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The Honorable Richard G. Lugar
Chairman
The Honorable Patrick J. Leahy
Ranking Minority Member
Committee on Agriculture, Nutrition,
and Forestry
United States Senate

The Honorable Pat Roberts
Chairman
The Honorable E (Kika) de la Garza
Ranking Minority Member
Committee on Agriculture
House of Representatives

Before 1985, an estimated 3 billion tons of soil eroded annually from the nation's cropland. Concerned about losing productivity on this cropland and the degradation of water quality caused by sedimentation, the Congress enacted the conservation compliance program--one of a number of programs to reduce soil erosion--in the Food Security Act of 1985. Under this program, farmers who participate in federal farm programs must implement approved soil conservation plans to reduce erosion on highly erodible cropland or face the possible loss of program benefits. The conservation compliance program is administered by the U.S. Department of Agriculture (USDA).

In preparation for the 1995 farm bill, you asked us to provide information on (1) whether USDA has been flexible when implementing program requirements in different regions of the country, (2) how the program has affected farming practices and farmers' costs, and (3) what benefits and drawbacks the program has provided.

In summary, we found the following:

-- USDA has been flexible in setting program requirements and in applying these requirements on a regional basis. For example, USDA relaxed the program's original

standard after it found that the standard could cause economic hardship for some farmers. The original standard required that erosion be reduced to the rate at which it does not impair the soil's productivity. The Department also allowed individual state offices to develop alternative conservation practices that farmers could use to comply with the new standard, which varies by geographic region. However, USDA's Office of Inspector General reported that the Department did not consistently apply the new standard among similar locations.

-- An estimated three-fourths of farmers' soil conservation plans specify practices that leave residue from the prior year's crop on the soil as the primary erosion control technique. Farmers have reduced tillage to retain crop residue on the soil's surface. The practice of reducing tillage increased over 30 percent (from occurring on 73.2 million to occurring on 97.5 million acres) between 1990 and 1994, according to one survey.

-- No comprehensive data are available on the net effect of federal conservation compliance provisions on farmers' costs. The available studies yield conflicting results. The results of these studies depend on soils, crops, farming practices, and other factors. Some studies have found that farmers using conservation tillage methods have lower costs and higher profits, while other studies report the opposite.

-- The program has multiple benefits, particularly reducing soil erosion and improving surface water quality. For example, for the 6.9 million acres it surveyed in 1994, USDA predicts that soil erosion will decrease by 10.4 tons per acre annually when farmers have fully applied their conservation practices. The program can also have some negative impacts. For example, some soil-conserving practices, such as crop residue management, hold excess fertilizer and pesticides on the fields, possibly allowing the chemicals to leach into groundwater supplies.

BACKGROUND

USDA's Natural Resources Conservation Service (NRCS) administers the conservation compliance program. It identifies highly erodible cropland, helps farmers plan and apply soil conservation practices, and annually inspects a sample of farms to ensure the proper installation and maintenance of conservation practices. The Department

defines cropland as highly erodible on the basis of soil type, field slope, rainfall, wind conditions, and other factors. NRCS state offices, through their local field offices, are responsible for implementing the program.

From 1986 through 1989, USDA helped farmers select which conservation practices they would include in their soil conservation plans to control erosion. Farmers had to develop their plans by January 1, 1990, and fully implement them by January 1, 1995. USDA encourages farmers to update their plans and revise erosion control practices as needed. USDA reported in September 1994 that farmers had prepared conservation compliance plans for about 142 million acres (37 percent of all cropland) and had fully implemented nearly 80 percent of the 1.8 million plans prepared for those acres.

Farmers can apply a number of practices to control soil erosion and meet program requirements. Among the many soil conservation practices USDA offers farmers are terraces, contour farming, and crop rotations. However, the principal practice farmers have chosen is crop residue management--spreading the crop residue remaining after harvest and keeping it on the soil's surface by reducing tillage operations. Conservation tillage is any tillage and planting system designed to leave at least 30 percent of soil surface covered by crop residue after planting.

USDA'S FLEXIBILITY IN SETTING AND IMPLEMENTING PROGRAM REQUIREMENTS

USDA has been flexible in both setting standards for acceptable levels of soil erosion and in applying these standards to farms at different locations. The Department initially required farmers to reduce erosion to the rate at which soil can erode and continue to be productive--called the soil loss tolerance level. In June 1987, USDA relaxed this standard if meeting it would prove an economic hardship for individual farmers. The relaxed standard, which varies by geographic region, requires farmers to essentially apply the most effective erosion control technique that is economically feasible. According to USDA officials, the relaxed standard still reduces soil erosion significantly. In May 1988, USDA offered the relaxed standard to farmers regardless of their economic circumstances.

USDA has also been flexible in implementing the soil erosion standards. The Department allowed individual state offices to develop alternative conservation practices that

farmers could use to meet conservation standards. However, in March 1994, USDA's Office of Inspector General reported that the Department applied the relaxed standard more strictly to some farmers than others. The Inspector General said that farms with similar soils, crops, and other conditions had to reduce erosion to different levels because the Department had applied the relaxed soil erosion standard inconsistently across adjoining counties in separate states.[1]

PROGRAM'S EFFECT ON FARMING PRACTICES AND FARMERS' COSTS

The conservation compliance program is contributing to farmers' increasing use of conservation tillage methods. However, the program's impact on farmers' costs is less certain. According to two surveys of tillage practices, conservation tillage increased by at least 30 percent during the 1990s. USDA officials estimate that about 75 percent of farmers' conservation plans call for using crop residue to reduce soil erosion.

The effect of the program on farmers' costs is uncertain. Meeting conservation compliance requirements may result in lower costs for some farmers and higher costs for others. The cost difference appears related to several factors, including the type of soil, climate conditions, crops, and management, according to several studies that compare tillage practices. For example, a study involving corn and soybean farmers in Indiana reported lower costs and higher profits using conservation tillage than with other tillage methods. For these farmers, operational costs--for less tillage--are lower, while crop yields remain about the same. In contrast, another study, in Oklahoma, reported that wheat farmers had higher costs and lower profits using conservation tillage than with other tillage methods. For these farmers, who planted wheat year after year, operational costs--for herbicides--were higher, while crop yields were lower.

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[1]For a more detailed discussion of USDA's decision to relax the soil loss standard, see Farm Programs: Conservation Compliance Provisions Could Be Made More Effective (GAO/RCED-90-206, Sept. 24, 1990). For more information on USDA's implementation of the program, see Soil and Wetlands Conservation: Soil Conservation Service Making Good Progress but Cultural Issues Need Attention (GAO/RCED-94-241, Sept. 27, 1994).

In addition, USDA's limited cost data indicate that certain conservation practices other than reduced tillage--such as using terraces and contour farming--increase farmers' short-term costs. However, USDA officials believe soil conservation practices will lower farmers' annual operating costs over time. (See enclosure I for a more detailed discussion of the program's impact on farming practices and farmers' costs.)

PROGRAM'S BENEFITS AND DRAWBACKS

The conservation compliance program is playing an important role in reducing soil erosion, but the methods used to meet program requirements may have environmental drawbacks. USDA estimates that soil erosion was reduced by about 3.3 tons per acre per year on highly erodible cultivated cropland between 1982 and 1992;[2] and it projects that soil erosion will be reduced by about 10.4 tons per acre per year when conservation plans are fully implemented for the 6.9 million acres it sampled during 1994. Most farmers use crop residue management techniques that control erosion by shielding the soil's surface from the impact of rain and wind shear and by reducing water runoff. In addition to controlling erosion, crop residue has been credited with improving surface water quality and increasing soil moisture and quality.

On the other hand, crop residue can complicate controlling weeds, insects, and diseases and create other problems. Tillage can help control some weeds, reduce insects' survival, and retard crop disease outbreaks. Conservation tillage, in contrast, places a greater demand on methods other than tillage to control these problems, such as the greater use of pesticides. In addition, crop residue can hold excess pesticides on cropland longer, which increases the chance that chemicals will leach into groundwater supplies. (See enclosure II for a more detailed discussion of the program's benefits and drawbacks.)

SCOPE AND METHODOLOGY

To obtain information for this product, we gathered and analyzed data and reports provided by USDA's Agricultural

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[2]USDA reports on the status of land, soil, water, and related resources on the nation's nonfederal land every 5 years. This information is the most comprehensive available on changes in soil erosion.

Research Service (ARS), Cooperative State Research, Education, and Extension Service, Economic Research Service, NRCS, and Office of Inspector General; the Environmental Protection Agency; the U.S. Geological Survey; the Conservation Technology Information Center; the Environmental Working Group; the Midwest Plan Service, Iowa State University; the National Association of Conservation Districts; the Center for Governmental Studies, University of Northern Illinois; and the Soil and Water Conservation Society. We also reviewed over 70 current articles, studies, and other pieces of literature.

We discussed the facts in this product with USDA officials, including the Associate Deputy Administrator, Natural Resources and Systems, ARS, and the Director, Conservation and Ecosystem Assistance Division, NRCS. They generally agreed with the information presented, and we have included their comments where appropriate.

We conducted our work between July 1994 and March 1995 in accordance with generally accepted government auditing standards. We did not independently verify the data on soil savings and implementation costs or research results showing the impact of conservation tillage methods on operating costs and yields that are used as examples in this product.

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Please contact me at (202) 512-5138 if you or your staff have any questions.

John W. Harman
Director, Food and
Agriculture Issues

Enclosures - 2

ENCLOSURE I

THE CONSERVATION COMPLIANCE PROGRAM'S EFFECT ON FARMING PRACTICES AND FARMERS' COSTS

This enclosure describes crop residue management--the maintenance of crop residue on a field to reduce soil erosion--and the effect of this practice on farming practices and net costs. About 75 percent of all conservation compliance plans specify crop residue management as the principal approach for controlling soil erosion.

PRACTICES USED TO REDUCE SOIL EROSION

The U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) offers farmers participating in the conservation compliance program a choice of a soil conservation practice or a combination of them to reduce soil erosion, such as maintaining crop residue cover on the soil's surface, annually rotating different crops on the same field, growing crops on the field's contour, building earthen terraces on the contour, and planting grassed waterways in natural drainage areas. NRCS estimates that 75 percent of farmers' conservation plans prescribe crop residue cover to control erosion. The practice of maintaining an effective amount of residue on the soil surface all year is called crop residue management.

Farmers keep crop residue cover on the soil's surface by reducing tillage operations. Tillage systems include all operations to cultivate the soil, plant and harvest crops, chop or shred crop residue, and apply pesticides and fertilizers. Tillage systems are broadly classified as conventional tillage and conservation tillage, according to the amount of crop residue maintained on the soil's surface after harvest.

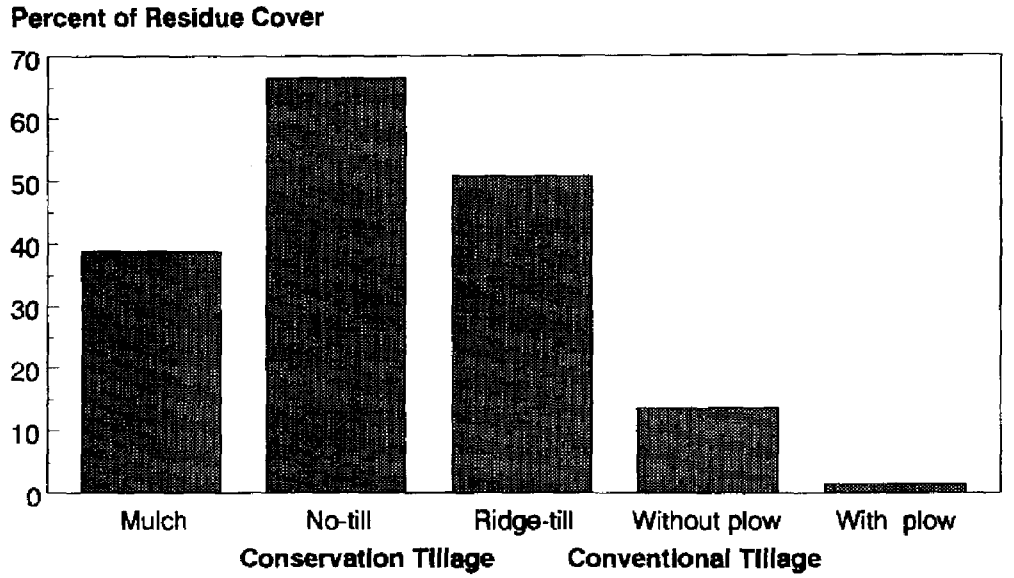
Conventional tillage is the sequence of operations commonly used in a given region that results in less than 30-percent residue cover on the soil's surface. The operations vary between regions.

Conservation tillage is any tillage system that maintains a residue of the prior year's crop on the soil after planting of the new crop. The residue from the prior crop must cover at least 30 percent of the soil's surface or equal 1,000 pounds per acre after planting and during other critical erosion periods. Conservation tillage encompasses no-till, ridge-till, and mulch-till field operations. No-till operations leave the soil undisturbed from harvest to planting, except for nutrient injection. Planting occurs in a narrow seedbed, or slot, and weeds are controlled primarily with herbicides. Ridge-till operations are similar to no-till, but planting occurs in a seedbed prepared on cultivated ridges, leaving residue between

the ridges. Mulch-till operations disturb the entire surface of the soil prior to planting but maintain at least 30-percent crop residue cover. Weeds are controlled with herbicides and/or cultivation.

NRCS advises farmers that most tillage operations bury some crop residues. The amount buried depends primarily on the type of machine used and the type of residue being tilled. Machines designed to turn soil over, throw soil, and till the entire machine width tend to bury more residue. The agency advises farmers to set equipment to work more shallowly and drive more slowly and to use tillage points that fracture the soil rather than turn or throw it. Figure I.1 compares the percent of soil surface with crop residue cover under conventional and conservation tillage operations during 1993.

Figure I.1: Percent of Soil's Surface With Crop Residue Cover During 1993



Notes: "Without plow" and "with plow" refer to use of a moldboard plow. These data are based on a survey conducted by USDA's National Agricultural Statistics Service and Economic Research Service. The survey examined cropland planted in corn, soybeans, upland cotton, and wheat in selected states.

Source: Data from USDA's 1993 Cropping Practices Survey.

GROWTH OF CONSERVATION TILLAGE

Surveys of tillage practices show conservation tillage increased during the 1990s. Table I.1 provides the results of annual national surveys of crop residue management by the Conservation Technology Information Center. Between 1990 and 1994, conservation tillage increased over 30 percent, from occurring on 73.2 million acres to occurring on 97.5 million acres; and no-till operations increased over 130 percent, from occurring on 16.9 million acres to occurring on 39.0 million acres. Annual USDA surveys that examine cropland planted in major field crops in selected states--the Cropping Practices Surveys--show similar increases.

Table I.1: Changes in Tillage Practices Between 1990 and 1994

Acres in millions

Year	Conservation tillage				Conventional tillage	Total cropland planted
	No-till	Ridge-till	Mulch-till	Total		
1990	16.9	3.0	53.3	73.2	207.7	281.0
1991	20.6	3.2	55.3	79.2	202.1	281.2
1992	28.1	3.4	57.3	88.7	194.2	282.9
1993	34.8	3.5	58.9	97.1	181.0	278.2
1994	39.0	3.6	56.8	97.5	184.6	283.9

Notes: Data for this survey are gathered by USDA's NRCS; Consolidated Farm Service Agency; and Cooperative State Research, Education, and Extension Service field staff. The survey includes all planted cropland.

Source: National Crop Residue Management Survey, Conservation Technology Information Center.

IMPACT OF CONSERVATION PRACTICES ON FARMERS' COSTS

Meeting the requirements of the conservation compliance program may lower costs for some farmers and raise costs for others. However, no comprehensive data are available on these costs. This section discusses regional studies of the costs of different tillage practices and other conservation compliance methods and the expected impact on farmers' operating costs.

Costs of Conservation Tillage

Studies by USDA, researchers, farmers' groups, and others have compared producers' inputs, outputs, costs, and profits

associated with different tillage systems and crops. The results of these studies depend on the soil type, climate conditions, crops, crop rotations, management practices, and other factors. The four studies discussed below--two finding that conservation tillage lowered costs and two finding that it did not--demonstrate the differences in study results for given areas.

-- Farmers participating in the Farming for Maximum Efficiency program[3] reported 5-year (1989-93) average conservation tillage costs were lower than conventional tillage costs for corn and soybean fields in 19 northern Indiana counties, while yields were comparable. Indiana and Iowa farmers in this program also reported higher 1993 profits for corn and soybean fields under conservation tillage than under conventional tillage. The 5-year comparison included 692 corn and 619 soybean fields, and the 1993 comparison included 488 corn and 392 soybean fields.

-- According to researchers from USDA's Agricultural Research Service and Washington State University, a study in the Palouse region of southeastern Washington showed that a wheat-barley-pea rotation with conservation tillage and maximum weed management was more profitable than other systems. The study compared the economic performance of 12 farming systems, field-tested during 1986-91, consisting of two crop rotations with two types of tillage practices (conventional and conservation tillage) and three types of weed management.

-- A 10-year study, from 1977 to 1986, conducted at an agricultural experiment station in Oklahoma, found that Oklahoma wheat growers in a humid part of the state could produce the best return per acre from a conventional tillage system. The study compared the relative impacts of six alternative tillage methods for continuous winter wheat on grain yield and costs. It found that the no-till system was the least economical of those evaluated because of high herbicide costs and low yields. The researchers believed a number of factors, including root- and soil-borne pathogens and competition from weeds, may contribute to the low yields in continuous wheat production in mulched soils.

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[3]This program--called the MAX program--began in 1987 under another name. It includes farmers from Corn Belt, Plains, and other states who voluntarily enroll acreage and record detailed cost and profit data. The results of the MAX program are not intended to be portrayed as research data.

-- Purdue University researchers reported net incomes for no-till systems on all farms in their computer model were consistently lower than incomes for conventional moldboard and chisel plow systems because of lower yields and higher herbicide costs. These findings resulted from an analysis of 1981-88 test plot data for corn, soybeans, and wheat from a Purdue agronomy farm. The study determined which crop rotations and weed management systems result in highest net farm income for three farm sizes under alternative tillage systems. The researchers used a soil type commonly found in the East-Central Corn Belt.

Estimated Costs of Other Conservation Practices

According to NRCS state officials, cost estimates for terraces, grassed waterways, and contour farming vary by state and within states, depending on the steepness of the land where the practices are installed. For example, NRCS officials estimate that terrace construction costs varied from $230 per acre in western Iowa to $720 per acre in eastern Iowa, according to soil depth and spacing requirements. In addition, NRCS officials estimate that between 80 and 90 percent of the terraces in Iowa are built on slopes ranging from 5 to 14 percent. In contrast, terrace construction costs in eastern Kansas range from $75 per acre to $350 per acre because of variations in the slope of the land. Table I.2 provides an example of estimated costs for three conservation practices in an area where the practices are commonly used.

Table I.2: Costs of Selected Conservation Practices in an Eastern Kansas Watershed

	Terraces	Grassed waterways	Contour farming
Percent slope	Installation cost per acre	Installation cost per acre	Additional cost per acre per year
0-3	$ 75	$500	$3.00
3-5	105	650	4.50
5-10	150	850	3.50[a]
>10 percent	350	0[b]	0[b]

[a]Contour farming costs increase as slopes rise to about 5 percent, then decrease for steeper slopes because the farmer makes fewer turns with machinery and consumes less fuel.

[b]Grassed waterways and contour farming are not used on field slopes over 10 percent.

Source: NRCS.

THE CONSERVATION COMPLIANCE PROGRAM'S BENEFITS AND DRAWBACKS

This enclosure discusses the advantages and disadvantages of crop residue on fields to reduce soil erosion. Crop residue is the principal method cited in conservation compliance plans to reduce soil erosion. USDA has reported that farmers prepared 1.8 million plans for soil conservation practices on 142 million acres of highly erodible land. USDA estimates annual soil erosion decreased 3.3 tons per acre on highly erodible cultivated cropland between 1982 and 1992, and it projects an annual decrease of 10.4 tons per acre when planned practices are fully installed for the 6.9 million acres it sampled in 1994.

BENEFITS OF CROP RESIDUE IN REDUCING SOIL EROSION

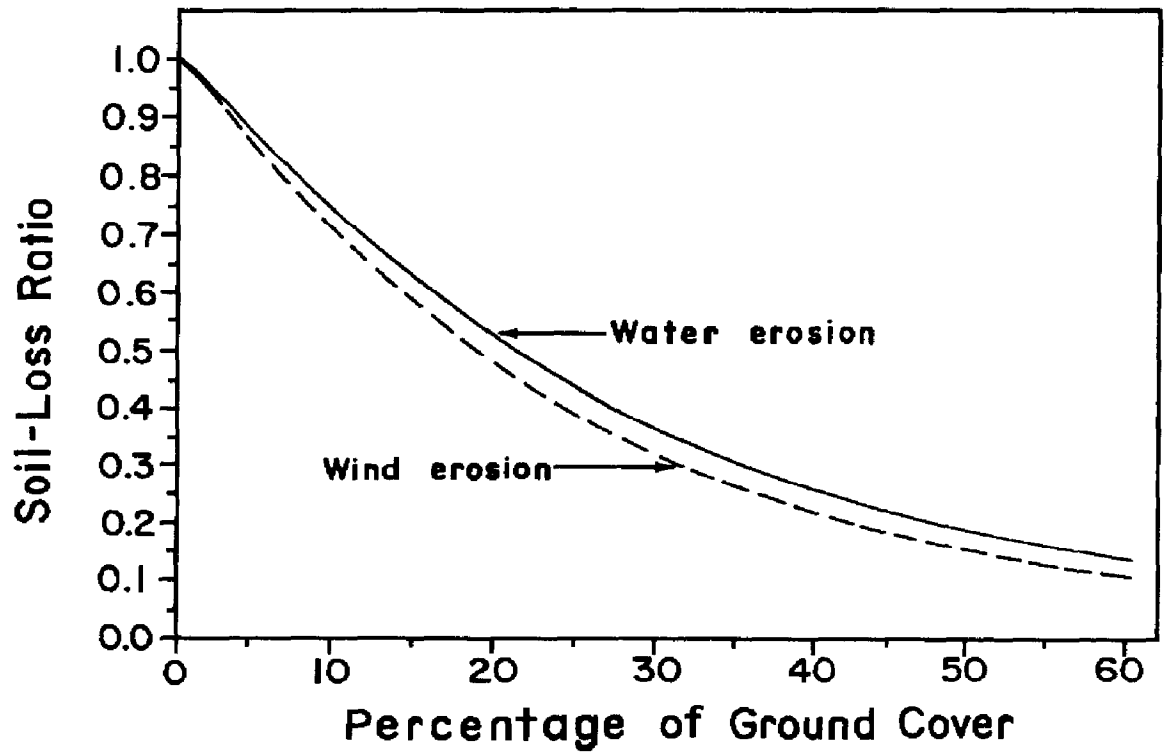
Crop residue can help reduce soil erosion, thereby keeping cropland productive and protecting the environment. This section presents data on reductions in soil erosion and discusses the benefits of crop residue in helping to reduce soil losses.

Reduced Soil Erosion

According to NRCS, conservation compliance is significantly decreasing soil erosion. Data from the agency's 1982 and 1992 national resources inventories show that the average annual soil erosion caused by water decreased by 1.9 tons per acre over the period and the average erosion caused by wind decreased by 1.4 tons per acre on highly erodible cultivated cropland. NRCS also predicts, for the 6.9 million acres it surveyed in 1994, that farmers will save 10.4 tons per acre when conservation practices are fully installed.

As of September 30, 1994, NRCS estimated that about 75 percent of the 1.8 million conservation compliance plans prepared by farmers for 142 million acres call for the use of crop residue to control erosion. Research shows that covering the soil surface with crop residue reduces soil erosion. Figure II.1 shows the effect of residue cover on soil erosion.

Figure II.1: Relationship Between Residue Cover and Soil Erosion



Note: The soil-loss ratio is the ratio of soil erosion with crop residue cover to soil erosion without crop residue under the same conditions. The percentage of ground cover is the amount of the soil's surface covered by crop residue.

Source: USDA's Agricultural Research Service.

How Crop Residue Reduces Soil Erosion

Crop residue protects the soil from the erosive effects of rain and wind. Overall, crop residue on soil cushions the impact of raindrops, thereby reducing or eliminating splash erosion, and forms small natural dams, which causes the runoff to form ponds. Sediment is deposited in these ponds and remains in the field. The percentage of rainfall retained by crop residue is inversely related to the amount and intensity of rainfall. Residue also prevents much of the wind from contacting soil particles, which causes soil movement, and traps moving soil particles. The ability of residue to control soil erosion also depends on the

type and position of the residue, rainfall, and the soil moisture and temperature.

The amount of protection crop residue provides also depends on the type of crop residue remaining in the field. Some crops, such as corn, sorghum, and small grains, typically produce more residue than others, such as cotton and soybeans. In addition, some crop residues are nonfragile, while others are fragile. Crops that produce more nonfragile residue leave more protective cover on the soil surface after field operations than do other crops. Corn, sorghum, wheat, oats, and barley are among the nonfragile crops; and soybeans, sunflowers, sugar beets, and potatoes are among the fragile crops.

The crop residue's distribution, position, and size are also important to erosion control. Uniform distribution of crop stalks and chaff behind a combine during harvest reduces residue clustering in the field and minimizes tillage operations, which destroy residue. Standing stubble is more effective at controlling wind erosion than the same amount of residue lying flat, and the higher the residue stands above the ground, the more it reduces wind erosion. Moreover, several pieces of small-stemmed residue, such as wheat or millet, create more wind friction than one large-stemmed piece, such as corn or sorghum.

The quantity of precipitation affects the amount of crop residue available to cover the soil's surface. Crops produce less residue under drought conditions. The amount of crop residue available is usually determined at harvest and is reduced by tillage and decay until seeding of another crop. Finally, the availability of moisture and the temperature influence residue decomposition. Residues decompose faster under warm temperatures and moist conditions, which enhance microbial activity. Decomposition is slower in dry or cold environments.

OTHER BENEFITS AND DRAWBACKS

This section discusses the advantages and disadvantages of crop residue in three areas: (1) water retention and quality; (2) soil quality, temperature, and moisture; and (3) weeds, insects, and diseases.

Water Retention and Quality

The water ponding and retention that crop residue causes can obstruct and divert runoff, thus diminishing its velocity. This increases the time water remains on fields and causes greater infiltration. Surface residue may also prevent the formation of networks of small furrows or channels that allow runoff and suspended sediment to be rapidly transported from fields. Crop

residue can also reduce runoff containing chemicals from entering into surface water and protect surface water from sediment-associated fertilizer and pesticide losses. However, reductions in chemical losses may not be proportionate to reductions in soil losses. This is because residue often reduces the transport of coarse soil particles (which absorb less chemicals) more than the transport of smaller clay particles and organic matter (which have higher capacities to absorb chemicals).

Although greater infiltration resulting from crop residue provides additional soil moisture to benefit crops during periods of low rainfall, it raises concerns about the potential leaching of excess nutrients and pesticides into groundwater. USDA's Economic Research Service and others report that some research results suggest that conservation tillage practices can increase losses through chemical leaching, while other studies suggest that the amount of leaching may depend on the chemical, type of soil, and weather--in addition to tillage practices.

Soil Quality, Temperature, and Moisture

USDA's Agricultural Research Service reports that leaving crop residue on the soil's surface by reducing tillage can increase the organic matter in the soil, primarily in the top inch of the soil, which results in higher-quality soil over time. Increases in organic matter depend on the amount and the management of crop residue left on the surface. Greater increases were found to occur where crop residues were augmented with winter cover crops. Lesser increases occurred in dry, warm regions, where the amount of crop residue was limited and high temperatures caused rapid biological oxidation of the organic matter.

Maintaining surface residue generally increases water infiltration and reduces evaporation, which allows more water to be stored in the soil. Additional soil moisture can benefit crops during low-rainfall periods, and when additional water is conserved, more intensive cropping is possible in certain areas. Conversely, surface residue may keep the soil cooler and wetter longer during high-moisture conditions and when soils are poorly drained. These conditions can cause problems in planting crops, especially in the early spring. Lower soil temperatures may also reduce yields of spring-planted crops in northern latitudes.

Weeds, Insects, and Diseases

Weed development and control vary with location and can be a challenge to successful conservation tillage systems. Converting from a conventional tillage to a conservation tillage system restricts the use of many tillage implements and places a greater demand on methods other than tillage to control weeds. This is

especially true with a no-till system. The choice of the tillage system affects which weed species occur, whether growth is discouraged or encouraged, and the choice and amount of herbicide used. Diversified crop rotation is considered one of the best ways to combat weeds in any tillage system and to lower herbicide inputs.

The potential for insect problems is slightly greater for conservation tillage than for conventional tillage. Insect control depends on the type of equipment, timing, depth, and frequency of tillage operations interacting with soil and environmental conditions. Insects that spend a portion of their life in the soil may develop more slowly in conservation tillage systems, but reduced tillage systems may also improve insects' survival during the winter. Some scientists believe insect problems can be decreased by increasing the diversity of crops.

Residue cover generally increases soil moisture, decreases the soil temperature early in the season, and potentially increases weeds and plants that reseed themselves from previous seasons. These factors affect the growth and survival of many important organisms that live in soil, crop residue, or weeds and cause crop disease. A number of strategies--such as seed treatment with fungicides, the use of disease-resistant varieties, and the use of high-quality seeds--can help battle crop diseases in the absence of tillage. Integration of several strategies is often necessary. Crop rotation, or the choice of the sequence of crops, is an effective means of controlling crop diseases under conservation tillage.

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