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# CONSERVATION TILLAGE FOR EROSION CONTROL

Of the 353 million acres of harvested cropland in the United States, 27.4 percent was in conservation tillage in 1981. The percentage of acres in no-till was 2.5.

These figures are encouraging to anyone who looks to conservation tillage as a means of reducing soil erosion. And there is cause for encouragement. While the shift to conservation tillage no doubt will be gradual, the farmer who buys a chisel plow for his soybean land is more likely to use it on his other land than the farmer who never uses a chisel plow.

Questions remain, however, about the effectiveness of conservation tillage systems in controlling soil erosion. How much does conservation tillage reduce erosion? On what slopes, in what rainfall areas, and with which soil characteristics will conservation tillage reduce soil erosion to acceptable levels?

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What follows is a region-by-region assessment of conservation tillage's effectiveness in controlling soil loss.

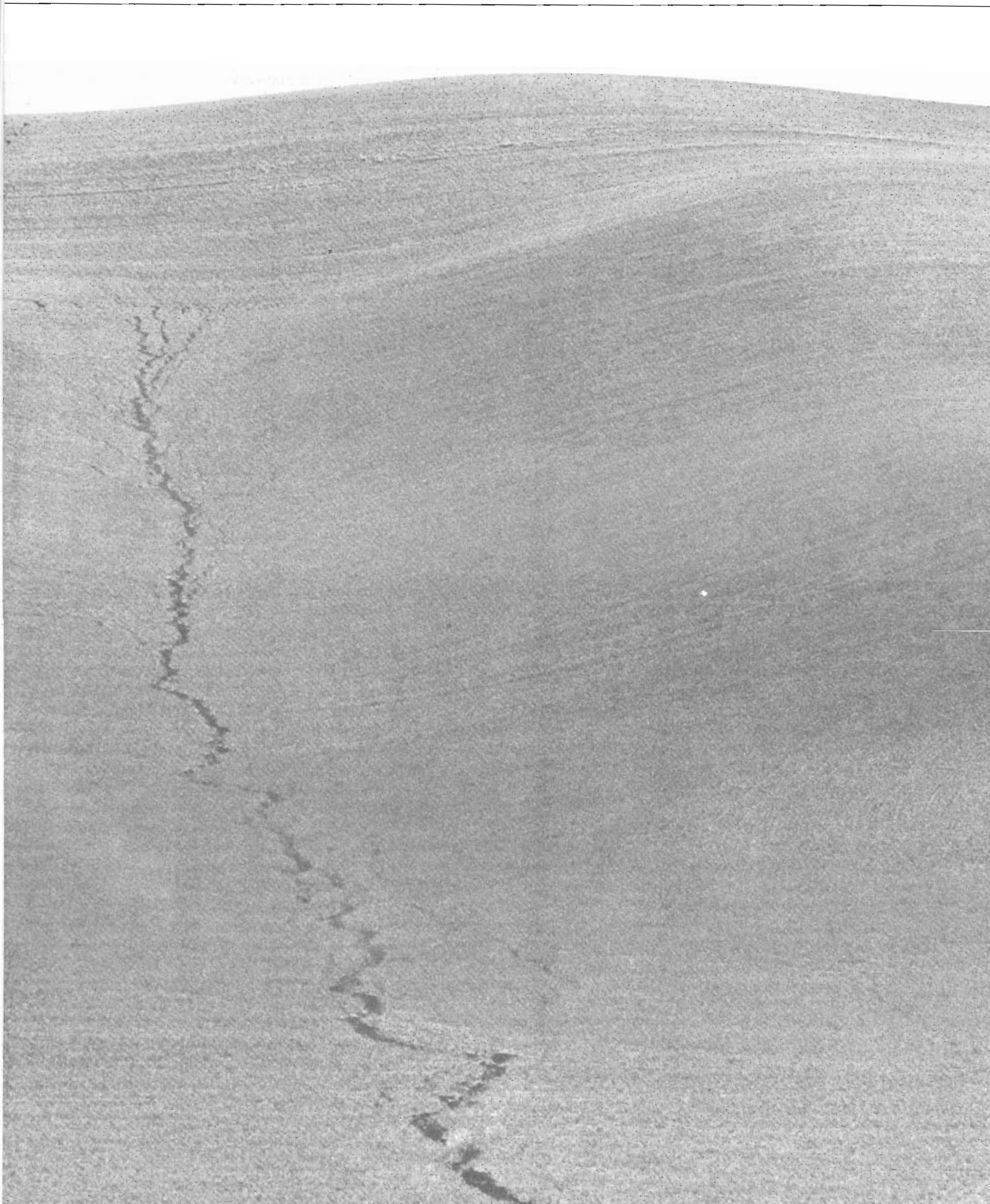
## Corn Belt

In 1981, conservation tillage was used on one-third of the harvested cropland in the Corn Belt. The percentage of cropland in no-till was near the national figure of 2.5 percent. The remainder was mainly chisel-plowed or disked with a heavy, primary-tillage disk (2).

The effectiveness of any tillage method for controlling erosion ultimately depends upon the amount of crop residue left on the soil surface (6). With a chisel plow, for example, the amount of residue left depends upon the type of chisel used and the type of crop residue. Following corn, the residue left may vary from 10 to 20 percent with 4-inch twisted shanks to 50 percent or more with narrow points. Much less cover is left after chiselling soybean ground (Table 1).

Regardless of how much residue is left after primary tillage, what is more important in the Corn Belt is the amount remaining after planting. The first 60 days after planting normally is the period of the most rain and the most intense rain.

The percentage of cover left on chiselled ground after planting depends upon how many secondary tillage operations are carried out in the process of smoothing the field surface and incorporating herbicide. Because tillage with 4-inch twisted shanks leaves little residue, there is little difference in erosion control after planting be-



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tween this method and use of the moldboard plow, which leaves less than 10 percent of the residue from cornstalks on the surface. Any chiselling on the contour is much more effective in controlling erosion than chiselling up-and-down slope.

Following primary tillage with straight chisel points or with sweeps, each secondary tillage operation with a disk in the spring cuts the percentage of cover in half (*19*). With 50 percent cover left in the fall, therefore, a spring disking would leave about 25 percent and a subsequent disking to incorporate herbicide would reduce the residue cover to 10 or 12 percent. This percentage of cover is not very effective in reducing erosion.

Using a field cultivator for secondary tillage leaves more residue than using a disk. This can be important from the standpoint of erosion control. For each 10 percent increase in groundcover, erosion is reduced about 40 percent (*6*). The greatest reduction in erosion comes between 0 and 20 percent cover. A 65 percent reduction in soil loss was achieved with 20 percent erosion cover.

Other research produced a 20 percent reduction in erosion for each 10 percent increase in groundcover (*23*). A 36 percent reduction in erosion was achieved with 20 percent cover. With 30 percent cover, the reduction was 48 percent.

One problem with straight-row farming are the up-and-down-hill tillage marks, especially from chisels or ammonia applicator knives. This effect is evident in the high erosion rates for chiselling (Table 1). Some manufacturers of chisel plows are aware of the effect up-and-down-hill chisel marks have on runoff and erosion. One has attached various smoothing devices behind the chisel plow to erase these marks and leave the residue better distributed. This also has the effect of smoothing the chiselled ground and reducing or eliminating the need for secondary tillage before planting with a fluted coulter. On the other hand, smoothing reduces the roughness effect, which influences runoff and erosion.

Research and development are needed to make chisel plowing a more effective conservation tillage practice. Now, much chisel plowing in the Corn Belt has little effect on soil erosion because of the small amount of residue left after planting. This is particularly serious in chiselled soybean stubble.

Ridge-till, strip-till, and disk-tillage all effectively reduce soil losses, depending upon how much residue remains on the soil surface. With all of these systems, however, it is important to avoid planting up-and-down hill if possible. Their erosion control effectiveness drops greatly when this is done. Ridge-tilling, when done correctly, allows runoff to move down the ridges and through the residue accumulated in the furrow bottoms. The result is very effective soil erosion control.

The correlation between percentage of residue cover and soil loss applies equally to no-till, ridge-till, strip-till, disk-till and all other systems. No-till is generally the most effective means of erosion control, mainly because more residue is left. The longer a field remains in no-till, the more effective erosion control becomes (*22*). Why? Because as the surface structure of the soil improves, infiltration improves. Also, detachment becomes more difficult because soil aggregates become larger and more stable. With no-till on moderate slopes (2.5%), row direction affects soil loss

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**West Tennessee cropland after a brief storm: No-till techniques hold promise for reducing rampant erosion in the Southeast.**

**Table 1. Crop and tillage effects on surface cover and soil loss, Morley clay loam, 4 percent slope (12).**

| Tillage | Percent Cover | | Soil Loss (t/ha) After | |
|---|---|---|---|---|
| | Soybeans | Corn | Soybeans | Corn |
| No-till | 26 | 69 | 13.4 | 2.4 |
| Chisel (up-and-down slope) | 12 | 25 | 30.3 | 15.0 |
| Plow | 1 | 7 | 40.0 | 21.8 |

**Table 2. Effects of soybean tillage and cropping systems on soil loss from a 63-millimeter rainfall at Milan, Tennessee, on June 11, 1981.***

| Tillage and Cropping System | Soil Loss (t/ha) |
|---|---|
| Conventional tillage, single-cropped soybeans, no winter cover | 62 |
| Conventional tillage, double-cropped wheat-soybeans | 0.3 |
| Disk tillage, single-cropped soybeans, no winter cover | 84 |
| No-tillage, single-cropped soybeans | 0.8 |
| No-tillage, double-cropped wheat-soybeans | 0.3 |

*Source: Personal communication with Shelton, Tompkins, and Tyler.

little. Up-and-down hill planting is nearly as effective as contouring. On slopes greater than 10 percent, the coulter slot can erode, especially after a soybean crop.

Soybeans in a corn-soybean rotation greatly reduce the effectiveness of no-till in controlling erosion (Table 1). Little residue remains following soybeans, and what residue there is breaks down rapidly in comparison with corn or wheat residue. For example, on slopes 300 feet long, a corn-soybean rotation effectively controls erosion on slopes up to 4 percent in the western Corn Belt. With continuous corn, no-till will protect slopes up to 6 percent under similar conditions.

Cover crops, such as legumes, certain grasses, and wheat or rye seeded into the senescing soybean crop, show promise for helping to control erosion following soybeans. The cover crop is killed with a contact herbicide in the spring and planting is done into the soybean and cover crop residue.

What is the status of conservation tillage in the Corn Belt? Chiselled corn residue is much more common now than a few years ago. Chiselled bean residue is widely accepted. Use of no-till, or a shallow pass with a field cultivator, for corn following soybeans is gaining acceptance rapidly. There is great interest in till-planting on ridges. It remains to be seen how many will actually accept this practice.

Interest in conservation tillage is the result of an economic situation that demands a reduction in costs. Research and farmer experience have shown the systems to be workable. Better equipment and chemicals are available, and equipment is available on loan through conservation districts, the Extension Service, and industry. There also is greater awareness of erosion problems and the fact that conservation tillage can solve them.

Most discouraging about the shift to nonmoldboard plow tillage systems is the small amount of crop residue left after planting, especially with chisel plow systems.

## Southeast

Use of fluted coulters for planting row crops in cool-season grass sods emerged during the late 1960s in the upper South. Little data for fluted-coulter, sod-base crops relate to soil erosion (*1*, *5*). What research has been done suggests that soil loss is not a hazard with this conservation tillage system.

In the early 1970s, use of fluted coulters in small grain residue began. Much of the fluted-coulter research in both cool-season sods and small grain residue was reviewed in 1977 (*17*) and again in 1980 (*16*).

Today, use of smooth, ripple (serrated), and fluted coulters remains a problem in heavy small grain residue because of the implements' poor cutting action. Poor seed germination and seedling emergence are associated with this problem. Many researchers and farmers now use a combination of these coulters in tandem to solve the straw-cutting problem.

Research relating the use of fluted coulters with soil erosion remains limited in the Southeast (*7*, *8*, *13*, *14*). Flume-measured sediment was reduced 99 percent by using continuous fluted-coulter procedures for both small grain and grain sorghum production on a Piedmont soil (*8*). Similar success with respect to erosion control was obtained in rainulator studies with soybeans following wheat, but runoff remained nearly constant at 57 percent (*7*).

Much higher watershed (no-till/double-crop) runoff and sediment transport was reported on loess silty clay loam soils in northern Mississippi (*14*). Runoff and soil losses declined about 21 percent and 86 percent, respectively, when no-till (fluted coulters) rather than conventionally tilled soybeans were used. C-factors experimentally determined for these conservation tillage systems were lower than those reported in Agriculture Handbook No. 537 (*13*, *23*).

Conservation tillage using fluted coulters has not been successful on southeastern soils where shallow subsurface or surface root-restrictive layers exist. Subsurface restrictive zones have been attributed, in part, to disk harrows and surface compaction by cattle grazing small grain in the winter and spring months.

Another conservation tillage system, the coulter in-row chisel/subsoil system, performs well under these conditions, however (*10*, *21*). This tillage innovation controls soil erosion and runoff on slopes up to 7 percent in the southern Piedmont (*11*, *21*). Runoff has declined to about 3 percent annually when this tillage procedure is used to plant soybeans in wheat residue (*11*). In dry and wet rainulator runs, runoff dropped to 4 percent and 37 percent, respectively, with the same cropping system on 6 percent slopes with up-and-down-hill rows (*9*).

Narrow-row smooth and serrated coulters are currently used in the Southeast to plant rye and clover seed through soybean or grain sorghum residue and in dormant warm-season grass sods in the fall. There is no soil erosion research in progress on these systems. Few attempts have been made in Kentucky and Tennessee to measure the effects of tillage and cropping systems on soil loss. Some erosion experiments are underway in both states, but data from them are preliminary.

One obvious effect though is evident from tests at the Milan Experiment Station in West Tennessee (*18*). Soil losses are a function of vegetative cover (Table 2). The

**Table 3. Effect of tillage on runoff and soil loss resulting from a 31-millimeter rainfall on corn watersheds in Clark County, Kentucky, November 25, 1982.***

| Tillage System† | Runoff (mm) | Soil Loss (t/ha) |
|---|---|---|
| Conventional tillage | 6.0 | 2.3 |
| Chisel plow and disk | 2.7 | 0.3 |
| Disk | 0.1 | trace |
| No-tillage | 0 | 0 |

*Source: Personal communication with Aswad, Bitzer, and Blevins.
†Watershed slope, 12 percent.

effect of no-till in controlling soil erosion is also apparent by comparing soil loss for single-cropped soybeans using conventional tillage [62 metric tons per hectare (27.7 tons/acre)] and single-cropped soybeans under no-till [0.8 metric tons per hectare (0.36 tons/acre)].

In an erosion study underway in Clark County, Kentucky, runoff and soil loss are being compared for corn grown under no-till, conventional tillage, chisel plowing followed by disking, and disking alone. The effectiveness of no-till in controlling soil loss was documented by a rainfall of 31 millimeters (1.2 inches) on November 25, 1982 (Table 3). Residue left on the soil surface with no-till and conventional tillage was 4.9 and 0.7 metric tons per hectare (2.2 and 0.3 tons/acre), respectively.

## Central and Northern Plains

Soil erosion in the Central and Northern Great Plains is generally caused by wind. The wind velocity, surface soil water content, soil cloddiness, surface roughness, field length in the direction of the wind, and vegetative cover on the soil all determine whether soil erosion occurs. Vegetative cover, field length, and soil cloddiness are the factors most easily manipulated by man.

Wheat is grown on more hectares in the Central and Northern Great Plains than any other crop, and wheat residue is an excellent means by which to reduce wind erosion. When wheat straw mulch on the soil surface exceeds 1,100 kilograms per hectare (980 pounds/acre), soil loss averages 2 metric tons per hectare (.9 ton/acre) compared to 32 metric tons per hectare (14.3 tons/acre) on bare soil (*25*).

Minimum tillage and no-till fallow practices are recent introductions in the Great Plains. These practices increase the quantity of residue on the soil surface (Table 4), which effectively protects the surface from wind erosion. The quantity of undecomposed wheat straw in the surface 7.6 centimeters of soil is also influenced by the method of fallow tillage. The quantity of residue remaining relates inversely to the intensity of fallow tillage.

The formation and stability of nonerodible soil aggregates depends upon the quantity of wheat straw residue on the soil surface in conventional stubble mulch tillage systems (*20*). The percentage of nonerodible aggregates for minimum tillage and no-till practices is significantly higher than for conventional stubble mulch tillage (Table 5). There also is correlation between the percentage of nonerodible aggregates and the quantity of wheat straw residue on the soil surface. The percentage of nonerodible aggregates relates to the amount of residue in the upper 7.6 centimeters of soil as well, but not to the extent that it does to residue on the soil surface.

The relative effectiveness of residue or nonerodible aggregates for wind erosion control was calculated with the wind erosion equation in a recent test (*24*). The increase in nonerodible soil aggregates and crop residue obtained with minimum tillage and no-till over that obtained with conventional stubble mulch tillage were compared while all other terms in the equation remained constant. Increasing the nonerodible aggregates 3.9 percent with minimum tillage reduced potential erosion 22.2 percent in comparison with conventional tillage. With no-till, the additional increase in nonerodible aggregates of 1.3 percent over the minimum tillage treatment reduced erosion potential an additional 5.6 percent. The 750-kilogram-per-hectare (670 pounds/acre) increase in residue on the soil surface with minimum tillage reduced the erosion potential 36 percent compared with conventional stubble mulch tillage (Table 4). The 1,000-kilogram-per-hectare (892 pounds/acre) increase in residue with no-till reduced erosion potential 45 percent compared with conventional tillage. The increase in residue amounts with minimum tillage and no-till were about twice as effective in reducing the wind erosion hazard as the increase in nonerodible aggregates.

Soil erosion by water is not considered a major problem in the Central and Northern Great Plains, but average annual soil loss is 1.3 metric tons per hectare (.7 ton/acre) with mechanical stubble mulch tillage on 5.4 percent slopes (*15*). Use of no-till fallow practices will reduce soil loss 95 percent, however (*3*).

During the normal fallow period in a wheat-fallow rotation in the Central and Northern Great Plains, soil water storage averages 31 percent for conventional stubble mulch tillage (*4*). The quantity of water stored relates directly to the quantity of residue on the soil surface at the start of fallow. The tillage tool used for weed control during fallow also influences water storage during the fallow period (Table 6).

Minimum tillage and no-till fallow practices increase fallow water storage efficiencies 40 percent and 49 percent, respectively. These increases are the result of the larger quantities of residue on the soil surface; the lack of disturbance by tillage, which promotes soil water loss; the fact that herbicides kill the weeds in their early seedling stage, which minimizes water use by the weeds; and the decomposing residue on the soil surface, which provides a means for ready acceptance of rain water, but becomes a barrier to water loss from the soil surface by evaporation.

In short, minimum tillage and no-till systems of fallow for winter wheat production in the Great Plains are superior to conventional mechanical stubble mulch tillage for minimizing the wind erosion hazard and for reducing soil loss by water erosion. These practices also enhance water storage (by as much as 18 percent).

## Southern Plains

Tillage systems used in the Southern Great Plains vary depending upon crop, soil, water management, and potential erosion. In most areas, tillage is used to prepare a seedbed, control weeds,

**Table 4. Wheat straw residue at the end of fallow in relation to fallow tillage practice.**

| | Residue Amount (kg/ha) | | |
|---|---|---|---|
| *Tillage Practice* | *On Soil Surface* | *In Upper 7.5 Centimeters of Soil* | *Total* |
| Conventional mechanical tillage | 1,050a* | 3,160 a | 4,210 |
| Minimum tillage | 1,800 b | 4,800 b | 5,680 |
| No-tillage | 2,050 b | 4,570 c | 6,620 |

*Values within columns followed by the same letter are not significantly different at the 95 percent level.

**Table 5. Percentage of soil aggregate size classifications in relation to fallow tillage practice.**

| Tillage | Aggregate Size Classification (mm) | | | | | |
|---|---|---|---|---|---|---|
| *Practice* | *<.84* | *.85-6.4* | *6.5-12.6* | *12.7-38* | *>38* | *Nonerodible* |
| Conventional | 35.9b* | 21.4a | 11.2a | 20.3a | 11.2a | 64.1a |
| Minimum | 31.9a | 20.5a | 11.2a | 21.8a | 14.6b | 68.1b |
| No-tillage | 30.6a | 20.0a | 11.2a | 23.9b | 14.3b | 69.4b |

*Values within columns followed by the same letter are not significantly different at the 95 percent level.

Soil Conservation Service-F. Dwain Phillips

**In the Southern Great Plains, tillage may be needed to mitigate wind erosion damage, such as occurred on this Oklahoma wheat field.**

improve water intake, and control erosion. The particular system depends upon whether the crop is drilled in wider rows, has high or low residue, is irrigated or rainfed, and whether wind or water erosion are problems.

Generally, the lower the residue potential and the coarser the soil texture the more numerous the tillage operations. For winter wheat, sorghum, or corn at the northern extreme of the Southern Great Plains, conservation tillage involves only that tillage necessary to reform ridges and furrows for irrigation. The success of these systems depends upon timely, effective herbicide application.

Because of the high probability of drought during the cropping period, it is difficult for one system to always be successful. If the soil surface is protected with residue, if weeds are controlled, and if the soil has good water intake, tillage is not needed. As residue levels decline, as the soil surface seals, and as the possibility for wind or water erosion increases, it becomes necessary to till the soil. As soil texture changes from clay loam to fine sandy loam, the herbicide tolerance level narrows and effectiveness declines. Also, as the number of tillage operations declines, weeds become more of a problem, and many perennial weeds are difficult to control because of plant stress during the periods when herbicides are most effective.

When crops with little residue are grown, such as cotton or sunflowers, the soil is not adequately protected from erosion. Tillage is needed to roughen the soil, which maintains water intake and reduces erosion. Tillage will control erosion effectively if performed after a rain and before soils start to erode.

In dryland agriculture, any successful tillage system will contain options for dealing with changing conditions. The type and frequency of tillage will depend upon the rainfall received. For bare soils, it may be necessary to roughen the soil with shallow tillage to reduce soil water evaporation in addition to controlling erosion. No single system will be successful throughout the region, and each year a different sequence of operations may be required to maximize crop response.

## Pacific Northwest

Runoff and erosion are frequently severe in the dryland grain areas of the Pacific Northwest. The Mediterranean climate (winter precipitation and dry summers) is ideal for producing winter small grain. Unfortunately, traditional tillage practices leave the soil unprotected except for the cover from the growing wheat crop. In much of the area, because of the cool fall and cold winter, the growing crop provides insufficient groundcover to protect the soil. The problem is compounded by rainfall and by snowmelt when the soil is thawing from the surface following periods of cold temperatures. With traditional tillage and rotations, soil erosion can reach 225 metric tons per hectare (100 tons/acre) or more in a single event of a day or a few days duration.

Conservation tillage systems with more surface residue are being emphasized as a means of preventing erosion and reducing crop production costs. In the low precipitation zone (200 to 350 millimeters a year), where winter wheat following a year of summer fallow is traditional and necessary, chisels are the standard primary tillage tool. If less-intensive secondary tillage is used, surface residues of 1,350 to 1,700 kilograms per hectare (1,200-1,500 pounds/acre) remain after seeding. These are sufficient to protect soil on all but the steep or concave field areas where water can collect and break across drill rows.

Soil Conservation Service

In this Washington field, wheat stubble fails to prevent "soil slipping," a spectacular form of water erosion.

In the intermediate precipitation zone (350 to 450 millimeters a year), where summer fallow is used every third or fourth year, both chisels and plows are used. Only by turning the plow furrow upslope and using minimal secondary tillage is it possible to retain sufficient residue for soil protection after the winter wheat crop is seeded. Even then, only moderate slopes will be adequately protected.

The moldboard plow has been the traditional primary tillage tool in the higher precipitation zone (more than 450 millimeters a year). Its use remains widespread. Newer models allow turning the furrow upslope on much steeper slopes than previously thought possible. The chisel is sometimes used as a primary tillage tool in the fall in preparation for seeding a spring crop. It is used prior to reseeding a fall crop only if the previous crop was a low-residue one, such as spring peas or lentils.

**Table 6. Effects of tillage implement on soil water loss 1 and 4 days after tillage.**

| Tillage Implement | Soil Water Loss (mm)* | |
|---|---|---|
| | 1 Day | 4 Days |
| Oneway disk | 21.3 | 33.0 |
| Chisel (5 cm wide, 61 cm apart) | 18.8 | 30.5 |
| Sweep plow | 5.8 | 9.1 |
| Rodweeder with semichisels | 2.5 | 14.2 |

*Loss from tillage depth, surface 12 centimeters.

In recent years, a number of mulch-type implements have been introduced. They are being used across all precipitation zones. These implements generally have a straight coulter, either smooth or fluted, preceding a chisel shank. The chisel shank may be twisted so it buries more residue. On some implements, horizontal rotating bars or rods behind the chisel shanks provide additional residue incorporation and flatten the ridges left by the shanks.

Attempts to deal with annual weed problems, such as downy brome (*Bromus tectorum*), have led to the use of heavy disk harrows in the fall, prior to primary tillage in the fall or spring. The intent is to incorporate the weed seed prior to early fall rains and encourage germination. Subsequent tillage operations kill the downy brome before seed set. Unfortunately, unless residue is quite heavy, the disking breaks the straw and pulverizes the surface soil so that, even though the soil may be chiseled later, the chisel marks fill with loose soil and runoff and erosion occur.

The heavy disk harrow is also used frequently as the main tillage tool after spring dry peas. The disk pulverizes the surface soil, buries the scant residue, and leaves an erosion-prone surface after winter wheat is seeded.

No-till seeding has been used by farmers in the Pacific Northwest since 1975. The area in no-till varies from year to year, but currently amounts to about 20,000 of the 4 million hectares (50,000 of the 10 million acres) of dryland.

There has been a substantial increase in no-till seeding within the past two years. Drills with fertilizer placement capability have been responsible for much of the increased interest and success.

No-till seeding into small grain stubble reduces erosion in comparison with most other conservation tillage systems. Runoff may or may not be less. No-till seeding into pea and lentil residue may not reduce runoff and erosion much in comparison with tillage systems that leave the soil rough.

Data from plots at the Palouse Conservation Field Station at Pullman, Washington, indicate reduced tillage and direct stubble seeding have significant impacts on runoff and soil loss on frozen soil. When soil on bare smooth-tilled plots is frozen to a depth of 10 centimeters (4 inches) or less, rough tillage and greater amounts of residue prevent a continuous concrete frost layer; hence, the land is less prone to runoff and soil loss from rain and snowmelt during the thawing period. When soil is frozen to greater depths, 15 to 20 centimeters (6-8 inches) or more, concrete frost forms under all treatments, and runoff quantities can be quite similar. Land with greater surface roughness and residue is better protected from erosion as the water runs off.

## Summary

Unquestionably, the most effective way to reduce erosion is to have living or dead vegetation on the soil surface. Surface roughness is important also in reducing erosion by both wind and water, but the protection is short-lived because of the beating action of raindrops. Close-growing vegetation is more effective than vegetation grown in wide rows. Perennial vegetation, provided the stand is good, is generally more effective than annual vegetation.

No tillage is generally more effective than some tillage in reducing soil erosion, even though tillage may open up the surface and allow greater intake of water, at least for a time. But tillage loosens the soil for easy detachment, and much is lost if runoff occurs.

In the Corn Belt, reduction of erosion seems to be a matter of leaving sufficient residue on the surface. Soybeans leave little residue, and this disappears quickly with any kind of disturbance. Controlling erosion following soybeans appears to require cover crops if slopes exceed 4 percent.

In the Southeast, it is important to break up the pan that forms each year in soil that is moldboard-plowed or even disked. Chiselling in the row breaks up the pan and allows moisture to get into the root zone, which greatly reduces both runoff and erosion.

In the Great Plains, wind erosion generally is more serious than water erosion. Surface roughness is an important means of erosion reduction, particularly in the case of low-residue crops on sandy soils in the Southern Great Plains. Inducing soil roughness is mainly for emergency erosion control, however. It must be repeated frequently to be effective.

Again, living or dead vegetation is much more effective than surface roughness in reducing erosion. Vegetation has the effect of lifting the wind. It also increases the percentage of nonerodible aggregates in conservation tillage practices.

In the Pacific Northwest, growing vegetation effectively reduces erosion once the vegetation is established. But, fall-seeded wheat may not grow enough during the winter to be effective when most erosion occurs. Residue from the preceding crop is effective, however, in protecting soils during this period. Unfortunately, spring dry peas and lentils provide little residue.

No-tillage seeding of wheat has proved successful in reducing erosion, though under deep frozen soil conditions it may not reduce runoff. Surface roughness and surface residue prevent a continuous frost layer under shallow frozen soil conditions and help to reduce runoff.

It has been encouraging in recent years to observe throughout the United States the effectiveness of no-till and other forms of conservation tillage in maintaining or even increasing crop yields. This is due to such factors as higher moisture use efficiency and reduced compaction, as well as stabilization of surface aggregates. Problems connected with weed control and fertilization are being solved, however slowly. Some of these solutions are the result of research; others are the result of innovative farm operators who are using the systems. Regardless, the efficiency and effectiveness of conservation tillage systems continue to improve, and this gives farmers an economic reason to adopt the systems, in addition to erosion reduction.


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