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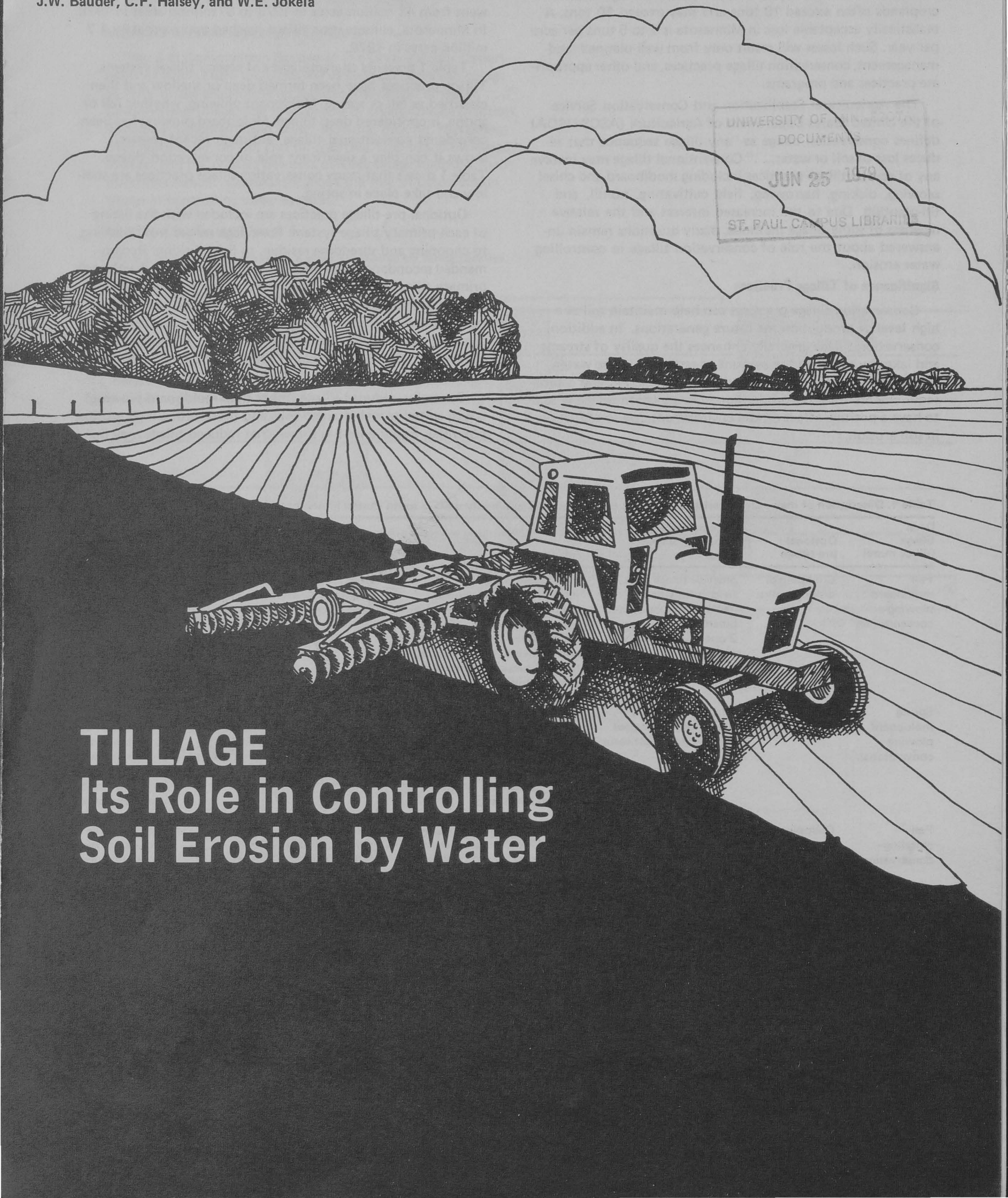

TILLAGE
Its Role in Controlling Soil Erosion by Water

Extension Folder 479—1979 errata sheet

substitute for second paragraph, page 2

The Soil Conservation Service of the United States Department of Agriculture (SCS-USDA) defines conservation tillage as "any tillage sequence that reduces loss of soil or water. . . ." Conservation tillage may involve any of several tillage practices including moldboard and chisel plowing, disking, harrowing, field cultivating, no-till, and till-planting. Due to the increased interest and the relative newness of some tillage methods, many questions remain unanswered about the role of conservation tillage in controlling water erosion.

substitute for figure 1, page 4

Figure 1. Soil loss and crop residue cover as affected by tillage practice.

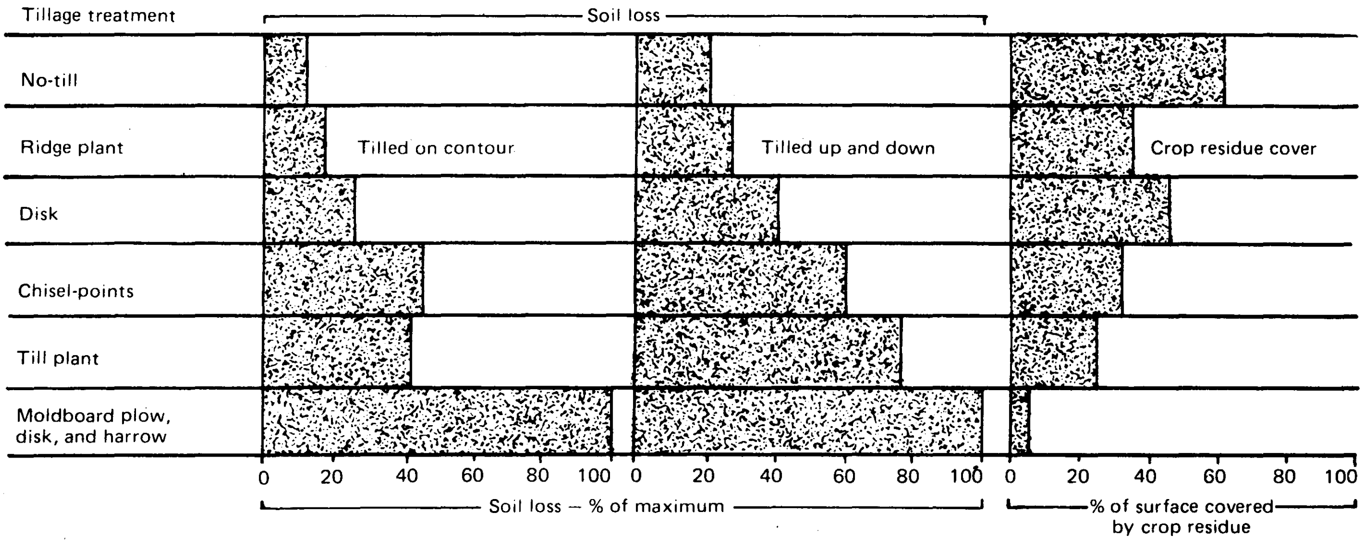

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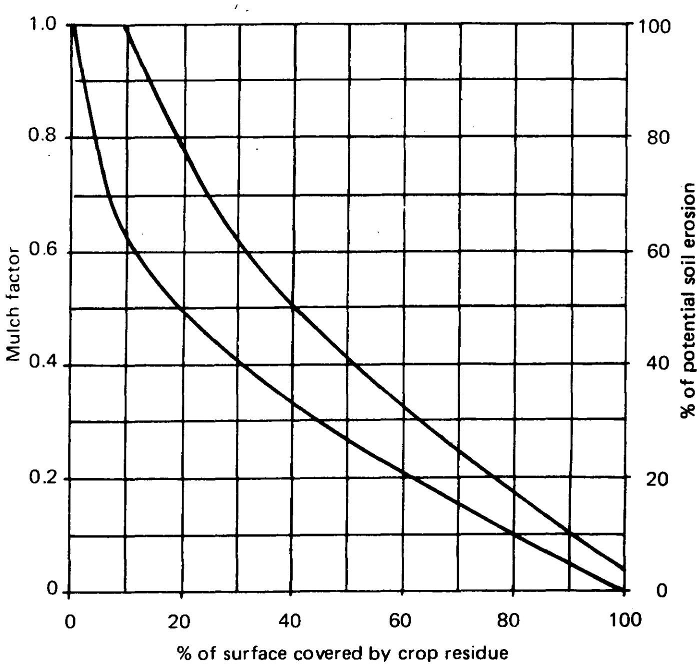
Figure 2. Mulch factor compared with percent of surface cover by crop residue.



Soil erosion by water is a process of nature. However, accelerated erosion is a destructive process that can and should be curtailed. Soil losses per acre, per year, from agricultural croplands often exceed 10 tons and may exceed 50 tons. A realistically acceptable loss in Minnesota is 1 to 5 tons per acre per year. Such losses will result only from well-planned land management, conservation tillage practices, and other appropriate practices and programs.

The Agricultural Stabilization and Conservation Service of the United States Department of Agriculture (ASCS-USDA) defines conservation tillage as "any tillage sequence that reduces loss of soil or water... ." Conventional tillage may involve any of several tillage practices including modlboard and chisel plowing, disking, harrowing, field cultivating, no-till, and till-planting. Due to the increased interest and the relative newness of some tillage methods, many questions remain unanswered about the role of conservation tillage in controlling water erosion.

Significance of Tillage Practices

Conservation tillage practices can help maintain soil at a high level of production for future generations. In addition, conservation tillage generally enhances the quality of streams and lakes by reducing the amount of sediment in the water. Conservation tillage also may reduce energy, labor, and capital requirements for crop production. Conservation tillage is said to have a positive effect on the environment due to reduction in soil erosion.

Although some conservation tillage practices are relatively new, conservation tillage is used widely in crop production. The increase in U.S. acres managed by conservation tillage practices went from 44 million acres in 1973 to 67 million acres in 1978. In Minnesota, conservation tillage reached approximately 4.7 million acres in 1978.

Table 1 presents characteristics of several tillage systems. Tillage practices have been termed deep or shallow and then classified as fall or spring. Moldboard plowing, whether fall or spring, is considered deep tillage. Moldboard plowing has been considered conventional tillage, although recent research shows it can play a significant role in conservation tillage. Table 1 shows that many conservation tillage practices are shallow and take place in spring.

Optional pre-tillage practices are included with the listing of each primary tillage system. Pre-tillage ranges from nothing, to chopping and shredding residue, to light disking. Recommended secondary tillage operations are also included with each primary tillage treatment. Secondary tillage is usually done to provide a smooth and uniform seedbed for good seed-soil contact. However, recent research indicates a favorable seedbed can result with little or no secondary tillage. The more obvious advantages and disadvantages of the several tillage systems are described here, with suitability ratings.

Generally, reduced tillage (other than moldboard plowing) is well suited to well-drained soils and those with a high erosion potential. Experience has shown that reduced tillage may be adapted to all soils. Farm managers should use judgment in selecting reduced tillage practices and consider wind and water erosion hazards, disease and insect problems, and timeliness of spring operations.

Table 1 illustrates the energy requirements of various tillage implements. Fuel costs per acre of tillage decrease three to five fold in changing from moldboard plowing to reduced tillage or no tillage. Yet, additional energy inputs, such as increased herbicides and pesticides, may be required with reduced tillage systems.

Soil is most apt to be lost where land is moldboard or chisel plowed in the fall and either no erosion control methods are used or additional secondary fall tillage smooths the soil surface and breaks down soil clods into more movable pieces (table 1). Erosion hazard increases when tillage goes up and down slopes rather than along the contour or across slopes. With less tillage comes less erosion, although the amount of water runoff may be increased with no-till. As tillage is reduced, however, the degree of coverage of the soil surface by crop residue is increased. Many studies have shown that maximum runoff may occur on no-till fields where crusting has occurred. Under these conditions, although runoff may be high, there may only be a small amount of soil actually eroded from a field.

Table 1 gives potential soil loss and percent of soil surface covered by corn residue. Soil loss (actual tons per acre) for any field and tillage practice varies considerably, depending on crop, slope, soil type, intensity and duration of rainfall, and

Table 1. Description of major characteristics of several tillage practices commonly used in south central Minnesota, following corn

Deep tillage (6" or more)	Optional pre-tillage	Recommended secondary-spring tillage	Advantages	Disadvantages	Suitability	Approximate energy requirements*	% Of soil surface covered by corn residue at planting	Average potential soil loss % of maximum**
Fall moldboard plowing—conventional.	Chopping or disking stalks.	Shallow tillage; disk, field cultivator or harrow. May be combined with planting; 2 operations usually maximum.	Good seedbed, soil-seed contact, insect and disease control. Allows for early spring operations. Promotes early surface drying. Mixes broadcast fertilizer and pesticides throughout plow layer. Buries crop residues and surface applied herbicides.	Greatest erosion potential—wind and water when followed by secondary tillage that leaves surface bare and smooth.	Poorly drained soils; those with excess moisture in spring. Level to nearly level. Soils where timeliness of spring operations is critical. Very fine textured soils with high incidence of disease, insects, weeds, or volunteer corn. Soils where excess residue buildup has occurred.	1.3 - 1.7 gal/A	0 - 10	100
Spring moldboard plowing—conventional.	Chopping or disking stalks.	Shallow secondary tillage may be needed. Disking, field cultivator, or harrow.	Less erosion hazard during winter. Good for well-drained soils, light soils. Mixes broadcast fertilizer and pesticides throughout plow layer. Buries crop residues and surface-applied herbicides.	Timeliness in spring-delayed operations under wet conditions. Cloddiness and poor soil-seed contact on fine-textured soils. Time consuming.	Well to excessively drained soils where timeliness of spring operations is not delayed by presence of excess surface moisture. Level to nearly level soils that are highly susceptible to winter wind erosion. Soils with high incidence of disease, insects, weeds, or volunteer corn, and where excess residue buildup has occurred.	1.3 - 1.7 gal/A	0 - 10	90 - 100
Fall chiseling—conservation.	Chopping or disking stalks or colter in front of chisel plow.	Similar to that for fall moldboard plowing. May use 2-3" points or 6-20" sweep shovels on 12" centers.	Good to intermediate erosion control—soil surface remains cloddy over winter. Allows for early spring operations. Inputs reduced.	Intermediate disease and insect control. Rough seedbed—may require additional tillage. Inadequate broadcast fertilizer incorporation if continuously used.	Poor to moderately poorly drained soils; those with excess moisture in the spring. Nearly level to gently sloping or undulating soils. Cross slope or contour plowing where erosion potential exists. Medium- to fine-textured upland soils. Recommended on soils that require fall tillage for one reason or another but are susceptible to wind and water erosion.	0.5 - 1.0 gal/A	30 - 60	20 - 60
Spring chiseling—conservation.	Chopping or disking stalks in fall or colters in front of chisel plow.	Similar to that for spring moldboard plowing. May use 2-3" points or 6-12" sweep shovels on 12" centers.	Well suited to well-drained soils. Reduced inputs required. Less erosion hazard during winter.	Timeliness in spring-delayed operations. Not suited to poorly and somewhat poorly drained soils because of cloddiness problems, rough seedbed and poor soil-seed contact. Inadequate broadcast fertilizer incorporation if continuously used.	Moderately well to excessively drained soils; medium- to coarse-textured soils. Nearly level to gently sloping and undulating soils. Cross-slope or contour plowing where spring and summer erosion potential exists. Recommended on soils that require little spring tillage, but some residue needs to be incorporated.	0.5 - 1.0 gal/A	30 - 60	20 - 60

***Medium-textured soils**

****Assumed maximum occurs where fall moldboard plow, disk, and harrow practiced.**

management and conservation practices in use. However, table 1 reflects the relative amount of soil loss for various tillage practices at different locations.

The amount of residue remaining on the soil surface after tillage has a lot to do with the possibility of soil loss. Figure 1 shows the relationship between tillage practices and soil loss. Actual loss from certain tillage practices and rainfall conditions was compared with soil loss from conventional tillage plots exposed to the same rainfall conditions. In these studies, the moldboard plow represented 100 percent of maximum soil loss, or the most extreme condition. Research has repeatedly demonstrated that maximum soil loss occurs when moldboard plowing is practiced, followed by secondary tillage, without control. Often, secondary tillage practices leave the soil surface in a very erodible condition. The greatest erosion hazard for row crops occurs during the first few weeks after planting while the soil surface is unprotected by living plant cover or old crop residue. Plow-plant tillage sequences and wheel-track planting, when combined with early erosion control tillage practices, have been successfully used to minimize erosion where moldboard plowing is required.

Figure 1. Soil loss and crop residue cover as affected by tillage practice.

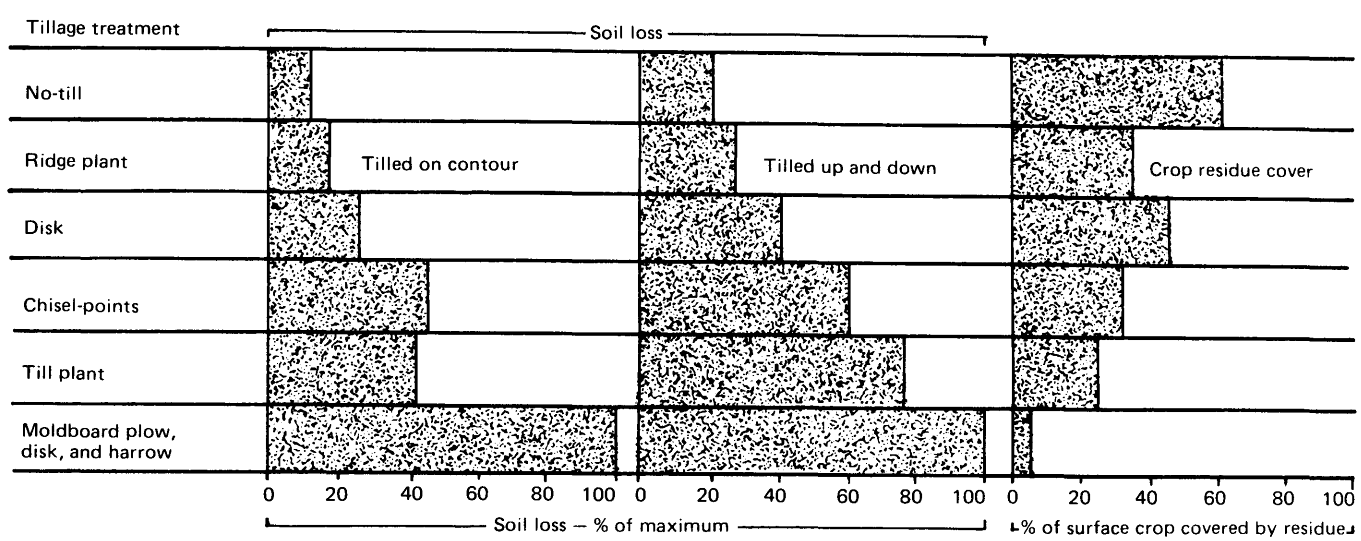


Table 1. Characteristics of tillage practices (Continued)

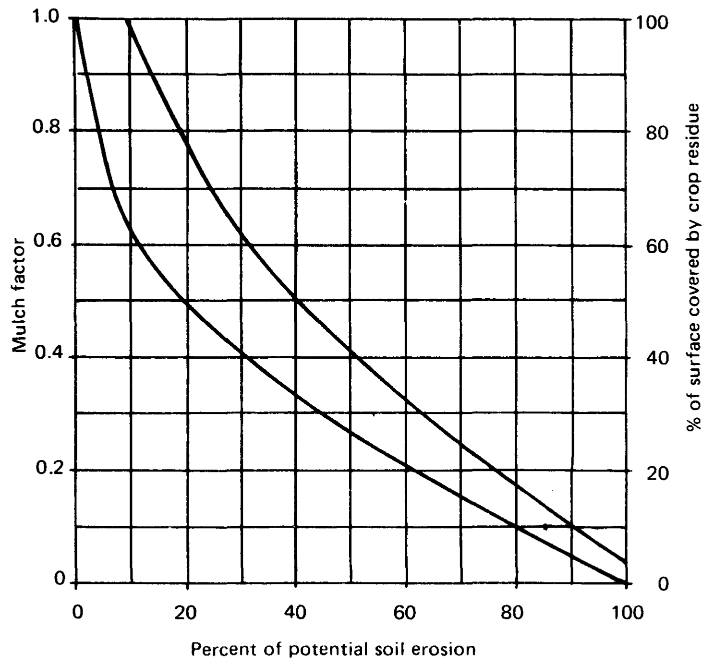
Shallow tillage (6" or less)	Optional pre-tillage	Recommended secondary-spring tillage	Advantages	Disadvantages	Suitability	Approximate energy requirements*	% Of soil surface covered by corn residue at planting	Average potential soil loss % of maximum**
Disking, fall and spring—conservation.	1 fall disking.	1-2 diskings or field cultivator. Last operation combined with planting. Tandem or double disking.	Good moisture conservation. Minimum erosion potential.	Slow soil warming in spring may result. Inadequate broadcast fertilizer incorporation if continuously used.	Applies to most soils where some residue incorporation is desired but reduced tillage is desired. Good method of pesticide and shallow fertilizer incorporation. Suitable to poorly drained soils requiring fall residue incorporation and some minimal seedbed smoothing in spring. Level to nearly level soils and cross-slope or contour disking where winter erosion potential exists.	0.8 - 1.2 gal/A	30 - 60	20 - 60
Disking, spring only—conservation.	No fall operation.		Good method when wet weather delays spring tillage. Excellent erosion control. Superior to spring plowing or chiseling for smooth seedbed on moderately fine fine-textured soils.	Slow soil warming in spring. Inadequate broadcast fertilizer incorporation if continuously used.	Well- to excessively well-drained soils and some moderately well-drained and somewhat poorly drained soils where minimal spring seedbed preparation is needed. Good for winter erosion control. Especially well suited to soils following soybeans in preparation for corn. Nearly level to gently sloping soils. Moderately sloping if cross-slope operations are used.	0.4 - 0.6 gal/A	45 - 60	20 - 45
Till-planting—conservation.	Chop stalks form ridge during last cultivation of previous year.	None—planting in previous year's ridges. Previous year's ridges made with a cultivator or disk-hiller.	Residues concentrated between rows. Excellent erosion control on contour and reduced energy requirements.	Slow soil warming in spring. Disease, insect, and weed control may be required. Little broadcast fertilizer incorporation. Difficult to maintain.	Suited to most soils, ranging from poorly drained to excessively well drained. Well suited to poorly drained soils (where fall tillage is not possible) and soils susceptible to water and wind erosion. Well suited to continuous corn, corn following sod rotations. Acceptable on moderately sloping, rolling soils with cross-slope or contour planting.	0.3 - 0.5 gal/A	15 - 30	40 - 85
Planting on ridges.	Ridging with large opposing disks after harvesting. May disk before ridging.	None—planting in previous year's ridges, maintained by row cultivation.	Good erosion control method. Provides for good seedbed, drainage and early soil warming. Reduced energy requirements.	Increased disease, insect and weed control may be required. Seedbed may be rough. Little broadcast fertilizer incorporation. Difficult to keep planter on ridges on turns.	Best suited to slowly warming and poorly drained soils where tillage is not recommended due to erosion hazards. Allows for good early seedbed drainage and warming. Well suited to situations where excessive trash has accumulated on surface, but tillage is not needed: nearly level to moderately sloping soils.	0.3 - 0.5 gal/A	35	35 - 55
Zero-till slot plant, colter.	Chopping, shredding, or disking in fall.	Strips prepared with non-powered fluted colters, harrow chisel points, angled disks, or narrow rotary tillers.	Excellent erosion control. Reduced soil disturbance and reduced energy requirements.	Excessive trash on surface; additional disease, insect, and weed control may be required. Soil temperatures may be low. Little broadcast fertilizer incorporation.	Best suited to soils susceptible to excessive erosion and/or excessive surface moisture in fall or spring. Applicable to situations where moisture conservation is required and timeliness in spring operations does not allow for other tillage operations. Works well following soybeans, in corn-soybean rotation, where plowing follows corn.	0.25 - 0.35 gal/A	55 - 75	15 - 35

***Medium-textured soils**
****Assumed maximum occurs where fall moldboard plow, disk, and harrow practiced.**

All the reduced tillage methods of figure 1 resulted in less erosion than conventional plowing. The least erosion occurred with no-till, about 5 to 20 percent of that conventionally tilled. Ridge-planting was slightly less effective. Chiseling, disking, and till-planting reduced erosion to 20 to 40 percent of the conventional tillage amount when contoured, but these are only half as effective when tillage is up and down hill. This is particularly evident with till-planting. On plots till-planted, up and down slope runoff tends to be channeled down the bare crop-row strip. This can result in considerable rill erosion though soil loss is still less than with conventional tillage. This same reaction occurs to a lesser extent with disking and chiseling. No-till effectiveness is less sensitive to row direction.

Reduced tillage and wise management can reduce water erosion. For example, suppose that erosion from a moldboard plowed field previously in corn with 5 percent slope is 5 tons per acre when tilled parallel to the contours and 10 tons per acre when tilled up and down slope. A change to disking as primary tillage would reduce soil loss by 80 percent to about one ton per acre (or 20 percent of 5 tons) if contoured and about 4 tons per acre (40 percent of 10 tons) if tilled up and down slope and the expected percent surface cover is achieved. However, repeated disking would both decrease surface cover and increase the erosion hazard by burying residue and leaving the soil with a smooth and fine-grained surface.

Figure 2. Mulch factor compared with percent of surface cover by crop residue.



Importance of Crop Residue Cover and Surface Roughness

The amount of surface covered by crop residue and the surface roughness during the critical erosion hazard period are two of the most important factors accounting for the amount of soil lost by erosion. Surface roughness is important up to the point when runoff starts. Tillage can be used to control both factors. Residue acts as an umbrella, reducing the pounding of raindrops, and as a barrier, slowing runoff. So residue uniformly spread on the soil surface reduces the effectiveness of rainfall at breaking down soil clods and transporting soil. In addition, residue reduces surface sealing and crusting, and the soil is able to take in more water during rainfall events. However, if sealing of the soil surface does occur, any crop residue on the soil surface is relatively ineffective at reducing runoff and runoff is the same as if no residue were present. Under these conditions runoff from smooth conservation tilled fields may be greater than from rough, conventional tilled fields. Where surface sealing occurs, rough surfaces created by conventional tillage trap more surface rainfall so runoff is reduced.

Figure 1 also shows the relationship between tillage practice, soil erosion and percent of surface covered by residue. The wide range of residue cover (table 1) reflects variability in collecting data for crops, soils, and slopes. Harvest and post harvest operations, including residue spreading and chopping operations, affect the amount of soil surface covered by residue. Generally the extent of residue coverage varies from the highest residue cover with no-till to the lowest with conventional plowing. Figure 2 indicates the soil loss increases as the percent of surface covered by residue decreases.

Researchers have extensively studied the relationship between soil loss and percent of surface covered by residue, and developed a mulch factor: the ratio of soil loss with a given mulch rate to the corresponding soil loss with no mulch (figure 2). The no-mulch condition is representative of conventional tillage. The mulch factor is a function of tillage practice, since tillage practice affects the extent of surface covered by residue. The mulch factor in figure 2 gives a range of conditions for a number of field crops.

Figure 2 provides a relatively easy method of assessing the impact of a conservation tillage practice on soil erosion. For example, 50 percent surface coverage by residue reduces soil loss to about 32 percent (mulch factor = 0.32) of the loss with no mulch; 80 percent cover reduces soil loss to about 13 percent (mulch factor = 0.13) of the loss with no mulch. Even with only a 20 percent wheat straw cover, soil losses are 60 percent (mulch factor = 0.60) of losses with no mulch. Using table 1 and figure 2 information, it is possible to estimate the expected reduction in erosion by switching from complete to reduced residue incorporation—a tillage practice which left some surface residue. For example, with till planting, 15 to 30 percent of the surface would be covered with residue and the soil loss would be only 50 to 70 percent of the loss from conventionally tilled land. With no-till planting, 55 to 75 percent of the surface would be covered with residue and the soil loss would be only 15 to 35 percent of the loss from conventionally tilled land. The mulch factor (figure 2) applies mainly to uniformly distributed residue and represents a range of conditions studied. Maximum residue accumulations usually occur following corn or small grains. In addition, corn and small grain residues decompose more slowly than other crop residues. As a result, the other crop residues are less effective at reducing erosion. Although the mulch factor has not been tested for all soils and all crop residues, it is true that the more surface protected by mulch, the less soil loss.

The erosion-reducing benefits of mulch residue and conservation tillage are most important when a growing crop is not present to provide a canopy to protect the soil from raindrop impact. The critical erosion hazard period is between April and June in much of Minnesota. Conservation tillage leaves some residue during the entire year. Disking, chiseling, and moldboard plowing are normally done in the fall or early spring. Till-planting leaves the residue cover until time of plantint. No-till leaves cover throughout the season (except for the narrow colter path).

Studies conducted on Barnes loam at Morris and Nicollet clay loam at Lamberton in western Minnesota show that the amount of surface roughness created by various tillage practices significantly affects soil erosion. Freshly tilled, rough, porous surfaces soak up more water than smooth surfaces, so tillage reduced runoff. However, where primary tillage alone was compared with primary tillage followed by secondary tillage, runoff occurred sooner as a result of secondary tillage. Although primary tillage practices such as moldboard and chisel plowing create ideal rough surfaces to soak up rainfall, secondary tillage which breaks down the soil clods and smooths the soil surface increases the erosion potential. Where fall or spring plowing is required, the potential erosion hazard can be reduced by leaving the soil surface rough following primary tillage, minimizing secondary tillage which smooths the soil surface, and delaying secondary tillage as much as possible.

Repeated secondary tillage operations also have an effect. The first tillage operation is usually the most effective at altering the distribution of residue. Secondary tillage operations are often used to smooth and pack the soil (as a seedbed). At other times, secondary tillage is used to incorporate, mix, and bury additional crop residues. In some instances secondary tillage operations, performed at right angles to the first operation, may cause no change or even a slight increase in the amount of residue on the surface. Spring disking may be more effective than fall disking in covering residue because residue partially decomposes over winter.

Some Precautions—Possible Problems

There are many erosion control benefits with conservation tillage. However, conservation tillage may cause or magnify other problems. Conservation tillage (especially no-till) usually requires a higher level of management and care in selection and use of equipment. Heavy mulch residue causes lower spring soil temperatures which can delay planting and germination and reduce yields on poorly drained soils. Weed control can be a major problem and requires careful use of effective herbicides at various rates. Crop residues may intercept and keep pesticides from reaching the soil. The presence of crop residues and a rougher seedbed calls for more careful selection, adjustment, and maintenance of planting equipment. Rotation of tillage and cropping sequences can be used to reduce weeds. On some soils, particularly ones tending to crust readily, smooth, no-till surfaces have often produced more runoff and lower infiltration of rainfall than rough, chisel or disked surfaces. Thus no-till may not be as effective as chisel plowing in conserving water on sloping soils which crust.

Reduced Tillage—A Soil Conserving Alternative

Reduced tillage systems are effective in minimizing soil erosion and are well adapted to today's large-scale, row-crop, intensive production methods. For many soils and crop situations, reduced tillage helps control soil erosion without sacrificing crop yields. Successful reduced tillage depends on a keen awareness and implementation of alternative management decisions. Reduced tillage is based on diversity, flexibility, and the ability of land managers to recognize the soil and crop needs on a year-to-year basis.

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