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Conservation Tillage

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Conservation Tillage

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CONTENTS

SUMMARY

You need to know, first:

1. How much residue you have to work with (page 6, 9).
2. The amount of residue needed to give adequate year-around protection for your particular soil type (page 6, 9).

Then:

3. Choose the tool that will leave the amount of residue needed.
4. Choose the proper tool width for your power source to minimize your cost (page 8, 9).
5. Plan future machinery replacements to give better residue management and lower operating costs.

COVER: Chisel plow. (Photo courtesy International Harvester).

WIND EROSION EMERGENCY TILLAGE

If erosion begins or is imminent, special emergency control methods are needed. Emergency tillage is usually the most common control method, and while it often provides only temporary control, it can be effective if properly applied.

The basic principle of emergency tillage is to provide a rough, cloddy surface to your field which will resist the force of wind and trap blowing soil. Choosing the specific implement and method of operation depends on the seriousness of the erosion, susceptibility of the particular soil, the duration of the needed protection and whether or not a crop is on the land.

Sandy soils are far more difficult to control by emergency tillage measures than finer textured soils. There are fewer clods to be formed no matter what implement is used, and those that are formed are usually fragile. Listing sandy soils at depths sufficient to produce good roughness is recommended. If erosion begins again, the ridges may be split to provide freshly roughened surfaces.

In fine and medium textured soils where clods are easier to produce, cultivation and chiseling or the use of other ridging implements are all satisfactory providing penetration of consolidated soil layers is maintained to produce and bring up a cloddy surface.

The direction of emergency tillage should always be perpendicular to the erosion winds for maximum protection. Tillage should begin on the upwind side of the field to prevent destruction of beneficial effects by eroding soil during the operation.

Emergency tillage should not be considered as a primary control method. It should only be employed as a last resort measure where vegetative or residue protection is unavoidably lost. The basic control should be through wise use of vegetation and crop residue management practices as discussed elsewhere in this publication.

Conservation Tillage

A combination of adverse moisture conditions and unfavorable extended weather outlook in the mid-1970's threatens farmers with serious wind erosion problems over vast areas in Central and Western South Dakota. Particularly affected will be land under summer fallow and newly plowed-out grasslands with little if any surface protection due to lack of vegetative residue.

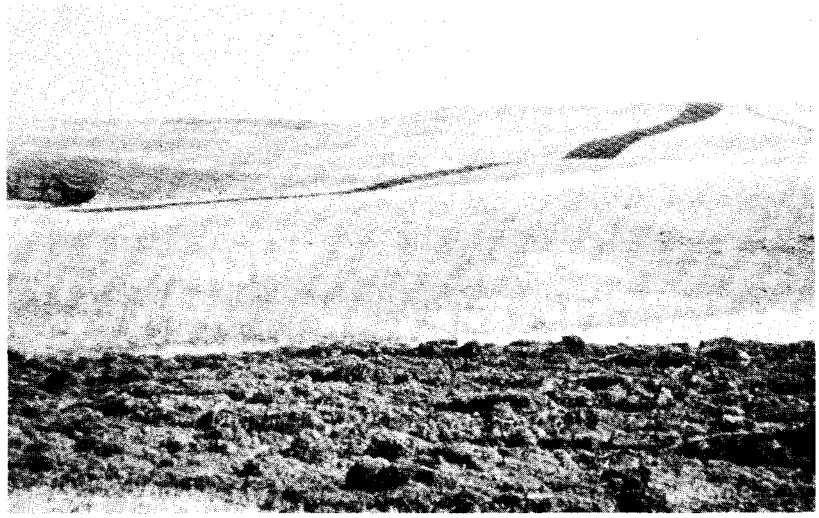
In South Dakota's winter and spring wheat production areas nearly 1.2 million acres of the crop are planted annually on summer fallow with an additional three-quarter million acres continuously cropped. Add to this a half million acres, about equally divided between new grassland plow-out and 1974 set-aside acres. An estimated one-third of the new plow-out acreage is of marginal and sub-marginal land, Classes IV, VI and VII.

Continuous cultivation on Class VI and VII land will result in serious soil deterioration. This land should be returned to permanent grasses. Class IV land can be farmed, but requires very intensive conservation treatment to sustain the soil resource. Classes I, II, and III lands are less hazardous to farm, but also require well-planned conservation systems for sustained cropland use.

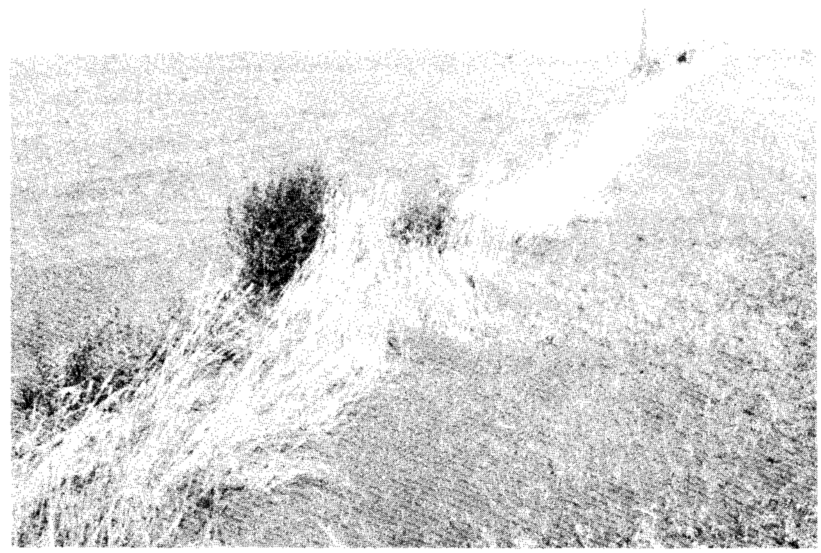
Tillage systems in the semiarid Great Plains have included summer fallow as part of the crop rotation for nearly 75 years. The moldboard plow was the primary tillage implement used in the early crop production programs. This implement turned under nearly all crop residue, producing an almost bare fallow surface highly susceptible to wind erosion.

Methods have since been developed to control wind erosion by using crop residues on the soil surface. This method also decreases water erosion because a plant residue mulch protects the soil surface from compaction and scaling by the beating action of rain drops. Plant residue also increases infiltration rate of moisture into the soil.

Conservation tillage systems are many and varied. Most can be adjusted to suit the individual's needs and his available machinery. Regardless of



Beginning of plow-out of grassland which is of the marginal land type described in the accompanying two photos of satellite imagery.



Wind erosion damage. Note lack of vegetative protective cover on field at left.

Wind and water erosion. Note fence is virtually buried from blown soil from unprotected field surface (at right) and effect of water erosion on wind deposits along fence line.

the terminology often used—such as stubble mulching, minimum tillage, or crop residue management—it will be referred to in this publication as *Conservation Tillage Systems*. The end objective is to keep as much protective cover on the soil surface as possible and to reduce the length of time the soil is exposed.

The farmer/rancher has a choice of conservation tillage methods he can use to minimize the rate of soil erosion and provide the greatest possible net return for his work.

KNOW YOUR SOIL

Your Soil Is a Factory

A good productive soil may be compared to a busy factory. Its end products are high yields of good quality crops. The manufacturing function of the soil supplies growing plants with the raw materials coming from its breakdown of organic and mineral matter. The manner in which you till and manage your soil greatly influences the efficiency and production capacity of this dynamic crop producing factory.

A representative silt loam surface soil in the best condition for plant growth is composed of about half solid material and half pore space (Figure 1). The solid material is approximately 45 percent mineral or inorganic material—stones, gravel, sand, silt, and clay—and about 5 percent organic matter. The pore space or space between the mineral particles is usually equally divided between soil-air and water.

Factory or Soil, Both Need Management

As in any factory, management largely determines the production capacity. Thus, the soil "machine" must maintain certain physical conditions as ideally as possible. This means, for example, that soil solids or particles (the sand, silt, and clay) must combine in aggregates that provide suitable pore space. Pore space is necessary for movement of air in the soil as well as for downward movement of water through the soil, both so important to good plant root development.

The clumping or aggregating of soil particles, often referred to as structure, is essential for rapid rainfall intake and reduced water erosion. The products of soil microorganisms, together

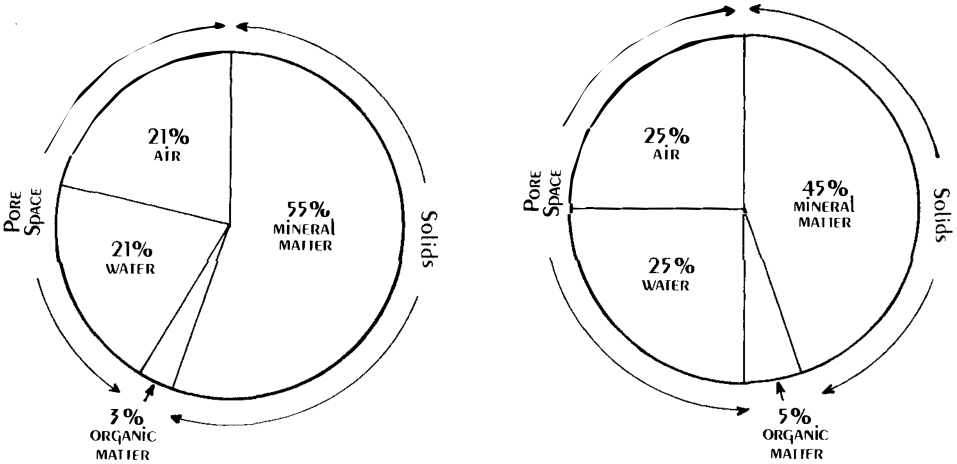


Figure 1. Volume composition of a silt loam surface soil in good condition for plant growth (right) and in poor condition for plant growth (left). These two charts can be matched with actual soil clods as shown in Figure 2.

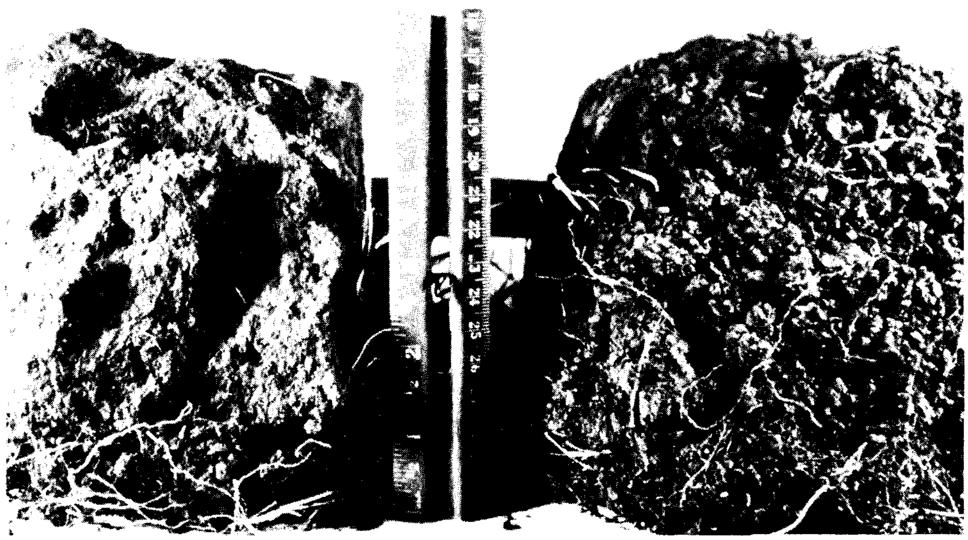


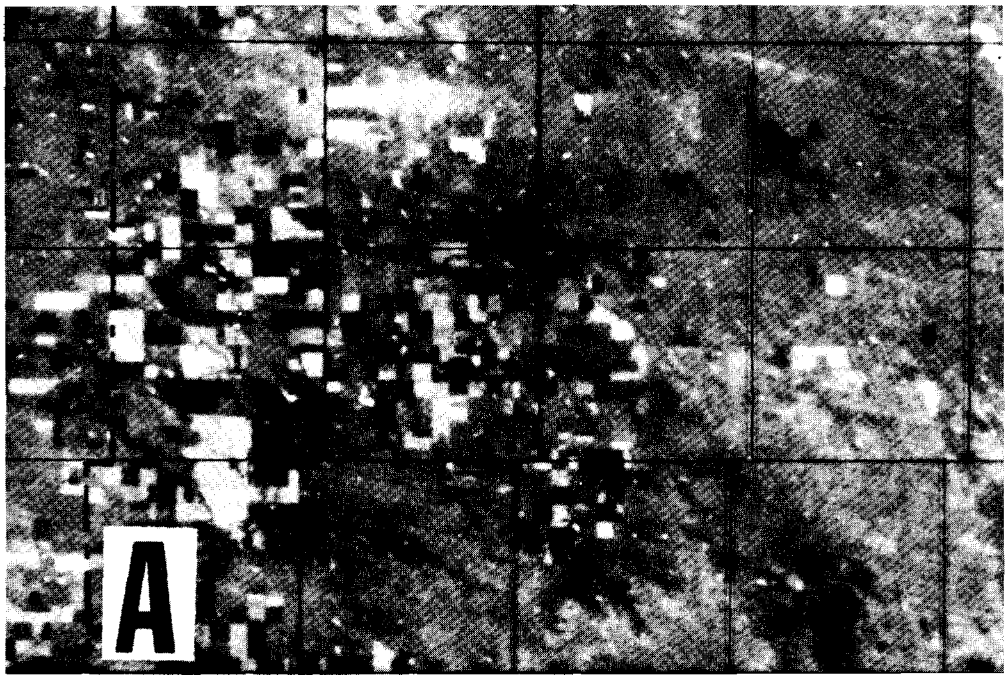
Figure 2. Ideal structural-unit development of soil particles under natural virgin conditions (right). A clod of the same soil after 70 years of tillage (left).

Figure 3. Gritty, unstable ribbon state of a wetted "sandy soil" when leafed through the fingers (left) and sticky, plastic and stiff ribbon of clayey soil (right).

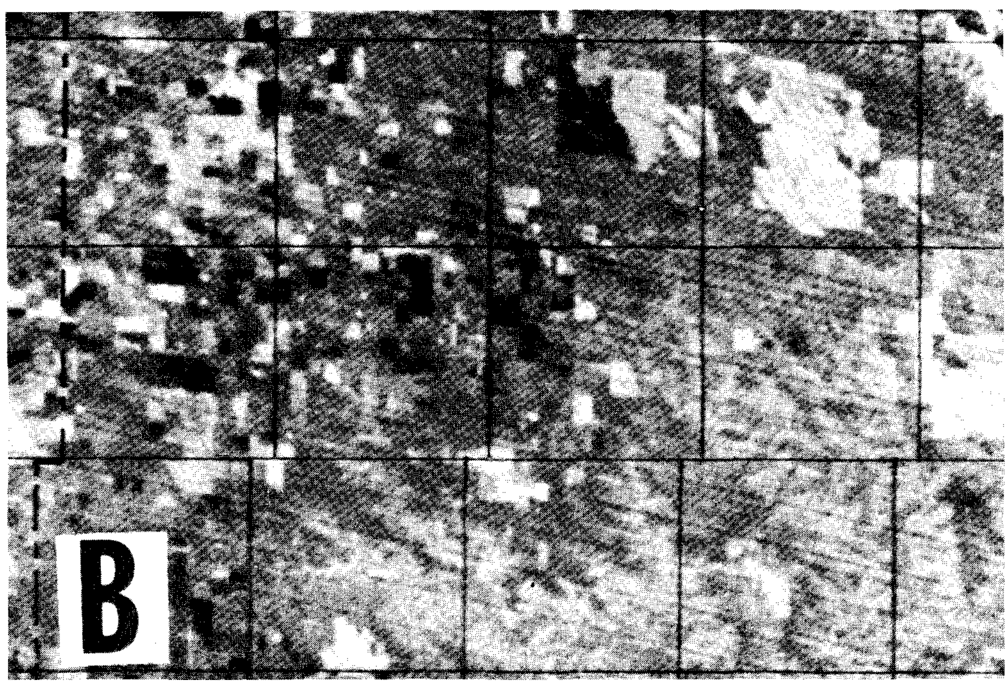
with organic matter decomposition and finer soil particles, are responsible for development of soil structural units which result in large soil pores and improved movement of air and water (Figure 2). This action also holds the soil materials together, giving them stability and resistance to wind and water erosive forces.

Overtillage and tillage of wet soils often causes compaction problems that tend to break down soil structure and decrease pore space (see Figures 1 and 2). In general, tillage operations *destroy* structure. Addition and decomposition of organic matter (crop residues) tends to *improve* and *maintain* structure.

Don't confuse soil *structure* with soil *texture*. Texture is the proportion of sand, silt, and clay particles of any soil. A moistened sandy soil feels gritty between the fingers. A clay loam or clay soil becomes very sticky and molds into a stiff ribbon (Figure 3). A silt loam soil feels slippery and smooth when rubbed in the palms of the hand.



Imagery of identical views taken 2 years apart by LANDSAT (formerly ERTS) satellite of a portion of western South Dakota grassland which shows plowed-out areas. Photo A was taken in September 1972 while Photo B was taken in November 1974 and shows several thousand acres of grassland plow-out. Each square of the superimposed grid represents 23,040 acres or a township 6 miles square consisting of 36 sections of 640 acres each. The light rectangular areas are former grasslands probably plowed out in the 1974 growing season and in fallow when this imagery was made. The darker, smaller adjoining areas are winter wheat fields sown in September 1974. Gray-toned areas are mostly remaining grasslands. An estimated 300,000 acres of South Dakota grasslands have been converted to cropland during the past 2 years. (Photo courtesy Remote Sensing Institute, SDSU.)



Plant Nutrient Storehouse

Our soil factory must provide for plant nutrient storage. This storehouse is provided by the finely divided, tiny soil particles (clays) and organic fractions of the soil. These materials act as "magnets" by holding and storing many plant nutrients, preventing them from being leached by rainwater as well as maintaining them in a form readily available for use by growing plants.

The proportion of sand, silt and clay make up the original supply and source of inorganic chemical elements in a soil. They furnish the needed plant nutrients to the storehouse along with the nutrients contained in the organic matter part of the soil. This storehouse releases nutrients through a chemical process into the soil solution and thus to plants.

However, nutrient release in many of our soils is not enough to support the rate of crop growth and production we now try to maintain. This is caused by several factors, but mainly is a result of nutrient depletion from years of continuous cropping plus topsoil losses by erosion. Consequently, use of commercial fertilizer for high production becomes increasingly important and actually a necessity for many South Dakota soils. Maintaining year-around protection of the soil surface with plant residues substantially reduces soil losses, and consequently nutrient losses, from both wind and water action.

Chisel plowing provides surface protection from both crop residue and cloddiness.

EROSION CUTS NET RETURN

Why Erosion Occurs— How to Prevent It

Wind and rainfall are two major forces causing soil erosion. Greatest damage results when wind and water are allowed to work on loose, unprotected soil.

Wind erosion starts on bare unprotected soil but can severely damage nearby marginally "protected" fields. Wind erosion generally starts with movement of single small sand particles. One windblown sand particle strikes another particle, dislodging it. The second particle strikes another and so on, soon causing detachment of the finer soil particles and movement of large soil masses. Once erosion starts, it spreads rapidly, damaging vegetation and even covering land considered to be "safe" from wind erosion.

Water, however, is the major cause of soil erosion in our Nation. Water erosion begins with falling raindrops. The impact of raindrops on bare, unprotected soil detaches soil particles. Once detached or disturbed, the particles are easily moved by running water or wind. Regardless of cause—by wind or water—erosion damage is directly related to the amount of soil protective cover: the more vegetative soil cover, the less damage by erosion.

EROSION CONTROL METHODS AND STRUCTURES

Strip Cropping

Strip cropping is one inexpensive and effective method of controlling erosion damage from both wind and water. Strip cropping uses strips of fallow or row crops alternated with strips of close growing crops. Wind erosion damage is decreased by the alternating strips which range from 10 to 30 rods wide, depending upon soil texture. The alternating strips of close growing crops also slows water runoff and decreases erosion damage. Sediment carried in the runoff is deposited in the strip.

Barrier Strips

Barriers such as trees, permanent grass strips, temporary crop strips or other obstructions also help prevent wind erosion. Wind velocity may be reduced as much as 75 percent near barriers at right angles to wind direction. Shape, width, height and porosity of the barrier influence its effectiveness. A general rule of thumb is 10 feet of protection for every foot of barrier height.

Contouring

Farming on the contour helps reduce water erosion by capturing runoff in rows or furrows across slope where it infiltrates down into the root zone. It is most effective for individual storms of light to moderate intensity and on uniform slopes in the range of 3 to 5 percent.

Terraces

A terrace or earthen ridge constructed across slope controls water erosion mainly on slopes of 5 percent or greater. The idea is to control length of slope. Interrupting runoff by terracing results in conservation of water and reduced flood or runoff damage.

Stubble Mulching

Soil cover is essential to an effective erosion control program. Stubble mulching leaves plant residue, either standing or partially exposed, on the soil surface. Various stubble mulching systems are flexible enough to accommodate specific needs of most farms or ranches. You may find it necessary to leave only a small amount of residue exposed during the winter months while your neighbor, operating under different soil and moisture conditions, may need to gear his entire production program on maintaining stubble all year long.

Stubble mulching is an effective, economical method for controlling wind and water erosion. Wind erosion is decreased by providing a rough surface along with surface residue cover which slows wind velocity, thereby reducing soil detachment. Water erosion is controlled by residue cover that absorbs the impact of raindrops, slowing runoff and allowing the moisture to infiltrate.

How Much Residue

You must know how much residue you have on your field and how much is needed for at least minimum protection of your soil. A handy rule of thumb to remember is that a wheat crop produces about 100 pounds of residue for each bushel of grain. A corn or sorghum crop produces about a pound of residue for each pound of grain. Several other methods are available to determine amount of residue on your field from the preceeding crop (see your county Extension agent or District Conservationist).

Typical amounts of wheat and sorghum residue needed on surface soils of various textures are shown in Table 1. The Table shows the minimum crop

Table 1. Minimum residue needed at seeding time (pounds per acre).

Soil Textures	Wheat	Sorghum or Corn
Coarse (sand, loamy sand, loamy fine sand)	1,750	3,500
Moderately coarse and fine (fine sandy loam, sandy loam, silty clay, clay)	1,250	2,500
Medium and moderately fine (very fine sandy loam, loam, silt loam, clay loam, sandy clay loam)	750	1,500

residue needed after stubble mulching to protect soil when the next crop is seeded.

CROPPING PRACTICES AND ROTATIONS

Production of cultivated crops is a land-disturbing activity. It increases stress on the soil resource. Cropping systems can be designed, however, to minimize destructive effects. Your conservation cropping system should have these objectives:

- Control erosion.
- Maintain good physical condition of the soil.
- Make most efficient use of available moisture for plant growth.
- Maintain an adequate supply of plant nutrients.
- Control weeds, insects, and diseases.
- Provide an economic return.

Crops and Cropping Systems

Cropping systems include the crops to be grown, their sequence or rotation, management and use of each crop, and methods of tillage and planting.

Growing vegetation or crop residues protect soil against erosion by:

- Reducing wind velocity near the soil surface.
- Absorbing the erosive force of raindrops.
- Decreasing velocity of runoff.
- Increasing soil porosity through the effects of root growth and biological activities.

Remember, land can be cropped and managed in many ways, resulting in wide variations in rates of erosion.

Close-grown crops, such as small grains, provide a canopy or "cover" that is more effective against erosion forces than the "exposed" soil in a row crop or in fallow. Small grains produce relatively large amounts of residues which can be effectively managed for erosion control and to return organic matter to the soil. Low-residue cropping, such as silage production, does not provide this advantage. Legumes and grass-legume mixtures maintain or increase both nitrogen and organic residue plus increasing soil porosity. Rotations with high-residue producing crops such as legumes combined with minimum tillage or stubble mulching maintain tilth, structure, and organic matter.

Summer fallow exposes soil to erosive forces over long periods of time. Protection is provided when you carefully manage crop residues. Summer fallowing in theory increases soil water available for crop growth. However, water storage efficiency is poor and can actually result in a loss of stored soil water in some years. Usually, the increased yield performance with summer fallow is a reflection of the additional nitrogen accumulated from fallowing rather than of the additional moisture storage.

Tillage—Good and Bad

Tillage methods can destroy or conserve soil. Conservation tillage uses as few trips as possible over a field to control weeds and produce the crop. This reduces soil disturbance and compaction, leaves more protective residue on the surface and decreases your costs.

Conservation tillage creates rough or ridged soil surfaces across the slope or perpendicular to prevailing wind direction. Conservation tillage systems minimize length of time the soil surface is exposed without protective crop residues. Residues provide buffers against erosion forces as well as help conserve moisture.

The amount of residue on the soil surface is an important factor. Amount of available residue varies widely, depending on yields and use made of the previous crop.

Subsurface tillage in fall kills weeds and improves moisture infiltration. Note amount of standing residue. (Photo courtesy of Noble Cultivators, Ltd., Nobleford, Canada.)

Rotation System

Rotation systems decrease infestations of insects, weeds, and diseases as compared to single-crop systems. Weeds are usually most troublesome in crops with similar life cycles—for example, cheatgrass associated with winter wheat. Rotating crops with different life cycles helps reduce populations of specific weeds. This is the most economical and effective method of weed control. Weed control is essential to make best use of available moisture. Single-crop or monoculture systems usually require greater use of pesticides and fertilizer and possibly more intensive erosion control measures.

Where erosion hazards are high as in the case in the western two-thirds of South Dakota in the mid-1970's, supporting practices such as strip cropping, terraces, or windbreaks are needed. These practices reduce the soil surface area exposed to erosion forces. Furthermore, strip cropping creates barriers to prevent spread of diseases or insects.

MACHINES, COSTS AND RETURNS

Fallowing programs are usually of three general classifications:

- Bare fallow, using a moldboard plow.
- Semi-bare fallow, using a one-way disk plow or tandem disk.
- Stubble mulch fallow, using chisel and subsurface tillage implements.

Most Great Plains cultivated fallow is in the last two categories because the moldboard plow has high tillage-energy requirements and the resulting fallow surface, lacking residue, is highly susceptible to erosion.

A Choice of Implements

A farm or ranch operator has a choice of many different machine systems for his summer fallow or conservation tillage program. The program you select depends upon:

- Net return on investment (considering machines available, tillage energy requirements, labor requirements, fertilizer requirements, and crop yield).
- The program's effect on erosion and moisture conservation.

An adequate residue management program for you means using only enough tillage operations for weed control. Any excessive tillage increases energy costs, reduces amount of protective residue and breaks down cloddiness and tilth of soil.

Planning Your Program

Plan your conservation tillage program to retain sufficient protective residue yet avoid unnecessary overhead cost (excessive machinery, unnecessary tillage operations, excess use of energy).

Since a wheat crop usually produces about 100 pounds of residue for each bushel of grain, use this as a guide to determine how much residue you have from the preceeding crop. Poor soil fertility, limited moisture, disease and insect problems can reduce this initial per acre amount of residue.

Tillage Considerations

Tillage implements—depending on type, adjustment, and speed of operation—destroy varying amounts of surface residue. The accompanying table (Table 2) lists average amounts of residue remaining after each tillage operation when the implement is properly adjusted and operated at the most suitable speed (usually about 4 miles per hour except for large sweep and blade type tools which will operate somewhat faster).

As travel speed increases above 4 miles per hour more residue is buried, except for blade or sweep type machines. This reduces effectiveness and defeats the purpose of your conservation tillage program. Additionally, the faster you go the more power you need and this costs you more for fuel, wear and tear.

If you increase the size of the tractor you use, you need to increase the width of your implement to fully use the power available when operating at optimum speed. Or you can gear up and throttle down with a large tractor and small implement. "Fast and deep" is wrong for conservation tillage.

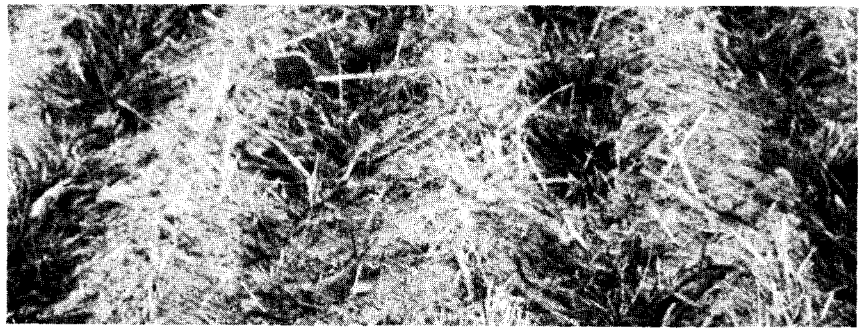
You can use Table 3 to estimate the implement width needed to fully use the power available from a given power unit at a set speed. In the example used in Table 3 the operator wishes to determine the most suitable width for for a one-way with 18-inch disk to pull with a 120 PTO horsepower tractor. He wishes to travel at a speed of 4 miles per hour.

Seeding Equipment

Fall seed with a deep-furrow press drill. This implement places the seed in firm, moist soil while leaving sufficient surface ridges with anchored residue to resist wind erosion until the crop has emerged and is capable of providing adequate protection.

Spring seeding may not require as much ridge for wind protection. This results in a smoother field at harvest time reducing wear and tear on harvesting machinery.

Value of upright surface residue is shown by trapped snow (right) while no snow is present where residues are incorporated into the soil (left).



Winter wheat growing in stubble mulch. Stubble protects soil from wind erosion until wheat is tall enough to offer protection.

Table No. 2. Average value of residue lost per operation, energy requirement (PTO horsepower per acre) and fuel consumption (gallons per acre) for selected tillage implements.

Implement	Residue remaining after Tillage (%)	Speed (mph)	Type of Tillage	Energy* Requirement PTO Hp hr/AC	Fuel Consumption (gallons/AC) Gasoline†	Diesel‡
Moldboard Plow (7" deep)	0-5	4	Primary	23.4	2.6	1.8
Chisel Plow 2" wide points (7" deep)	75	4	Primary	18.9	2.1	1.5
One-way (18" to 20" disks)	60	4	Primary	10.0	1.1	0.8
			Secondary	13.6	1.5	1.0
One-way (24 to 26" disks)	50	4	Primary	12.5	1.4	1.0
			Secondary	15.4	1.7	1.2
Heavy Tandem or Offset disks	60	4	Primary	10.7	1.2	0.8
	50		Secondary	14.5	1.6	1.1
Field Cultivator (12" to 18") Sweeps	80	4	Primary	5.3	0.6	0.4
			Secondary	7.3	0.8	0.6
V-Sweep (20-30-In wide)	85	6	Primary	8.0	0.9	0.6
			Secondary	10.9	1.2	0.8
V-Sweep (over 30" wide)	90	6	Primary	9.3	1.0	0.7
			Secondary	12.7	1.4	1.0
Mulcher Treader (spade tooth)	75-80	6	Secondary	4.0	0.4	0.3
Rodweeder (with semi point chisel or shovel)	85	5	Secondary	8.5	0.9	0.7
Rodweeder (Plain rotary rod)	90-95	5	Secondary	6.9	0.8	0.5

*Tractive Efficiency Factor included.
†9 hp. hr/gallon.
‡13 hp. hr/gallon.
Note: Values in Energy Requirement and Fuel Consumption columns vary depending on the type of tillage, primary or secondary.

Table 3. Determining Implement Width

Estimate the implement width required to fully use the power available from a given power unit at a set speed as outlined in the following table:

	Example	Your figures
1. Factor (a constant, use in all cases)	8.25	8.25
2. Rated PTO horsepower (from manufacturer or from Nebraska Test)	120 (h.p.)	
3. Implement Energy Requirement (from Table 2)	10 (pto h.p. Hrs./Acre)	
4. Speed (from Table 2)	4 (m.p.h.)	
5. Multiply No. 1 by No. 2	990	
6. Multiply No. 3 by No. 4	40	
7. Implement width in feet (No. 5 divided by No. 6)	24.75	

Not Enough Residue?

If your program plans show a final residue which is insufficient, a herbicide may be used to eliminate one or more tillage operations. Check with your county Extension agent or Soil Conservation Service district conservationist as to the advisability of using a herbicide under your conditions.

Too Much Residue?

If residue is so heavy that it is difficult to drill, you may need to break it up and distribute it more evenly on the field. A rotary hoe, pulled at fairly high speeds (about 6 miles per hour) when the residue is dry, breaks up the material and distributes it fairly uniformly. In extremely heavy residue the rotary hoe may need to be pulled backwards (from the back hitch) for trash clearance.

A single, or tandem disk, pulled straight when residues are dry, will chop and punch much residue into the soil. You will need weight on the disk, however. Skew treaders help considerably to distribute and anchor some residues in the soil. Be careful when using these implements so you do not dry out the surface soil to the seeding depth.

EXAMPLES OF PROGRAMS

Table 4 shows typical pounds of residue remaining after summer fallow tillage with a 27-bushel wheat crop the previous season. This table also shows the usual gallons of diesel fuel required and expected total costs for all tillage operations prior to seeding. Total costs include annual charges for fixed and variable machinery costs, fuel, lubrication, and labor for five different examples of conservation tillage systems.

Plan number 2 leaves enough residue at seeding time for wheat to meet minimum residue needed standards for all but our coarser soils (see Table 1). This plan is also the lowest cost and requires fewer gallons of fuel than any of the other plans.

Table 4. One example of good residue management, two examples of marginal residue management and two examples of poor residue management.

Tillage Operation	Depth of Tillage (inches)	Residue Remaining (Pounds)	Gallons Diesel Per Acre	Cost Per Acre
Plan Number 1—Initial Residue		2,700		
Chisel plow (Fall) (2 in. wide points, 12" o-c)	7	2,025	1.5	$ 2.30
One-Way (Spring) (18" to 20" disks	4	1,215	1.0	2.20
Field Cultivator (18 in. Sweep, 12" o-c)	2	972	0.6	1.50
Field Cultivator	2½	778	0.6	1.50
Field Cultivator	2	622	0.6	1.50
Rodweeder (Plain rotary rod)	2	560	0.5	1.25
TOTAL DIESEL FUEL USED AND TILLAGE COSTS			4.8	$10.25
Plan Number 2—Initial Residue		2,700		
V-Sweep (Spring) (over 30-inch wide)	3	2,430	0.7	$ 1.80
V-Sweep	3½	2,187	1.0	2.00
V-Sweep	3	1,968	1.0	2.00
V-Sweep	3½	1,771	1.0	2.00
Rodweeder (Plain rotary rod)	2	1,594	0.5	1.25
TOTAL DIESEL FUEL USED AND TILLAGE COSTS			4.2	$ 9.05
Plan Number 3—Initial Residue		2,700		
Chisel Plow (Fall) (2 in. wide points, 12" o-c)	7	2,025	1.5	$ 2.30
Off-set Disk (Spring)	4	1,013	1.1	2.30
V-Sweep (over 30-inch wide)	3	911	1.0	2.00
V-Sweep	3½	820	1.0	2.00
V-Sweep	3	738	1.0	2.00
Rodweeder (Plain rotary rod)	2	664	0.5	1.25
TOTAL DIESEL FUEL USED AND TILLAGE COSTS			6.1	$11.85
Plan Number 4—Initial Residue		2,700		
One-Way (Spring) (24" to 26" disks)	4	1,350	1.0	$ 2.00
One-Way	4½	675	1.2	2.20
One-Way	4	338	1.2	2.20
One-Way	4½	169	1.2	2.20
Rodweeder (Plain rotary rod)	2	152	0.5	1.25
TOTAL DIESEL FUEL USED AND TILLAGE COSTS			5.1	$ 9.85
Plan Number 5—Initial Residue		2,700		
Moldboard Plow (Fall) (5-16's)	6	135	1.8	$ 3.90
Tandem Disk (20 foot)	4	68	1.1	1.70
Field Cultivator (18 in. Sweep, 12" o-c)	2	54	0.6	1.50
Field Cultivator	2½	43	0.6	1.50
Field Cultivator	2	35	0.6	1.50
Rodweeder	2	31	0.5	1.25
TOTAL DIESEL FUEL USED AND TILLAGE COSTS			5.2	$11.35

Cost calculations were based on 1974 purchase prices for machinery, 35 cents per gallon for diesel fuel and $2.50 per hour for labor.

MACHINERY NEEDED

Plan 1: Tractor, chisel plow, one-way, field cultivator, rodweeder.
Plan 2: Tractor,V-sweep, rodweeder.
Plan 3: Tractor, off-set disk, V-sweep, rodweeder.
Plan 4: Tractor, one-way, rodweeder.
Plan 5: Tractor, moldboard plow, tandem disk, field cultivator, rodweeder.

Plan number 3 is the highest cost plan and requires the most gallons of fuel. Residue remaining is marginal for even our medium and moderately fine textured soils (see Table 1).

Plan number 4 shows the extreme reduction in residue that results from the use of disk type implements. Each time a disk is used about half of the remaining residue is buried. After the second time over, residue remaining is 75 pounds less than is needed at seedtime (750-675). A good general rule to follow is that a disk should not be used more than once in a season and possibly not at all.

Plan number 5 shows that if both a moldboard plow and a tandem disk are used in the same season residue remaining at seeding time is essentially zero. NOTE: If the ground is fall plowed, only 135 pounds of residue remains for the winter, exposing these fields to severe wind erosion for several months.

Table 5 demonstrates the calculation of residue remaining. With a wheat yield of 27 bushels, you would expect to have 2,700 pounds residue per acre before the first tillage operation if 100 pounds of residue is produced per bushel of wheat harvested. To find residue remaining after the chisel plow operation, go to Table 2, to find that 75 percent of the residue remains after chisel plowing. Convert this percentage figure to a decimal (75%÷100) and multiply it by the initial residue. Residue after chisel plowing is 2,025 pounds (.75 x 2,700). The one-way used in Plan 1 leaves 60 percent of the residue, so you multiply the 2,025 pounds left after chisel plowing by .60 to estimate that 1,215 pounds remain after the one-way is used. Continuing these calculations for the rest of the tillage operations in Plan 1 shows that only 622 pounds of residue

Table 5. Estimating residue remaining at seeding time from Plan 1.

Tillage Plan 1	Calculations	Residue Remaining
Initial residue	27 bu.x 100	2,700
Chisel plow	.75x2,700	2,025
One way	.60x2,025	1,215
Field cultivator	.80x1,215	972
Field cultivator	.80x 972	778
Field cultivator	.80x 778	622
Rodweeder	.90x 622	560

remain per acre to protect the soil when the wheat is seeded.

Table 6 is a "Work Form" that you can use to estimate residue remaining from your tillage plan. Compare the residue remaining for your plan with minimum residue needed standards in Table 1. If the residue remaining from your plan is significantly lower than the standards, you need to consider alternative plans that will leave adequate residue to protect your soil from erosion.

Table 6 can also be used to estimate gallons of fuel required per acre for your plan and approximate total tillage costs per acre. Use primary fuel requirements from Table 2 if the tillage operation is the first one after harvest. For all other operations use the fuel gallons on the lines marked secondary in Table 2. To estimate your total cost per acre use figures from Table 4 for tillage operation that come closest to the kind of tillage machines that you are using.

Table 6. Work form to estimate residue remaining, fuel requirements and expected costs for your system.

Your Tillage Plan	Calculations	Residue Remaining	Fuel Used	Cost Per Acre
Initial Residue	___bu. x100		____	____
	x			
	x			
	x			
	x			
	x			
	x			
	x			
TOTAL FUEL USED AND TILLAGE COSTS			____	____

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