. A residue cover of 20% to 30% after planting reduces soil erosion by approximately 50% compared to a bare field. A residue cover of 70% after planting reduces soil erosion more than 90% compared to a bare field. On long, steep slopes, even conservation tillage may not adequately control soil erosion. Other practices may be required on such fields, such as contouring, grass waterways, terraces, or structures. For technical assistance in developing erosion control systems, consult your district conservationist or the NRCS.

## Residue Cover

The percentage of the soil surface covered with residue after planting is affected by both the previous crop grown and the tillage system used. In general, the higher the crop yield, the more residue the crop produces. More important, however, is the type of residue a crop produces. Plant characteristics such as composition and sizes of leaves and stems, density of the residues, and relative quantities produced are all factors in the effectiveness of soil protection.

Often there is a desire to predict the amount of residue that will remain on the soil surface using a particular tillage system. This estimate is important for compliance with conservation measures. The prediction requires knowing the amount of residue cover remaining after each field operation included in the tillage system. Typical percentages of the residue cover remaining after various field operations are given in **Table 10.2**.

A corn crop that yields more than 120 bushels per acre will usually provide a residue cover of 95% after harvest. Grain sorghum, most small grains, and lower-yielding corn will generally provide a cover of 70% to 80%. In all cases, the residue must be uniformly spread behind the combine to most effectively prevent erosion. For a given tillage system, a rough approximation of the residue cover remaining after planting can be obtained by multiplying the initial percentage of residue cover by the values in **Table 10.2** for each operation. To leave

**Table 10.2.** Residue cover remaining on the soil surface after weathering or specific field operations.

| | % of residue remaining | |
|---|---|---|
| | **Nonfragile** | **Fragile** |
| **Climatic effects** | | |
| Overwinter weathering following summer harvest[a] | 70–90 | 65–90 |
| Overwinter weathering following fall harvest[a] | 80–100[b] | 75–100[b] |
| **Field operations** | | |
| Moldboard plow | 0–10 | 0–5 |
| V ripper/subsoiler | 60–80[b] | 40–60[b] |
| Disk-subsoiler | 30–50 | 10–20 |
| Chisel plow with straight spike points | 35–75[b] | 30–60[b] |
| Chisel plow with twisted points or shovels | 25–65[b] | 10–30[b] |
| Coulter-chisel plow with straight spike points | 35–70[b] | 25–40[b] |
| Coulter-chisel plow with twisted points or shovels | 25–60[b] | 5–30[b] |
| Offset disk harrow—heavy plowing > 10-in. spacing | 25–50 | 10–25 |
| **Tandem disk harrow** | | |
| Primary cutting > 9-in. spacing | 30–60 | 20–40 |
| Finishing 7- to 9-in. spacing | 40–70 | 25–40 |
| Light disking after harvest | 70–80 | 40–50 |
| **Field cultivator as primary tillage operation** | | |
| Sweeps 12 to 20 in. | 60–80 | 55–75 |
| Sweeps or shovels 6 to 12 in. | 35–75 | 50–70 |
| **Field cultivator as secondary tillage operation** | | |
| Sweeps 12 to 20 in. | 80–90 | 60–75 |
| Sweeps or shovels 6 to 12 in. | 70–80 | 50–60 |
| Combination finishing tool with disks, shanks, and leveling attachments | 50–70 | 30–50 |
| Combination finishing tool with spring teeth and rolling baskets | 70–90 | 50–70 |
| Anhydrous ammonia applicator | 75–85 | 45–70 |
| Conventional drill | 80–100 | 60–80 |
| No-till drill | 55–80 | 40–80 |
| Conventional planter | 85–95 | 75–85 |
| No-till planter with ripple coulters | 75–90 | 70–85 |
| No-till planter with fluted coulters | 65–85 | 55–80 |
| Ridge-till planter | 40–60 | 20–40 |

From *Estimates of Residue Cover Remaining After Single Operation of Selected Tillage Machines,* developed jointly by the Soil Conservation Service, USDA, and Equipment Manufacturers Institute. First edition, February 1992.

[a]With long periods of snow cover and frozen conditions, weathering may reduce residue levels only slightly, while in warmer climates, weathering losses may reduce residue levels significantly.

[b]Value adjusted based on University of Nebraska research and field observations.

30% or more residue cover following corn, only one or two tillage operations can be performed. To leave 30% cover following soybeans essentially requires that a no-tillage system be used. Even strip-till or fall application of ammonia might reduce residue cover to less than 30% in soybean stubble.

## Crop Production with Conservation Tillage

Crop response to various tillage systems is variable in both farmers' fields and experimental plots. The variability is often difficult to explain because so many factors that directly affect crops are influenced by tillage. Crop germination, emergence, and growth are largely regulated by soil temperature, aeration, and moisture content, by nutrient availability to roots, and by mechanical impedance to root growth. All of these factors are affected by tillage.

### Soil Temperature

Crop residue on the soil surface insulates the soil from the sun's energy. In most of Illinois, soil temperatures in the spring are usually less than ideal for plant growth, and an insulating cover of residue both deflects warming sunlight and prevents warm air from warming the soil. Later in the season, soil temperatures are often warmer than ideal, and ways to cool the soil would be helpful.

Minimum daily temperatures of the soil surface usually occur between 6 a.m. and 8 a.m., and in spring they are often the same or slightly higher with residue cover than without. Maximum daily temperatures of the soil surface occur between 3 p.m. and 5 p.m., and with clean tillage they are 3 to 6 °F warmer than those with residue cover. During the summer, a complete crop canopy restricts the influence of crop residue on soil temperature, and soil surface temperatures are about the same with and without surface residue.

During May and early June, the reduced soil temperatures caused by a surface mulch influence early plant growth. In northern regions of the state, average daily soil temperatures are often close to the temperature required for corn growth, and the reduced temperatures caused by surface residues result in slow plant growth. In southern regions of the state, average daily temperatures are usually well above the temperature required for corn growth, and the reduced temperatures caused by surface residues have less effect on early corn growth.

The amount of residue influences soil temperature. Residues from corn, wheat, and grass sod maintain cooler soil than residue from soybeans and other crops that produce less residue or residue that decomposes rapidly.

Whether the lower soil temperature and subsequent slower early growth result in lower yields depends largely on weather conditions during the summer. Research shows that lower yields with reduced tillage systems occur most often on poorly drained soils and on most soils in northern Illinois in years not affected by drought. In these situations, soil temperature, corn growth, and yield potential often improve when residues are removed from the row area. However, on well-drained soils in southern Illinois, reduced soil temperature caused by in-row residues may increase crop growth and yield.

An example of daily fluctuation of soil temperature in the row (about 2 in. deep) from three different tillage systems is shown in **Figure 10.1**. Night temperatures are similar for all treatments, but soil that is tilled and mostly free of residue heats more quickly and to higher temperatures during the day. Strip-till closely resembles chisel-plowed (conventionally tilled) soil in the way it heats during the day.

### Moisture

A soil surface reside cover of 30% or more decreases the amount of water evaporated from the soil surface and increases water infiltration rates, leading to more water stored in the soil. More stored water is usually advantageous in dry summer periods, but it may be disadvantageous at planting time and during early growth, especially on soils with poor internal drainage.

In most years in Illinois, the crop needs more water than rainfall supplies after the crop canopy closes. Soil moisture saved through reduced tillage systems may be important in years with below-normal rainfall. In the northern half of Illinois, excessive soil moisture in the spring months often reduces crop growth because it slows soil warming and may delay planting. However, on soils where drought stress often occurs during summer months, additional stored moisture leads to higher yields.

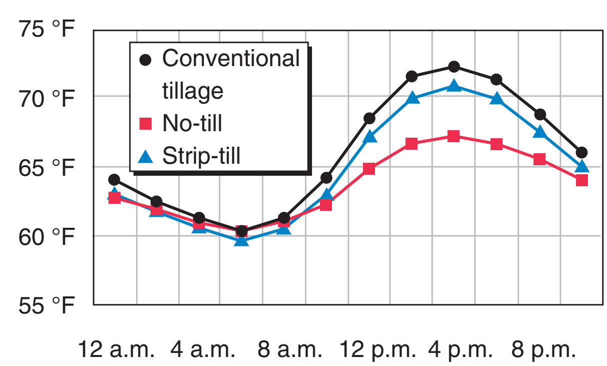


**Figure 10.1.** Soil temperatures across the day (averaged over several weeks after planting) in no-till, strip-till, and conventional tillage systems.

## Organic Matter

Soil organic matter tends to stabilize at a certain level for a specific tillage system used in fields with a particular soil texture. Moldboard plowing buries essentially all residues and increases oxidation of organic matter. With conservation tillage systems, especially no-till and ridge-till, residue is left on the soil surface where decomposition is slow, which then causes organic matter in the upper few inches to increase after several years. Crop roots decompose more slowly than aboveground residue, and so tend to contribute relatively more to soil organic matter than does aboveground residue.

Both the amount and distribution of organic matter change with the tillage system. Compared to moldboard plowing, organic matter with no-till gradually increases near the soil surface and is maintained or increased slightly below a depth of 4 inches. With mulch tillage systems, organic matter will typically approach a level between those in conventional tillage and no-till systems.

## Soil Density and Compaction

The loss of air-filled pore volume in soils caused by mechanical compression results in an increase in soil density, referred to as soil compaction. Excessive compaction restricts plant root growth, impedes drainage, reduces soil aeration, increases injury potential of some herbicides, and reduces uptake of potassium and nitrogen. Untilled soil usually has a greater density than freshly tilled soil. However, after soil is loosened by tillage, density increases over time as a result of wetting and drying, wheel traffic, and secondary tillage operations. By harvest time soil density is often about equal to that of untilled soil. Wheel traffic of heavy equipment such as tractors, combines, and grain carts may cause plant rooting to be limited or redirected with any tillage system.

In an experiment at the University of Illinois, corn and soybeans were grown with and without wheel traffic compaction on tilled soil before planting (**Table 10.3**). Heavy wheel traffic on the entire soil surface significantly decreased corn yields when rainfall was adequate or excessive. In years with excessive rainfall, ponding of water occurred on plots with the entire surface compacted, and corn yields were reduced significantly. On other plots, wheel traffic was applied to every other row of the plot area before planting—which may be more typical of field conditions. On these plots, yields were not significantly affected compared to yields from no-extra-compaction plots.

Problems such as compacted layers or "tillage pans," excessive traffic areas, ruts from wheel traffic, and livestock trails are troublesome with no-till. Compacted layers from previous field operations can limit rooting. Natural soil processes such as freezing and thawing, wetting and drying, and the channeling of earthworms and roots eventually act to reduce the effects of compacted zones under no-till, but these processes are slow, and they may not be effective for deep compaction. The use of a chisel plow or subsoiler before beginning no-till should speed the process if compaction is not reintroduced by subsequent traffic and excessive secondary tillage. Benefits from subsoiling can generally be expected only when it disrupts or loosens a drainage- or root-restricting layer. The disruption allows excess water to drain and plant roots to explore a greater volume of soil.

**Table 10.3.** Effects of wheel traffic compaction on soybean and corn yields at Urbana.

| | 11-yr avg yields (bu/A) | |
|---|---|---|
| **Compaction treatment** | **Soybeans** | **Corn** |
| No extra compaction | 40.3 | 163 |
| Half-surface compaction | 40.0 | 160 |
| Entire surface compacted | 38.8 | 150* |

*Soil compaction caused water to pond after heavy rain in some years.

There have been considerable expenditures in recent years aimed at breaking through compacted soil layers using a tillage procedure usually called *deep ripping*. A large, heavy tractor pulls an implement with 5 or 7 heavy standards, usually on 30-inch spacing, equipped with one of several types of points. These are typically run at depths of 12 to 16 inches, or at a depth below the depth of the compacted layer. Research at the University of Illinois showed that such deep tillage operations, done annually or every two or four years on fields with only minor compaction, had little effect on corn or soybean yield. On fields where very heavy equipment is operated, deep ripping may well improve rates of water infiltration and may improve yields. Such ripping should usually be done only in parts of the field that have a compaction problem, and it should be done when soils are dry enough to shatter; if done when soils are somewhat wet, compaction from driving the heavy equipment across the field may well negate the benefits of breaking up the compacted zone. Rather surprisingly, deep ripping, if done carefully using "minimum residue disturbance" shanks and points that do not disturb the soil surface much, can be done in "no-till" fields.

Some soils, including those found in parts of southern Illinois, have a natural hardpan or claypan at a depth of 12 to 18 inches. Generally, the layers below the pan are also compacted and poorly drained. In such cases, chiseling or subsoiling is ineffective because it is impossible to break through to a better-drained layer.

Soil surface compaction and non-uniformity from wheel or livestock traffic can cause uneven seed placement and poor stands in no-till. To the extent possible, no-till fields should be kept smooth. Where the soil surface is not smooth, shallow tillage may be needed to obtain uniform seed placement.

### Stand Establishment

Uniform planting depth, good contact between the seed and moist soil, and enough loose soil to cover the seed are necessary to consistently produce uniform stands. Planting shallower than normal in the cool, moist soil common to many conservation tillage seedbeds may partially offset the disadvantage of lower soil temperatures. However, if dry, windy weather follows planting, germination may be poor, and shallow-planted seedlings may be stressed for moisture. A normal planting depth is thus suggested for all tillage systems.

For most conservation tillage systems, planters and drills are equipped with coulters in front of each seed furrow opener to cut the surface residues and penetrate the soil. Row cleaners can also be mounted in front of each seed opener. Generally, coulters should be operated at seeding depth. Row cleaners should be set to move the residue from the row area and to move as little soil as possible. Extra weight is sometimes needed on planters and drills for no-till so that the soil-engaging components function properly and sufficient weight is ensured on the drive wheels. Heavy-duty, down-pressure springs may also be necessary on each planter unit to penetrate firm, undisturbed soil.

Two major challenges in no-till are stand establishment and development of the nodal root system. These are more likely to be problems when soils are somewhat wet at planting. Wet soils at the time of planting, especially when planting no-till, usually result in what is commonly called sidewall compaction. Better described as sidewall smearing, this results from the sealing of the soil where it makes contact with the opener disks. This surface hardens as it dries and can become a serious barrier to penetration of roots, especially nodal roots of corn. This lack of nodal root penetration into the bulk soil can result in "rootless" corn, which can cause corn plants to fall over or desiccate. Failure of roots to penetrate into the bulk soil will often cause corn roots to grow up and down the row, or down through the bottom of the planting furrow (forming what some call "tomahawk" roots) rather than diagonally out into the soil.

### Fertilizer Considerations in Reduced Tillage

Since soils are cooler, wetter, and less well aerated with no-till, the ability of crops to utilize nutrients may be altered, and adjustments in fertilizer management may be important.

Stratification of relatively immobile nutrients, such as phosphorus and potassium, with high concentrations near the soil surface and decreasing concentrations with depth has been routinely observed where no-till and other conservation tillage systems have been used for at least 3 to 4 years. This stratification results from both the addition of fertilizer to the soil surface and from the "cycling" of nutrients, in which roots take up nutrients from well below the soil surface; some of these nutrients are then deposited on the soil surface in the form of crop residue.

When soil moisture is adequate, nutrient stratification has not been found to decrease nutrient availability because root activity in the fertile zone near the soil surface is sufficient to supply plant needs. The residue enhances root activity near the soil surface by reducing evaporation of water, which helps keep the surface soil moist and cool. If the surface dries out and the shallow roots become inactive, nutrient uptake could be reduced, especially if the lower portions of the old plow layer are low in nutrients.

Details on soil fertility are covered in Chapter 8. The key points on fertility management for no-till are as follows:

- Liming to neutralize soil acidity is important, especially with surface applications of nitrogen fertilizer. Lime rates may need to be adjusted and applications more frequent with no-till, with care taken not to raise surface pH levels much above 7.2 or 7.3. Where possible, lime should be incorporated as needed before establishing a no-till system.
- Any phosphorus and potassium deficiencies should be corrected prior to switching to no-till because surface applications move into the soil very slowly.
- After several years of no-till, it may be desirable to take samples for nutrient analysis from near the soil surface (0 to 3 inches deep) and from lower portions of the old tillage zone (3 to 7 inches deep). If depletion of nutrients or accumulation of acidity (pH less than 5.3 or so) in the lower portion occurs and crops show nutrient deficiency, moldboard or chisel plowing can correct the stratification problem. If there has been stratification but no deficiency symptoms appear, then such tillage may not be necessary.
- Starter fertilizer appears to be more important with no-till, especially for continuous corn. More information on the use of starter for no-till is provided in Chapter 8.
- Nitrogen management is very important to success with no-till planting of corn. Anhydrous ammonia applied in the spring before planting can severely injure or kill seedlings if corn is planted directly above it. Anhydrous

ammonia can safely be applied in the fall or in the spring before planting, if application is made between rows to be planted. If rain is not received within 3 days after application, there is a potential for loss of a portion of the nitrogen surface applied on no-till in the form of urea or urea–ammonium nitrate solutions. To minimize this loss potential, apply these products 1 to 2 days before a rain, or use a urease inhibitor.

## Weed Control

Controlling weeds is essential for profitable production with any tillage system. With less tillage, weed control becomes more dependent on herbicides. However, effective herbicides are available for controlling most weeds in conservation tillage systems. Herbicide selection and application rate, accuracy, and timing become more important. Application accuracy is especially important with drilled or narrow-row soybeans because row cultivation is impractical.

Perennial weeds such as milkweed and hemp dogbane may be a problem with no-till systems. Small-seeded, surface-germinating weeds, such as grasses, waterhemp, and nightshade, may also increase with reduced tillage systems. Some large-seeded broadleaf weeds, such as velvetleaf, cocklebur, and jimsonweed, are often less of a problem with no-till. With glyphosate now used on most fields of soybean where reduced tillage is practiced, some of these weed shifts have begun to change. Glyphosate-tolerant weeds are starting to appear, and we can expect this to alter weed management strategies.

Soil-applied herbicides may not give optimal performance under tillage systems that leave large amounts of crop residue and clods on the soil surface if the herbicides adsorb onto the crop residue.

Herbicide incorporation is impossible in no-till systems. Residual or postemergence herbicides are effective, and mechanical cultivation is usually not done.

Heavy-duty cultivators are available to cultivate with high amounts of surface residues and hard soil, but these are not widely used. High amounts of crop residues interfere with most attempts at mechanical weed control, leading to dependence on chemical control.

## Crop Yields

Tillage research is conducted at University of Illinois Agricultural Research and Demonstration Centers (see the map on the inside front cover) to evaluate crop yield responses to different tillage systems under a wide variety of soil and climatic conditions. Crop yields vary due more to weather conditions during the growing season than to the tillage system used. Corn and soybean yields are generally higher when the crops are rotated compared to either crop grown continuously. It is important with any tillage system that plant stands be adequate, weeds be controlled, soil compaction not be excessive, and adequate nutrients be available.

Data from recent Illinois studies show that, on average, tillage tends to increase yields slightly (**Table 10.4**). This was true at Monmouth for corn and soybean grown continuously or in rotation with each other or with wheat. At Perry, no-till produced yields as high as those with tillage for continuous corn, for corn rotated with soybean, and for soybean and wheat, but not for corn in the 3-year rotations. So responses to tillage are somewhat affected by crop and rotation and by soil and weather. Most yield differences favor tillage over no-till, but because no-till typically has lower cost, profitability may not be much different. No-till also reduces soil loss. On the negative side, getting good seed placement and good stands for a crop like wheat is more challenging with no-till, and there has been a tendency for soils under no-till to show more signs of increasing bulk density (more compaction.)

On well-drained to moderately well-drained, medium-textured soils, expected yields with all tillage systems are quite similar for rotated corn and soybeans, though there may be some exceptions. In previous research, yields of continuous corn were often found to be lower as tillage was reduced. There is less evidence for this in more recent

**Table 10.4.** Yields of corn, soybean, and wheat in a crop rotation and tillage study at two locations in western Illinois.

| Crop and rotation | Monmouth (bu/A) | | Perry (bu/A) | |
|---|---|---|---|---|
| | Tilled | No-till | Tilled | No-till |
| **Corn** | | | | |
| Continuous corn | 202 | 193 | 180 | 180 |
| Soybean–corn | 210 | 207 | 186 | 189 |
| Soybean–wheat–corn | 220 | 214 | 197 | 188 |
| Wheat–soybean–corn | 221 | 219 | 200 | 193 |
| **Soybean** | | | | |
| Continuous soybean | 69 | 68 | 45 | 44 |
| Corn–soybean | 72 | 70 | 46 | 46 |
| Wheat–corn–soybean | 75 | 72 | 46 | 45 |
| Corn–wheat–soybean | 76 | 72 | 43 | 40 |
| **Wheat** | | | | |
| Corn–soybean–wheat | 92 | 87 | 77 | 73 |
| Soybean–corn–wheat | 89 | 83 | 78 | 74 |

The study was established by the late 1990s, and these data are from three years, 2006–2008.

research, as shown in **Table 10.4**. The soils in that study are Clarksdale silt loam at Perry and Muscatune silt loam at Monmouth, both of which are moderately well drained and medium textured. On very well-drained, sandy soils, conservation tillage systems that retain surface residues reduce wind erosion and conserve moisture, typically producing high yields. Soils such as Cisne silt loams, which are very slowly permeable and poorly drained, have a clay pan that usually restricts root development regardless of tillage system. On such soils, yields are frequently higher with less tillage. This is partly due to the fact that they are mostly in southern Illinois, where soil temperature is less of an issue, and because surface residue helps to retain soil water, which is more often limiting in such soils.

The SOILS Project, an initiative funded by the Illinois Department of Agriculture, used demonstration sites across the state to compare mulch-till, strip-till, and no-till systems. In three years of the demonstrations (2000–2002), corn grain yields increased slightly as the amount of tillage increased, and there was a substantial difference in the retention of crop residue after planting (**Table 10.5**). In the first two years of this work, it was relatively warm and dry near the time of planting, and there was little difference among treatments. The third year was not as warm at planting, and the treatments with less tillage, especially no-till, did not do as well in some of the northern locations. Much of this was a result of stand reductions with no-till. As we have seen in other studies, cooler soils at planting due to less tillage often mean a slower start to the crop, and in some cases lower stands and lower yields. These are the major drawbacks to no-till systems. Strip-till usually produces a better seedbed and so seldom results in stand problems, as long as the planting conditions are uniform. As shown in **Figure 10.1**, soil temperatures with strip-till are closer to those in tilled soils than in no-till.

**Table 10.5.** Corn yields and residue cover under different tillage systems.

| Tillage system | Corn yield (bu/A) | Residue after planting (%) |
|---|---|---|
| **Mulch-till** | 164 | 19 |
| **Strip-till** | 161 | 52 |
| **No-till** | 158 | 63 |

Data, from 2000–2002, are averaged over 30 on-farm sites.

## Adaptability of No-Till to Specific Soils

Soil, climate, and crop rotation influence the success of no-till. In addition, success is influenced by pest control, fertility practices, and management experience of the farm operator. The decision to adopt no-till may be based on net return, potential for reduced soil erosion, or eligibility for government programs. Yield potential of crops grown with no-till is an important consideration.

Several states have classified soils into tillage management groups for corn and soybean production. Soil types are grouped according to unique soil properties and their influence on crop yield with no-till planting. Soil characteristics include drainage, texture, organic matter, and slope. A summary of the classification as might be applied to Illinois follows:

- *Equal yield.* In central and northern Illinois, when crops are rotated and when no-till is used on naturally well-drained soils or on slopes greater than 6%, no-till should provide yield potential equal to that of other systems for corn, soybeans, and wheat.
- *Equal or higher yield.* In southern Illinois, with crop rotation, well-drained soil, slope greater than 6%, or very low organic matter soil, no-till will often produce higher yields than other tillage systems, especially in years when there are dry periods during the season.
- *Higher yield.* In southern Illinois, on light (very low organic matter), somewhat poorly drained, and poorly drained silt loams (that are nearly level to gently sloping and overlie very slowly permeable fragipan-like soil layers that restrict plant rooting and water movement), no-till yield potential should be higher than with other tillage systems.
- *Lower yield.* On dark, poorly drained silty clay loams to clay soils with 0% to 2% slope, lower yields are typically expected with no-till compared to other tillage systems.

## Machinery and Labor Costs

Machinery-related costs include the expenses for owning and operating machinery and the labor to operate it. Many factors must be taken into account to estimate these costs for a farm and for various tillage systems.

Machinery costs include depreciation, interest, insurance, housing, repairs, fuel, and lubrication, as well as costs of labor to operate equipment. Programs are available to determine the optimal machinery set for various tillage systems and farm sizes. For the latest information on machinery costs, see the website www.farmdoc.illinois.edu/manage/machinery.

Total costs for machinery and labor per acre decrease as the amount of tillage is reduced and as farm size increases. For reduced tillage, fewer implements and field operations are used, and the necessary power units are sometimes smaller for a given farm size. If a reduced tillage system is used on only part of the land farmed, implements and tractors will need to be available for other portions, so savings may be smaller than indicated.

With reduced tillage systems, labor costs are less because some fall or spring tillage operations are less intensive or are eliminated. The labor saved in this way has value only if it reduces the cost of hired labor or if the saved labor time is directed into other productive activities, such as raising livestock, working off-farm, or farming more land.

While equipment and labor costs are typically lower when less tillage is done, whether it pays to convert to systems with less tillage depends on several factors. The type of soil and the location often influence the effect of tillage changes on yield. No-till systems, while they tend to lower costs and in some cases increase yields, often require more attention to soil conditions, and they may be more difficult to impose in fields with a wide range of soil types. No-till fields tend to have cooler and wetter soils than tilled fields, and while the common advice to "wait a few days extra" before starting to plant no-till fields is sound, it can also mean planting delays that reduce yields in some years. Strip-till might reduce this need to wait and so may be a solution for some producers in some fields. At the same time, few changes in tillage are "free"—most bring new challenges, and few solve all problems.

In general, while almost any tillage system can be made to "work" on almost any field, factors like soil variability, especially in conjunction with factors like a rapidly expanding farm operation, may mean that the drawbacks to no-till are greater than the benefits. No matter what tillage system is used, however, it is essential that everything possible be done to maintain soil productivity, by working to keep soil in the field and to manage the soil properly.

Using a drill or narrow-row planter for soybeans is an option for most tillage systems. However, owning a drill for soybeans and a planter for corn often increases the machinery inventory and costs for a corn–soybean farm. This is part of the reason why many producers have moved to split-row planters, using 30-inch rows for corn and 15-inch rows, formed by splitter units, for soybean. This allows the use of the wider planter for both crops and of row units for soybean seed placement, which often improves stands. The effects on machinery cost for the farm depend on farm size and the cost of planting equipment.

An extra cost for additional or more expensive pesticides may be associated with some conservation tillage systems. For example, a burndown herbicide may be needed with no-till and ridge tillage systems. These increases are usually more than offset by reduced machinery and labor costs with conservation tillage.

Costs for corn and soybean seeds are usually the same for different tillage systems. However, when soybeans are drilled or planted in narrow rows, the seeding rate is usually increased by 10% to 20% compared to planting in rows 15 or 30 inches apart.

In most cases the amounts of fertilizers and lime do not change with different tillage systems. However, the forms and application techniques may vary depending on the tillage system. For example, surface-applied urea works well if the field is tilled after application, but it does not work well in no-till, when the weather may stay dry after application and N losses may be high. Any differences in such costs should be considered when considering a change in tillage system. As another example, starter fertilizer for corn is often recommended with conservation tillage, especially with the no-till system, and planter attachments to apply starter fertilizer in a separate band represent an additional cost, both in equipment and in the time needed to supply the fertilizer at planting.