CROP RESIDUES REDUCE SOIL EROSION

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ABSTRACT

Erosion of cropland is a severe problem. This article reviews some general soil erosion processes and emphasizes the role of crop residues in reducing soil erosion. Discussions include interrill erosion, rill erosion, surface seals, plant canopy, and tillage implements. Research results from laboratory experiments on soil erosion and field experiments help to appraise the effectiveness of crop residues in reducing cropland soil erosion. The article also discusses application of low cropping and management factor values for conservation tillage used in the revised universal soil loss equation (RUSLE).

INTRODUCTION

Advances in chemical weed control technology have allowed many farmers to either eliminate or minimize tillage practices. No-till farming, in which crops are planted in residues left from the previous season, has gained acceptance throughout the country. Erosion is reduced because of protective cover left on the surface. No-till also reduces erosion because of minimum disturbance of the soil. The crop is planted in narrow slots opened in the soil by rolling coulters or small chisels and no secondary tillage is done.

A combination of tillage and cropping practices that reduces the amount and frequency of tillage as much as possible while maximizing the amount of crop residues left on the soil surface effectively reduces erosion as compared to conventional-till. We believe any change in cultural practices that provides significantly increased amounts of protective cover almost always reduces soil erosion. Plant roots and incorporated plant residues also help to reduce soil erosion.

The frequency and intensity of tillage operations in conventional tillage need to be reduced to utilize potential benefits of crop residues for erosion control. Reduced tillage systems eliminate use of the turnplow that almost completely incorporates crop residue. Reduced tillage systems may consist of one or more operations with implements such as disks, chisels, and "do-all' cultivators. A "do-all" cultivator is a seedbed conditioning implement that, in a single pass, loosens, pulverizes, and smooths the soil surface in preparation for planting. Reduced tillage systems also may eliminate use of cultivation for row crops.

The objectives of this article are to:

(1). Summarize some general observations about the soil erosion process, and

(2). Appraise the effectiveness of crop residues in reducing cropland soil erosion.

THE SOIL EROSION PROCESS

Soil erosion occurs on two areas known as rill and interrill areas. A rill may be defined as a miniature trench or incised area in the soil surface. A rill can be caused by concentrated flow, but also can be initiated by a tillage implement such as a spiked-tooth harrow. In the latter case, the harrow causes marks or depressions to be left in the soil surface. Furrows between ridged rows act as large rills. Interrill areas, as the terminology implies, include the soil surface contained between rills.

Simply put, soil erosion by rainfall occurs as a result of soil detachment by raindrops and runoff and transport by runoff. Detachment by rainfall, transport by rainfall, detachment by runoff, and transport by runoff contribute to the total soil erosion process, although all of these sub-processes may not occur on all source areas (Foster and Meyer 1975). Soil erosion is further complicated because rainfall, which provides the initial energy, is made of raindrops of varying sizes and impact velocities. Soils being eroded have primary particle sizes, cohesiveness, structure, and other characteristics that affect the erosion process.

The amount of soil eroded from a field area is limited by the transport capacity of runoff. Runoff amounts are directly affected by rainfall amounts, but are also influenced by any soil properties that affect the infiltration rate of water through the soil profile. Antecedent soil moisture content, amount and type of protective cover, slope gradient, and slope length also affect runoff amounts.

CROP RESIDUE EFFECT

Crop residues left on the ground surface provide considerable protection of the soil surface from the impact of raindrops. The surface residue also acts as surface roughness that increases surface retention and enhances infiltration. The residue creates barriers and obstructions over or around which runoff has to move (Mannering and Meyer 1963). Thus residue reduces flow velocity and reduces the surface area exposed to direct raindrop impact (McGregor, Mutchler, and Römkens 1990; Foster and Meyer 1975). Crop residues reduce surface seal formation and increase surface detention (Lang et al. 1984). Increased flow depth on the soil surface acts as a protective cushion and further decreases soil detachment by raindrops (Mutchler and Young, 1975; Onstad, 1984). Residues dissipate a part of the energy of the falling raindrops and of flowing runoff (Mannering and Meyer 1963; Meyer, Wischmeier, and Foster 1970); Lang et al. 1984).

The process of raindrops breaking soil aggregates into smaller more easily transported sizes is either eliminated or reduced because of surface cover. Likewise, surface cover reduces the splash of soil particles down-slope or to runoff channels. Soil moisture under residue cover is increased as infiltration rates increase. There is less detached material available for transport by runoff (Meyer and Mannering 1967; Foster and Meyer 1975). Runoff amounts and velocities are reduced because of the prevention of soil splash, which would tend to close soil pores used for infiltration (Meyer and Mannering 1963; Mannering and Meyer 1963).

The type of crop, the amount and type of residues produced, removal or non-removal of residues, and tillage effects on residue placement influence the effectiveness of crop residues in controlling erosion. Quantity, distribution, and durability of residues vary for different crops. Corn residue amounts are normally higher than residues from small grain, soybean, cotton, and tobacco (Mannering and Fenster 1977).

Incorporated residues add organic matter to the soil that improves soil conditions and infiltration characteristics. The soil condition and infiltration characteristics are improved. Obviously, surface residues help control erosion better than incorporated residues. Some researchers feel that mechanical treatment of surface residues, such as spreading and shredding, often provides the most effective surface cover (Meyer and Mannering 1963). Shredding increases the total surface area of residue, which is an advantage in covering the ground surface.

Rainfall Simulation Research

Rainfall simulation research as compared to that under natural rainfall allows experiments to be conducted so that variables affecting runoff and soil erosion can be isolated and evaluated. Also, collection of data under these controlled conditions is quicker than under the varying conditions of natural rainfall. Some of the beneficial effects of residue, noted above, in controlling erosion were observed with field experiments using rainfall simulation (Mannering and Meyer 1963; Mannering and Fenster 1977; Meyer and Mannering 1963; Meyer, Wischmeier, and Foster 1970; McGregor, Mutchler, and Römkens 1990).

The effects of residue cover on soil erosion also have been conducted with rainfall simulation in the laboratory (Franti, Foster, and Monke 1996b; Harmon and Meyer 1978; Lang et al. 1984; Lattanzi, Meyer, and Baumgardner 1974; McGregor, Bengtson, and Mutchler 1988a; McGregor, Bengtson, and Mutchler 1988b). Such research generally has shown that increases in surface residue cause significant exponential decreases in soil loss over time under simulated rainfall and that interrill erosion can be virtually eliminated by complete residue cover.

Rainfall Simulation Research with Soybean and Corn Residues

Various soybean tillage and planting systems in an Iowa study were evaluated under simulated rainfall using replicated plots on a silt loam soil on a 10% slope (Shelton, Jasa, and Dickey 1986). The most intense tillage was done with a double disk system.

Residues from soybean in narrow spaced rows significantly reduced soil erosion and soil erosion rates for the double disk tillage system compared to the same tillage system used in residues from soybean in wide spaced rows. Accumulated runoff, runoff rate, and sediment concentration were reduced for all tillage systems used in narrow row soybean residue compared to the same systems used in residue from wide spaced rows.

Rainfall simulation tests in Nebraska were conducted on six tillage treatments used on both 5 and 10% slopes in continuous corn (Dickey et al. 1984). Those treatments that left 20% or more of the soil surface covered with residue reduced soil erosion by at least 50% of that which occurred under a moldboard plow system.

A simulated rainfall study in Nebraska was conducted on 5 and 10% sloping plots where corn and soybean had been grown the previous season (Dickey et al. 1985). Soil losses from a chisel-disk-plant operation was 37% greater from soybean plots than from corn plots because of 48% less surface cover provided by the soybean residue. Soil losses from a no-till and plant operation were 116% greater from soybean plots than from corn plots because of 28% less surface cover provided by the soybean residue.

Corn residue produced substantial reductions in runoff rate, runoff velocity, sediment concentration, and soil loss rate along the entire 22.1- m plot slope-length in an Iowa simulated rainfall study (Gilley et al. 1986). Corn residue rates ranged from 0.0 to 6.7 t/ha and slopes averaged about 5%. Runoff rate, sediment concentration, and soil loss rate usually increased with down-slope distance on plots subject to rilling. Little change in interrill sediment concentration occurred with down-slope distance although greater interrill soil loss rates increased with slope length. Soil loss rates and sediment concentrations from rills increased rapidly near the bottom of their plots.

Interrill and Rill Erosion

Processes related to raindrop impact predominate on interrill areas, and processes related to the runoff predominate on rill areas. Crop residues affect rill and interrill erosion differently in these respective areas because of differences in rill erosion relative to interrill erosion.

Soil is detached and moved from interrill areas by raindrop impact and splash (Mutchler and Young 1975; Young 1984). The amount of raindrop splash is partially dependent on raindrop size, which in turn is a function of rainfall intensity. The erosive potential of rainfall is directly related to raindrop fall velocity, size distribution, and total mass at impact (Meyer and Mannering 1967). Loose unprotected aggregates of cohesive soils (loams, silty clay loams, and silt loams) are easily detached, broken down, and washed away (Epstein and Grant 1971).

The resistance of a soil to erosive forces depends on the size distribution, shape, density, cohesiveness, degree of aggregation etc. of soil particles, plus the soil's macrostructure (cloddiness) as it affects ease of detachment from the soil mass and transportation by runoff. The smaller and rougher particles are generally less easily detached but more easily transported. Loam and silt loams are generally more erodible than soils with high clay or sand contents. The loam and silt loams also are more susceptible to surface sealing. Soils with a high clay content do not easily erode because the soil particles are resistant to detachment. Soils with a high sand content do not easily erode even though particles from these soils are very easily detached. Soil particles do not erode easily when there is reduced transport capacity associated with low runoff rates.

Silt and clay particles are often eroded together in the form of sand-size aggregates. Cohesive soils usually produce sediment that consists of both primary particles and soil aggregates. Non-cohesive soils usually produce sediment composed of primary particles (Young, 1980; Meyer and Mannering 1967).

Rills in soils without incorporated residue tend to be deeper and narrower than those in soils with medium and high rates of incorporated residue (Van Liew and Saxton 1983). The shearing forces of flowing water in existing rills accelerates rill erosion. The amount of rill erosion depends on hydraulics of flow in the rills and the soil resistance to rill erosion (Foster, Huggins, and Meyer 1984; Young (1984). Heavy residue cover on moderate slopes and low slope lengths may reduce shear stress to where very little rill erosion will occur.

In a simulated rainfall field experiment in Indiana, critical slope lengths (where rill erosion begins underneath residue) were determined for unanchored corn stalks (Foster, Johnson, and Moldenhauer 1982a). Those soils not susceptible to rilling had critical slope lengths of 45 to 200 m for residue rates ranging from 2 to 9 t/ha. Soils susceptible to rilling had critical slope lengths of 40 to 150 m for residue rates ranging from 6 to 13 t/ha. At low residue rates, corn stalk residue was washed away piece by piece when critical slope lengths were reached. At greater residue rates, a sectio'. of residue (1-m or longer) moved away from the original site and lodged against other residue or stubble down-slope. In a related study, equations were derived that give critical slope lengths for failure of unanchored residue on untilled soils as a function of residue type (corn stalk or wheat straw) and amount, slope, rainfall erosivity, runoff, and soil susceptibility to rill erosion (Foster, Johnson, and Moldenhauer 1982a).

Incorporated Residue Effect

The effectiveness of incorporated residues in reducing soil erosion is generally thought to depend on the erosivity of the runoff, steepness of slope, erodibility of soil, and the amount of residue on the surface. Heavy surface residue, for example, reduces the shear stress to where very little rill erosion would occur regardless of the amount of incorporated residue. The same amount of incorporated residue with little surface residue would be expected to reduce the soil erosion, especially the rill erosion.

Incorporated residues become exposed as rills begin to develop in soils containing them. These exposed residues help to reduce rill erosion by reducing the shear stress of flowing water (Van Liew and Saxton 1983). Scouring is also reduced when the incorporated residues halt head-cut advance (Franti, Foster, and Monke 1996a). Incorporated residues act as a binding agent in the soil.

In laboratory and field studies under simulated rainfall in northern Mississippi, incorporated residues had little effect on interrill erosion immediately following the incorporation of the residues on soil with low to moderate slopes (McGregor, Bengtson, and Mutchler 1988b; McGregor, Bengtson, and Mutchler 1990; McGregor, Mutchler, and Römkens 1990). Soil erosion benefits usually credited to incorporation of crop residues may not always be merited for recently incorporated residues. The laboratory studies were conducted with wheat straw residue applied on soils with slopes of 2.5%. The field studies had some plots with corn residues and others with wheat residues, all on slopes of about 4%.

Rill erosion rates immediately following incorporation of corn stalk residues were significantly less under simulated rainfall for large amounts of incorporated residue compared to no residue in an Indiana field study (Brown, Foster, and Beasley 1989). Two different sizes of corn stalk residues were incorporated at rates from 0 to 4.5 t/ha. The relative size of the incorporated material was not a significant factor in reducing soil loss rates. The study was conducted with added water inflow in addition to the simulated rainfall on higher slopes (7 to 11%).

In a follow-up study, simulated rainfall and added inflow were used to study rill erosion one year after the incorporation of corn stalk residue. On freshly tilled soil, rill erosion rates were reduced by as much as 30% for a residue rate of 4.5 t/ha compared to the 0 t/ha treatment. Residue had little effect on erosion of consolidated soil. The soil consolidation was only for a one year period, but considerable residue decomposition may have taken place. The researchers reported that average soil loss from the freshly tilled soil was almost twice that from consolidated soil (Brown et al. 1990).

Stable, equally spaced residue elements were incorporated along a single, field-scale rill in a laboratory study to examine the effect of spacing on soil loss. Adjusted soil loss per unit length of rill, emphasizing the effect of residue spacing, increased with greater discharge rate and residue spacing. No significant scouring occurred below a residue element when they were spaced at least 1.2 m apart (Franti, Foster, and Monke 1996b).

Plant Canopy

Agricultural crops provide protective canopy that absorbs the impact of falling raindrops. Weeds also provide protective canopy. The effectiveness of the canopy in reducing raindrop kinetic energy depends primarily on the amount of soil surface covered and the height of the canopy (Khan, Monke, and Foster

1988).

Canopy protects the soil from raindrops. However, waterdrops that form on canopy are larger than raindrops. These large waterdrops have a greater terminal velocity and hence greater kinetic energy than raindrops. Thus the benefit of canopy is somewhat reduced for high growing crops such as corn.

Crop Residues and Tillage Implements

Tillage practices influence the placement of crop residues. The placement of the residues can have major effects on soil losses from erosion (Mannering and Fenster 1977). Although the surface micro-topography and plow-layer porosity of the soil following tillage strongly affect soil erosion, residue placement is usually the dominant factor affecting the erosion process (Mannering and Fenster 1977).

Tillage implements commonly used for a wide range of residue placement include moldboard plows; chisel plows and offset disks; field cultivators and shallow disks; and sweep or blade type implements (Mannering and Fenster 1977). Moldboard plows leave little residue on the surface. Most of the residue is buried to a depth of 12 to 25 cm. Chisel plows and offset disks can leave appreciable amounts of residue on the surface, but partially incorporate some of the residues. These implements are also normally used to till at depths of 12 to 25 cm. Field cultivators and shallow disks leave appreciable amounts of residues on the surface and partially incorporate residues to a depth of 7 to 15 cm. Sweep or blade type implements can be used to undercut residues at shallow depths of 7 to 12 cm, while most of the residues are left on the soil surface (Mannering and Fenster 1977).

Field data were collected in Kansas to determine the mass reduction of standing residue by selected tillage operations (Wagner and Nelson 1995). A wide-sweep plow flattened 7% of standing corn residue. Tandem-disk harrows with a straight-shank chisel plow flattened 89 to 100% of standing corn residue, but tandem-disk harrows with a twisted-point chisel plow flattened 76% of the standing corn residue. An implement such as a rotary cutter that spreads nearly all of the residue over the surface, without also tilling the soil, is preferable for erosion control purposes.

MULCH FACTOR AS A FUNCTION OF PERCENT GROUND COVER

A mulch factor for use in estimating soil loss is equal to the ratio of soil loss with a given percentage of mulch cover to the soil loss with no mulch (Wischmeier 1973; Wischmeier and Smith 1978). The following equation closely approximates the relationship of their mulch factor (MF) as a function of percent ground cover (P) when there is no plant canopy:

$$MF = e^{-0.031(P - Ps)} \qquad (1)$$

where MF = 1 for $P < P_s$ and P_s is the percent ground cover (4%) at which cover begins to have a beneficial effect. The mulch factor represents both the rill and interrill components of the erosion process.

The mulch factor has also been expressed as:

$$F = e^{-bm} \qquad (2)$$

where F is the mulch factor, m is percent residue cover, and b is a regression constant (Cogo, Moldenhauer, and Foster 1984). The effects of surface roughness and cover interact, but the effect of residue cover is greater than the effect of surface roughness for high values of residue cover (Cogo, Moldenhauer, and Foster 1984). A roughness index was defined as the standard error among logarithms of surface elevations obtained with a 102-cm micro-relief meter with pins spaced on a 5.1-cm grid.

Research results from Indiana, Illinois, and Iowa showed values of b ranging from -0.016 to -0.72 (Laflen, Moldenhauer, and Colvin 1981). The scientists involved in the research compared these values to an approximate value of -0.025 for the combined rill and interrill cover relationship that they estimated from Figure 6 in Agriculture Handbook 537 (Wischmeier and Smith 1978).

An interrill mulch factor as a function of percent of wheat straw cover was derived using rainfall simulation in the laboratory (McGregor, Bengtson, and Mutchler 1988a). The b value for this mulch factor was -0.015. More research is needed to evaluate the effectiveness of incorporated residues and the effectiveness of different ratios of surface-to-incorporated rates of residues.

REVISED UNIVERSAL SOIL LOSS EQUATION

Potential for erosion varies across the country depending upon the distribution and intensity of rainfall throughout the year. Some areas have more rainfall than others. Residue and canopy cover and minimal soil disturbance help to protect the soil surface during periods when the most erosive storms are expected to occur.

The revised universal soil loss equation (RUSLE) has wide applicability. The equation has been a dependable guide for resource conservationists in making practical recommendations for long-range planning. Interaction occurs with many of the variables that influence erosion. These interaction effects are lumped together in RUSLE (Renard et al. 1997).

The equation contains an erosivity (EI or R) factor that can be evaluated on the basis of local climatic conditions. Development of the EI concept helped to allow the original universal soil loss equation (USLE) to apply in different regions of the country (Wischmeier and Smith 1958; Wischmeier 1959; Wischmeier and Smith 1965).

The RUSLE equation is a "hybrid" equation in that it retains the main USLE structure and the empirical relationship of soil loss with storm erosivity while also using equations based on fundamental erosion processes to define the factor values (Renard et al. 1997). The RUSLE equation is:

$$A = R\,K\,L\,S\,C\,P \tag{3}$$

where A is the computed soil loss per unit area per time. The unit of measure is the same as that of K times R.

R, the rainfall factor, is the number of erosion-index (EI) units in a normal year's rainfall. The EI of each storm is the kinetic energy (MJ/ha) of storm rainfall times the maximum 30-minute intensity (mm/h) of storm rainfall.

K, the soil erodibility factor, is the soil loss (t) per unit of erosion index (MJ•mm/ha•h) per unit of area (ha) for a specific soil in cultivated continuous fallow up and down-slope on a 9% slope that is 22.1-m long.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 22.1-m length on the same soil type and gradient.

S, the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a 9% slope.

C, the cropping-management factor, is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which factor K is evaluated.

P, the support practice factor, is the ratio of soil loss with contouring, strip-cropping or terracing to that with straight-row farming up-and-down-slope.

Recent research showed that erosivity (R) values used in RUSLE for northern Mississippi needed to be adjusted upward by about 30% (McGregor et al. 1995). These R-value evaluations provided impetus needed for current on-going Natural Resource Conservation Service (NRCS) re-evaluation of R values in the eastern United States. The Illinois Water Survey is under contract to the NRCS to develop a new R factor, 10 year EI, and possibly new EI distribution zones for the Eastern United States. These maps should be available for use in RUSLE2 by the end of 2000.

Some soils erode more readily than others even with the same rainfall, land slope, and cropping management factors. This difference, due to properties of the soil, is known as soil erodibility (Wischmeier and Smith 1978). Soil erodibility is affected by physical, chemical, and mineralogical soil properties and by their interactions (Renard et al. 1997). Soil erodibility is a function of soil properties that affect runoff and its capacity to detach and transport sediment. Soil erodibility also is a function of those soil properties that affect detachment of soil particles by raindrop impact. Soil properties reported to influence erodibility by water are: (1) those that affect the infiltration rate, permeability and total water capacity; and (2) those that resist the dispersion, splashing, abrasion, and transporting forces of rainfall and runoff. The best estimates of soil erodibility are obtained by using standard erosion plots under natural rainfall over several years. But soil erodibility can be estimated with a soil-erodibility nomograph that uses five soil and soil-profile parameters (Wischmeier, Johnson, and Cross 1971).

The RUSLE uses the C-factor to reflect the effect of cropping and management practices on erosion rates (Renard et al. 1997). Canopy, cover, tillage and residual effects can be used as sub-factors to estimate C-factors for undisturbed lands (Wischmeier 1975). Sub-factors for land use residual, incorporated residue, tillage intensity and recency, macro-roughness, canopy, and cover has been proposed to compute C-factors for cotton (Mutchler, Murphree, and McGregor 1982). The C values in RUSLE are computed as a function of prior-land use, canopy-cover, surface-cover, surface-roughness, and soil-moisture sub-factors.

Early versions of the USLE had limited information about how conservation tillage affects soil loss. Limited information was available about the long-term benefits of no-till and how organic matter builds up in the soil with long-term no-till.

Recent versions of RUSLE use large data sets for conservation tillage practices. Also, a subroutine is included that calculates the rate of residue decomposition as a function of residue characteristics and climate variables. New features, larger data sets, and addition of process-based functions in recent versions of RUSLE make them far superior to the old USLE that they replaced. New algorithms and functions are expected in the RUSLE2 version. Present and expected widespread usage by action agencies give impetus to continued research in improving and maintaining RUSLE as an ARS soil erosion prediction tool even while concerted research efforts continue on other soil erosion prediction models.

In RUSLE 1.04, the effect of surface cover on soil erosion is given as an exponential function of percent land area covered by surface cover and surface roughness. The empirical coefficient, b, in the equation indicates the effectiveness of surface cover in reducing erosion. The user of RUSLE 1.04 is allowed to select a b-value from a menu of values based on the ratio of rill to interrill erosion. But RUSLE 1.06 computes the b-value as a function of the computed ratio of rill erosion to interrill erosion. This ratio is based on soil texture, hillslope gradient, percent surface cover, and land use. The user also can input b-values from an expanded menu (Toy et al. 1999). Toy reported that the RUSLE 1.06 version was modified and improved to accommodate the special conditions of mining, construction, and reclamation lands. This version also contains an improved method to estimate the prevalence of rill erosion based upon soil texture, hillslope gradient, percent surface cover, and land use. The 1.06 version also offers improvement in cropland erosion prediction.

Researchers at the USDA National Sedimentation Laboratory have contributed toward improvements for application of RUSLE (McGregor et al. 1995). These improvements included a reduction in the R-factor for northern Mississippi, an improved slope steepness relationship for low slopes; a sub-factor method to compute the effect of cover and management for a wide range of conditions; the consideration of the effect of winter weeds; and improved accuracy for cropping and management factors for no-till.

Cropping and management factors have been measured on erosion plots under natural rainfall on the Holly Springs, MS, experiment station for over 30 years (McGregor et al., 1996). Cropping and management C-factors that reflect the benefits of conservation tillage practices are considerably lower than those for conventional-till. Some examples of tillage practices and cropping systems with low C-values include no-till soybean, no-till corn and soybean in a rotation system, double-cropped no-till soybean and wheat, no-till corn for silage and grain, reduced-till corn for grain, and conventional-till corn for silage and grain (McGregor, 1978; McGregor and Greer, 1982; McGregor and Mutchler, 1983). Soil losses from each of these practices were measured from 0.022 ha, 5% sloping plots at Holly Springs Mississippi for at least three years under natural rainfall. These soil loss values and measured values of the R and K values at Holly Springs were used to derive C-values. The resulting low C-values significantly improve soil loss predictions in RUSLE and demonstrate the large soil conservation benefits of no-till practices relative to conventional-till. The corn for silage and grain C-values allow users in different locations to adjust C-values downward to account for the weed cover in their local area.

NEEDED RESEARCH

Research data are needed to quantify the amount of residues that should be incorporated or left on the surface for various reduced tillage systems. Further research also is needed to resolve conflicts among particular data sets from different regions of the country.

SUMMARY

Rainfall and runoff on unprotected soils cause severe soil erosion. Soils being eroded have primary particle sizes, cohesiveness, structure, and other characteristics that affect the erosion process. Runoff transports soil detached by raindrops and runoff. Crop residues left on the ground surface provide considerable protection of the soil surface from the impact of raindrops. Heavy crop residue on moderate slopes and low slope lengths may reduce runoff shear stress to where very little rill erosion will occur. Field experiments under simulated and natural rainfall demonstrate that surface crop residues effectively reduce erosion. Residue and canopy cover and as little soil disturbance as possible help to protect the soil surface. The revised universal soil loss equation (RUSLE) has wide applicability for use in conservation planning. Cropping and management C-factors derived for conservation tillage practices for use in the revised universal soil loss equation (RUSLE) are considerably lower than those for conventional-till. The RUSLE equation allows conservationists to select a conservation plan that will provide maximum soil loss protection.

All programs and services of the U. S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, marital status, or handicap.

REFERENCES

Brown, L.C., G.R. Foster, and D.B. Beasley. 1989. Rill Erosion as affected by incorporated crop residue and seasonal consolidation. Trans. of ASAE 32(6):1967-1977.

Brown, L.C., L.T. West, D.B. Beasley, and G.R. Foster. 1990. Rill erosion one year after incorporation of crop residue. Trans. of ASAE 33(5):1531-1540.

Cogo, N.P., W.C. Moldenhauer, and G.R. Foster. 1984. Soil loss reductions from conservation tillage practices. Soil Sci. Soc. Am. J. 48:368-373.

Dickey, E.C., D. P. Shelton, P.J. Jasa, and T.R. Peterson. 1984. Tillage, Residue, and Erosion on Moderately Sloping Soils. Trans. of ASAE 27(4):1093-1099.

Dickey, E.C., D.P. Shelton, P.J. Jasa, and T.R. Peterson. 1985. Soil erosion from tillage systems used in soybean and corn residues. Trans. of ASAE 28(4):1124-1129.

Epstein, E. and W.J. Grant. 1971. Soil erodibility as affected by soil surface properties. Trans. of ASAE 14(4):647-648, 655.

Foster, G.R. and L.D. Meyer. 1975. Mathematical simulation of upland erosion by fundamental erosion mechanics. In: Present and Prospective Technology for Predicting Sediment Yields and Sources. Proc. of Sediment Yield Workshop, ARS-USDA, ARS-S-40, 190-206.

Foster, G.R., L.F. Huggins, and L.D. Meyer. 1984. a laboratory study of rill hydraulics: I. Velocity relationships. Trans. of ASAE 27(3):790-796.

Foster, G.R., C.B. Johnson, and W.C. Moldenhauer. 1982a. Critical slope lengths for unanchored cornstalk and wheat straw residue. Trans. of ASAE 25(4):935-939, 947.

Foster, G.R., C.B. Johnson, and W.C. Moldenhauer. 1982b. Hydraulics of failure of unanchored cornstalk and wheat straw mulches for erosion control. Trans. of ASAE 25(4):940-947.

Franti, T.G., G.R. Foster, and E.J. Monke. 1996a. Modeling the effects of incorporated residue on rill erosion. Part I: Experimental results and model validation. Trans. of ASAE 39(2):535-542.

Franti, T.G., G.R. Foster, and E.J. Monke. 1996b. Modeling the effects of incorporated residue on rill erosion. Part 11: Experimental results and model validation. Trans. Of ASAE 39(2):543-550.

Gilley, J.E., S.C. Finkner, R.G. Spomer, and L.N. Mielke. 1986. Runoff and erosion as affected by corn residue: Part II. Rill and interrill components. Trans. of ASAE 29(1)161-164.

Harmon, W.C. and L.D. Meyer. 1978. Cover, slope, and rain intensity affect interrill erosion. Proc. Mississippi Water Resource Conf, by the Water Resources Research Institute: Mississippi State University, 9-16.

Khan, M.J., E.J. Monke, and G.R. Foster. 1988. Mulch Cover and Canopy Effect on Soil Loss. Trans. of ASAE 31(3):706-711.

Laflen, J. M., W.C. Moldenhauer, and T.S. Colvin. 1981. Conservation tillage and soil erosion on continuously row-cropped land. Proc. of Crop Production with conservation in the 80's. ASAE Pub. 7-81. ASAE, St. Joseph, MI, 121-133.

Lang, K.L., L. Prunty, S. a. Schroeder, and L.A. Disrud. 1984. Interrill erosion as an index of mined land soil erodibility. Trans. of ASAE 27(1):99-104.

Lattanzi, A.R., L.D. Meyer, and M.F. Baumgardner. 1974. Influences of mulch rate and slope steepness on interrill erosion. Soil Sci. Soc. of Am. Proc. 38(6): 946-950.

Mannering, J.V. and C.R. Fenster. 1977. Vegetative water erosion control for agricultural areas. In: Soil Erosion and Sedimentation, Proc. of the National Symposium on Soil Erosion and Sedimentation by Water, ASAE Pub 4-77, St. Joseph, MI., 91-106.

Mannering, J.V. and L.D. Meyer. 1963. The effect of various rates of surface mulch on infiltration and erosion. Soil Sci. Soc. of Am. Proc. 27:84-86.

McGregor, K.C. 1978. C-factors for no-till and conventional-till soybeans from plot data. Trans. of ASAE 24(6):1119-1122.

McGregor, K.C. and J.D. Greer. 1982. Erosion control with no-till and reduced-till corn for silage and grain. Trans. of ASAE 25(1):154-159.

McGregor, K. C. and C. K. Mutchler. 1983. C-factors for no-till and reduced-till corn. Trans. of ASAE 26(3):785-788, 794.

McGregor, K.C., R.L. Bengtson, and C.K. Mutchler. 1988a. Effects of surface straw on interill runoff and erosion of Grenada silt loam soil. Trans of ASAE 31(1):111-116.

McGregor, K.C., R.L. Bengtson, and Mutchler, C. K. 1988b. Effects of incorporating straw residues on interrill soil erosion. Trans. of ASAE 31(1):81-85.

McGregor, K.C., R.L. Bengtson, and C.K. Mutchler. 1990. Surface and incorporated wheat straw effects on interrill runoff and soil erosion. Trans. of ASAE 33(2):469-474.

McGregor, K.C., R.L. Bingner, A.J. Bowie, and G.R. Foster. 1995. Erosivity index values for northern Mississippi. Trans. of ASAE 38(4):1039-1047.

McGregor, K.C., C.K. Mutchler, and M.J.M. Römkens. 1990. Effects of tillage with different crop residues on runoff and soil loss. Trans. of ASAE 33(5):1551-1556.

McGregor, K.C., G.R. Foster, C.K. Mutchler, and L.M. Golden. 1995. Application of revised universal soil loss equation (RUSLE) to Mississippi. Proc. of the Twenty-fifth Mississippi Water Resources Conf., April 11-12, by the Water Resources Research Institute: Mississippi State University, 94-100.

McGregor, K.C., C.K. Mutchler, J.R. Johnson, and D.E. Pogue. 1996. USDA and MAFES cooperative soil conservation studies at Holly Springs 1956-1996. Mississippi

Agricultural and Forestry Experiment Station, Mississippi State, Mississippi. Bulletin 1044, 21 pp.

Meyer, L.D. and J.V. Mannering. 1963. Tillage and land modification for water erosion control. Proc. ASAE-ASA-SCSA Tillage Conf., 58-62.

Meyer, L.D. and J.V. Mannering. 1967. Tillage and land modification for water erosion control. Proc. ASAE-ASA-SCSA Tillage Conf., 58-62.

Meyer, L.D., W.H. Wischmeier, and G.R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. Proc. 34:928-931.

Mutchler, C.K., and R.A. Young. 1975. Soil detachment by raindrops. In Present and Prospective technology for Predicting Sediment Yields and Sources. Proc. of Sediment Yield Workshop. ARS-USDA, ARS-S-40, 113-117.

Mutchler, C.K., C.E. Murphree, and K.C. McGregor. 1982. Subfactor Method for Computing C Factors for Continuous Cotton. Trans. of ASAE 25(2):327-332.

Onstad, C.A. 1984. Depressional storage on tilled soil surfaces. Trans. of ASAE 27(3):729-732.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, coord. 1997. Predicting Soil Erosion by Water: a Guide to Conservation Planning with the revised Soil Loss Equation (RUSLE). USDA Agric. Handbook No. 703, 404 pp. Washington, D.C.: GPO.

Shelton, D. P., P.J. Jasa, and E.C. Dickey. 1986. Soil Erosion from Tillage and Planting Systems Used in Soybean Residue: Part I - Influences of Row Spacing. Trans. of ASAE 29(3):756-760.

Toy, T.J., G.R. Foster, and K.G. Renard. 1999. RUSLE for mining, construction and reclamation lands. J. of Soil and Water Conservation 54(2):462-467.

Van Liew, M.W. and K.E. Saxton. 1983. Slope steepness and incorporated residue effects on rill erosion. Trans. of ASAE 26(6):1738-1743.

Wagner, L.E. and R.G. Nelson. 1995. Mass reduction of standing and flat crop residues by selected tillage implements. Trans. of ASAE 38(2):419-427.

Wischmeier, W.H. 1959. a rainfall erosion index for a universal soil-loss equation. Soil Sci. Soc. of Am. Proc. 23:246-249.

Wischmeier, W.H. 1973. Conservation tillage to control water erosion. In Proceedings of the National Conservation Tillage Conference. Des Moines, IA., March 28-30, 1973, by the Soil Conservation Soc. Am., Ankeny, IA, 133-144.

Wischmeier, W.H. 1975. Estimating the soil loss equation's cover and management factor for undisturbed lands. In: Present and Prospective Technology for Predicting Sediment Yields and Sources. Proc. of Sediment Yield Workshop, ARS-USDA, ARS-S-40, 118-125.

Wischmeier, W.H., and D.D. Smith. 1958. Rainfall energy and its relationship to soil loss. Trans. Of American Geophysical Union 39(2):285-291.

Wischmeier W.H., and D.D. Smith. 1965. Predicting rainfall -erosion losses from cropland east of the Rocky Mountains - Guide for selection of practices for soil and water conservation. Agric. Handbook 282. Washington, D.C.: GPO.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall erosion losses-a guide to conservation planning. USDA Agric. Handbook 537. Washington, D.C.: GPO.

Wischmeier, W.H., C.B. Johnson, and B.V. Cross. 1971. a soil erodibility nomograph for farmland and construction sites. J. of Soil and Water Conservation 26:189-193.

Young, R.A. 1980. Characteristics of eroded sediment. Trans. of ASAE 23(5):1139-1142, 1146.

Young, R.A. 1984. A method of measuring aggregate stability under waterdrop impact. Trans. of ASAE 27(4):1351-1354.