Cover crops for clean water

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WIND AND WATER EROSION

Cover crop effects on soil erosion by wind and water

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A principal function of cover crops is to prevent land degradation by wind and water erosion. Available conservation tillage technology to manage cover crops prior to the late 20th century was elementary, but the practice of green manuring is very ancient. The Greeks turned under broadbeans (*Vicia faba* L.) about 300 B.C. *(40)*. Cropping strategies for soil improvement were also a common practice for early Roman and Chinese empires. Many 20th century land stewardship initiatives accompany successful cover crop strategies.

Long-term benefits of cover crops extend beyond the published definitions in a holistic sense *(18, 52)*. Crop residue rather than cover crop management becomes important on water deficient soils (xeric climate) where cover crops cannot be grown successfully between periods of regular crop production. Similar scenarios can be used for soils developed in boreal climates. In this chapter, we will focus on the protective value of plant vegetative and residue cover for controlling soil erosion.

In addition to providing resistance to soil particle detachment and transport as described by wind *(68)* and water *(66)* models, decomposing plant materials give rise to other hallmark functions. These functions, which contribute to the maintenance of dynamic soil organic matter levels, are inherently related to soil erosion control because of increased rainfall capture and retention *(6, 36)*.

Accelerated soil erosion is often associated with deficient vegetative land cover, and may be partially responsible for societal failures *(19, 26)*. In colonial North America, considerable land degradation occurred because of the abundance of land accompanied with soil stewardship illiteracy. European people migrated to North America with little agricultural experience to deal with a high-rainfall, erosive climate. Ruffin *(47)*, Hilgard *(17)*, and Trimble *(56)* documented accelerated soil erosion following European settlements. Bennett *(5)*, Lowdermilk *(26)*, Jenny *(19)*, and Barnett *(3)* described some human misery associated with about 200 years of continuous land degradation into the 20th century. The first U.S. legislative action mandating research for control of soil erosion was authorized by the 1928 Buchanan Amendment to the Agricultural Appropriation Bill *(58)*. Bennett's passionate soil conservation leadership also continued to arouse the stewardship conscience of the nation during the dust bowl era.

Williams et al. *(63)* summarized the results of the early soil erosion research activities. Positive soil erosion control results were associated with cover crop treatments used in our first national environmental research thrust. Conservation technology developed in the 1930s and 1940s to derive the universal soil loss equation (USLE) *(67)* C and P factors as well as the Conservation Reserve Program (Soil Bank), authorized in Title I of the Agricultural Act of 1956, all served to significantly decrease off-site sediment damage *(56)*. Sedimentation rate decreased 73% from 1939 to 1967 (107 to 29 acre-feet/year) in some northern Georgia reservoirs *(2, 60)*.

Increased export market opportunities for U.S. soybea

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and wheat farmers during the 1970s and early 1980s significantly expanded monocropped, conventionally tilled acreage *(59, 61)*. The diminished use of cover crops during this era degraded U.S. agroecosystems significantly *(12, 63)*. The recent low-input sustainable agriculture thrust and ground water quality initiatives are currently serving to provide more cover crop opportunities for American agriculture. In this chapter, we will describe the importance of cover crops for protecting U.S. agroecosystems through soil erosion control.

Soil surface management with cover crops on dominant soil orders of the United States

Ultisols. Because of Ultisol formation processes in udic thermic climates, cover crop management on these soils in the southeastern United States *(7, 53)* tends to be more inextricably related to the USLE C factor *(65, 67)*. This climate regime permits vigorous growth of many cool-season cover crops. For soil erosion control purposes, cropping stages SB, 1, and 2 of an annual C factor are highly dependent upon the cool-season crop. Sojka et al. *(54)* demonstrates this in a review. When clover and perennial grasses were included in a conventional tillage system on Paleudult soils of the Atlantic and Gulf Coastal Plains, C factors declined 38% *(55)*. These values are relatively high because bare fallow and intensive crop rotating plots were used to calculate the soil loss ratios. However, generalized annual C factors associated with a conventional, monocropped tillage system are usually greater than 0.30 on both Hapludult and Paleudult soils.

Considerably more cover crop soil erosion research has been accomplished on Hapludult soils of the Southern Piedmont than on other Ultisols. Conventionally tilled cotton (*Gossypium hirsutum* L.) farming in the Southern Piedmont has caused soil losses averaging at least 20 tons/acre/year *(8, 10)*. This continuous row-crop management system was used as a standard for comparison with other tillage and cropping systems. Beginning in the early 1930s, warm-season annual and perennial cover crops, such as lespedezas (*Lespedeza cuneata* L. and *stricta* L.), alfalfa (*Medicago sativa* L.), and kudzu (*Pueraria thunbergiana* L.), were used to effectively reduce soil losses well below an accepted soil loss tolerance (T) value *(10, 16, 39)*. Most cover crop research during the 1930s used annual rather than seasonal rotations. Only conventional-tillage technology was available to plow-down these annual cover crops. Acceptance of cool-season cover crops came only with successful mulched tillage procedures developed during the 1940s and 1950s *(4)*. Mulch tilling corn (*Zea mays* L.) into vetch (*Vicia villosa* Roth), rye (*Secale cereale* L.), and crimson clover (*Trifolium incarnatum* L.) was compatible. Cover crops decreased soil losses on these runoff plots 62% (Table 1). In addition to improving soil characteristics for erosion control, a biological nitrogen (N) supply was available for each corn crop.

Concomitant tillage and herbicide development during the 1970s and early 1980s provided the first technology for using conservation tillage to plant summer annual row crops into cool-season cover crops *(14, 42, 57, 59)*. A long-term soil erosion data set *(25, 35)* from a Southern Piedmont watershed was chosen to represent this era (Table 2). These multiple crop systems tend to mimic forest systems studied by Copley et al. *(10)* during the 1930s. These data express the long-term value of a cool-season leguminous cover crop for soil erosion purposes in the Southern Piedmont.

Alfisols. Alfisols are found most extensively in humid and subhumid temperate regions *(7)*. The presence of winter cover crops on these soils has proved to be effective in

Table 1. Reduction of average annual runoff and soil loss with cool-season cover crops on USLE runoff plots.*

Location	*Slope (%)*	*Cropping System*	*Average Annual Runoff (inches)*	*Average Annual Soil Loss (tons/acre)*
Clemson, South Carolina	8	Continuous corn	6.0†	3.4†
		Corn with vetch & rye	1.7†	1.4†
Baton Rouge, Louisiana	4	Continuous corn	11.5	7.3
		Corn with winter cover	9.5	7.3
		Continuous cotton	14.6	4.8
		Cotton with winter cover	14.1	2.2
Tyler, Texas	9	Continuous cotton	12.1	60.7
		Cotton with vetch	10.7	57.7
State College, Mississippi	3-13	Cotton-cotton-corn	3.5	10.0
		Cotton-cotton-corn with winter cover	2.6	6.4

*After Wischmeier (64)
†Corn growing season only

Table 2. Annual stochastic soil loss comparisons expressing the value of cool-season crop in conservation tillage systems on an Ultisol*.

Tillage	*Cropping System*	*Soil Loss by Exceedance Probability* 0.2	0.4	0.6	0.8
		tons/acre			
Conventional	Fallow/soybean	22.30	17.40	13.80	10.70
Conservation	Wheat/soybean	0.05	0.02	0.01	0.01
Conservation	Crimson clover/grain sorghum	0.04	0.00	0.00	0.00

*After Mills et al. (35)

Table 3. Soil erosion losses on Alfisols in systems including cover crops compared to no cover crop systems.

Summer crop	Winter Cover Crop	Tillage System	Soil Loss (tons/acre)	Location and Reference
Soybean	No cover	No-till	1.09	Missouri (69)
	Chickweed	No-till	0.19	
	Canada bluegrass	No-till	0.08	
	Downy brome	No-till	0.10	
Soybean	No cover	Conventional	3.34*	Tennessee (48)
	Wheat	Conventional	0.75*	
	No cover	No-till	0.05*	
	Wheat	No-till	0.04*	
Soybean	No cover	Conventional	4.04	Kentucky (45)
	Wheat	Conventional	0.51	
	No cover	No-till	0.19	
	Wheat	No-till	0.12	
Cotton†	No cover	No-till	8.93	Mississippi (37)
	Weeds	No-till	8.21	
	Hairy vetch	No-till	1.03†	
Cotton§	No cover	Conventional	0.45‡	Mississippi (37)
	Weeds	No-till	0.58‡	
	Hairy vetch/wheat	No-till	0.40	
Cotton#	No cover	Conventional	33.35	Mississippi (37)
	Weeds	Conventional	32.90	
	Hairy vetch/wheat	Conventional	9.11	

*Mean soil loss associated with soybean cropping/tillage systems during April-July study periods. Mean of 17 storms of high intensity that occurred in 1980-1986 that included natural storms and simulated rainfall.
†Following reduced tilled soybean
‡One year of data
§Following no-till soybean-wheat double-cropped.
#Following 11 years of conventional tilled corn/soybean.

reducing soil erosion. Recent studies on a Udollic Ochraqualf in Missouri *(69)* compared no-till soybean plots seeded to cover crops with a check-treatment without cover crops. Mean annual soil losses from chickweed (*Stellaria media* L.), Canada bluegrass (*Poa compressa* L.), and downy brome (*Bromus tectorum* L.) treatments were decreased 87%, 95%, and 96%, respectively, compared with the check plot with no cover crop (Table 3).

Studies conducted in western Kentucky on a Typic Fragiudalf soil showed an 88% (Table 3) reduction of soil erosion for conventionally tilled soybeans planted following double-cropped wheat compared with conventional tillage without a cover crop. In the no-till system, soil losses were small for treatments with and without cover crops. But, there was less soil erosion on plots planted to a wheat cover crop.

Studies on a Typic Paleudalf soil in western Tennessee *(48)* measured soil losses from 0.25-acre runoff plots, where soybeans were grown with different cropping systems. These systems included wheat planted as part of a double-crop system with conventional tillage and no-till and the same tillage comparison without a cover crop. The data in table 3 represent mean soil loss measured during April-July study periods. During this period, 17 high-intensity storms occurred in 1980-1986. Most of this was natural rainfall, however, supplemental events using a rainfall simulator were included. These findings were similar to those observed in western Kentucky. With conventional tillage, soil losses were significantly greater for single-crop soybeans without a cover crop than for treatments seeded to a wheat cover crop (Table 3). The no-till treatment showed no significant advantage of wheat as a cover crop as part of a wheat/soybean double-crop system compared with no-till without a cover crop.

Mutchler et al. *(38)* and Mutchler and McDowell *(37)* showed that conservation-tilled cover crops reduced soil erosion 47% and increased seed cotton yield 20% on a Providence silt loam (Typic Fragiudalf) soil in Mississippi. Their use of vetch and winter wheat cover crops with conventionally tilled cotton was beneficial in reducing soil loss, but not sufficient for acceptable soil erosion control. With no-till, the cover crop contribution toward reducing soil erosion depends on the quantity of residue and its distribution on the soil surface. For some conservation tillage systems, residue of the previous year's crop may be sufficient to provide effective erosion control.

Mollisols. USLE research in the 1930s and 1940s established the role of meadow rotations for controlling soil erosion on midwestern soils (Table 4). Interest in growing cover crops for soil erosion control, especially following soybeans, was renewed with findings by Laflen and Moldenhauer *(23)*. They reported that between 1963 and 1969, soil loss from a Grundy silt loam (fine, montmorillonitic, mesic Aquic Argiudoll) was 35% greater for corn following soybeans than for either soybeans after corn or a continuous corn rotation. They attributed the increased soil erosion following soybeans to lower dry matter production, less residue cover, and soil-loosening action of soybean roots. These data compare favorably with a generalized meadow-rotation/cover crop soil erosion hazard (Table 5) developed by Miller et al. *(34)*.

When mean annual precipitation decreases from more than 40 inches on midwestern Mollisols to less than 12 inches on the western edge of the Great Plains, vegetative cover is a cardinal rule for controlling wind and water erosion *(9, 29)*.

For more northern locations, however, Karlen *(20)* recently reported that a major need in conservation tillage research was to develop cropping strategies and management schemes that make cover crops more compatible with common crop rotations. Power *(42)* also identified improving shade and cold tolerance of legume cover crop germplasm as a major research need for the Midwest.

An on-farm study recently demonstrated that the combination of ridge-tillage, cover crops, and manure applications significantly decreased runoff from a Clarion (fine-loamy, mixed, mesic Typic Hapludoll) hillside soil *(46)*. This was attributed in part to higher earthworm populations that were probably enhanced by overseeded cover crops because of increased protection during the fall and winter months *(51)*.

Model development for cover crop management

Historical perspective. National research needs for water and wind erosion control became highly visible with the dust bowl era *(5)*. A national research thrust to control soil erosion began during the early 1930s *(62)*. Wind *(68)* and water *(66)* models that assimilated the long-term national data sets for management planning were initially published during the early 1960s. These models, with revisions and their crop residue requirements, were published in a review format during the 1970s *(15, 49, 50)*. The water erosion model was referred to as the universal soil loss equation (USLE), and the wind erosion model as the wind erosion equation (WEQ). These and other selected soil erosion models, which include a cover crop management component, are discussed herein.

Universal soil loss equation. A data set that includes 8,000 runoff-plot years from 21 states was used to develop the USLE *(66)*. By analysis of this data set, Wischmeier *(66)* concluded that seeding vetch and ryegrass in cotton or corn plots before harvest and plowed-down the following spring was effective erosion control (Tables 1 and 4). These cover crops reduced soil erosion during winter months, as well as the following crop year *(44)*. For USLE crop stage 1, corn plots without winter cover had a soil loss ratio of 36%, while those with winter crop cover had a ratio of 22%. For USLE crop stage 2, soil-loss ratios were 63% and 46%, respectively.

The USLE data set included six research sites (Table 4) with meadow rotation treatments and four (Table 1) with winter cover crop treatments. The meadow rotation treatment reduced average annual runoff 31% to 65% and accompanying soil losses 42% to 92% . Winter cover crop treatment produced similar results. Plot slope and row direction also significantly influenced runoff and soil losses *(8, 10)*. Beale et al. *(4)* and Bruce et al. *(6)* described other factors and mechanisms that explain the effects of cool-season cover crops on soil erosion.

Wind erosion equation. Skidmore and Siddoway *(50)* demonstrated the paramount importance of crop residues for controlling wind erosion. The data set assembled in this review publication accompanies the WEQ *(68)* to provide wind erosion control technology on about 74 million acres of the nation's land resource area *(60)*. Additional literature review only creates redundancy, so only research associated with the WEQs vegetative components since 1978 follows herein.

Lyles and Allison *(27, 28)* reported the protective role of crop residue and range grasses as flat small-grain equivalent of the form:

$$SGE = ax^b \quad [1]$$

where SGE is flat-small-grain equivalent (pounds/acres), x is the quantity of residue or grass to be converted, and a and b are experimentally determined regression constants. The flat-small-grain equivalent is converted to the vegetative factor that is needed to estimate wind erosion by the Woodruff and Siddoway *(68)* procedure.

Woodruff and Siddoway *(68)* graphically demonstrated the relationship between flat-small-grain equivalent (SGE) and vegetative factor (VE). Williams et al. *(62)* fit an equation to the graphical relationship to give:

$$VE = 0.253\,(SGE)^{1.363} \quad [2]$$

Until recently, all small-grain equivalence data have been limited to dead crop residue or dormant grass. Armbrust and

Table 4. Reduction of average annual runoff and soil loss with meadow rotations on USLE runoff plots.*

Location	*Slope (%)*	*Cropping System*	*Average Annual Runoff (inches)*	*Average Annual Soil Loss (tons/acre)*
Bethany, Missouri	8	Continuous corn	8.2	50.9
		Corn-wheat-clover & timothy	4.9	9.1
LaCrosse, Wisconsin	16	Continuous corn	9.9	111.7
		Corn-barley-clover	5.8	27.8
Clarinda, Iowa	9	Continuous corn	5.6	37.8
		Corn-oats-meadow	2.7	11.7
Tifton, Georgia	3	Continuous corn	2.9	1.2
		Corn-oats-meadow-meadow	2.0	0.7
Guthrie, Oklahoma	8	Continuous cotton	4.1	24.2
		Cotton-wheat-clover	2.7	5.9
Ithaca, New York	19	Continuous corn	6.5	6.6
		Corn-oats-meadow	2.3	0.6

*After Wischmeier, (64)

Table 5. Relative erosion hazard of selected crop sequences (continuous corn = 100) on Mollisols.*

Crop Sequence†	Relative Erosion Hazard
Fallow	256
C-Sb	131
C-C-Sb	120
Continuous corn	100
C-C-C-Ox	74
C-C-Ox	64
C-Ox	46
C-C-C-O-M	49
C-C-O-M	36
C-C-O-M-M	28
C-C-O-M-M-M	26
C-O-M	18
C-C-O-M	15
C-C-O-M-M	13
C-C-O-M-M-M	10
Continuous cover	[illegible]

*After Iowa State Extension Services, Ames, Iowa.·Miller et al. (34).
†C-corn; Sb-soybeans; O-oats; Ox-oats with green manure crop; M-meadow

Lyles *(1)* reported flat-small-grain equivalents for growing corn, cotton, grain sorghum [*Sorghum bicolor* (L.) Moench], peanuts (*Arachis hypogaea* L.), and soybeans [*Glycine max* (L.) Merr.],

$$SGE = a_1 R_w^{b1} \qquad [3]$$

where Rw is the aboveground dry weight of the crop to be converted (pounds/acre), and a_1 and b_1 are constant coefficients for each crop. They found that if only rough estimates of SGE are needed, an average coefficient could be used. An average equation determined from pooling all crop data with rows running perpendicular to wind direction yielded 8.9 and 0.9 for a_1 and b_1, respectively.

Cover crops, where they can be grown, give effective wind erosion protection. They are especially applicable in regions more humid than the semiarid lands of the historical dust bowl. Their protective value at a specific growth stage for use in the Woodruff and Siddoway *(68)* wind erosion prediction method, and variations thereof, can be estimated by using equation 3.

In the developing the "Wind Erosion Prediction System" *(13)*, crop growth is simulated by a generalized growth model, CROP, which calculates potential growth of leaves, stems, yield, and root components. The potential growth is modified by stresses of temperature, fertility, and water. The CROP submodel, using biomass as an independent variable, also predicts distributions of leaf and stem silhouette area with height, canopy height, canopy cover, and flat biomass cover. That information, along with other pertinent information, then is input into an EROSION submodel for computing soil loss from wind.

Erosion-productivity impact calculator. The Erosion-Productivity Impact Calculator (EPIC) was originally designed to determine the relationship between soil erosion and soil productivity in the 1985 Soil and Water Resource Conservation Act (RCA) Analysis *(43)*. The model has been adapted for solving numerous agricultural management problems. A recent adaptation of that model was motivated by the need to determine the effects of winter cover crops on ruoff and soil erosion. Data sets from three small watersheds near Riesel, Texas, were used for testing purposes (Table 6 and 7). These Vertisol watersheds are dominated by Houston Black (fine,

Table 6. Observed and EPIC-simulated flume yields from three watersheds during a cover crop period, October-May.

	Oat Cover Crop				Fallow			
	Runoff		Sediment		Runoff		Sediment	
Watershed	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated
	inches		tons/acre		inches		tons/acre	
No. 1	3.35	3.11	0.29	0.27	4.29	3.82	0.85	0.87
No. 2	5.24	4.13	0.21	0.17	3.66	4.02	0.63	0.67
No. 3	2.95	4.13	0.09	0.15	5.98	5.79	1.43	1.19

Table 7. EPIC-simulated (20 years) watershed flume yields associated with fallow, wheat, and clover cover conditions.

		Cotton/Grain Sorghum		Cotton/Wheat/Grain Sorghum		Cotton/Clover/Grain Sorghum	
Month	Rainfall (inches)	Runoff (inches)	Sediment (tons/acre)	Runoff (inches)	Sediment (tons/acre)	Runoff (inches)	Sediment (tons/acre)
January	1.50	0.16	0.01	0.12	0.00	0.16	0.00
February	2.17	0.28	0.05	0.20	0.01	0.24	0.00
March	2.20	0.20	0.03	0.08	0.01	0.12	0.01
April	3.50	0.71	0.12	0.47	0.02	0.51	0.03
May	4.37	1.10	0.18	0.91	0.06	0.87	0.07
June	2.83	0.35	0.02	0.31	0.02	0.31	0.02
July	1.85	0.08	0.01	0.08	0.01	0.08	0.01
August	1.89	0.12	0.01	0.12	0.01	0.12	0.01
September	2.32	0.32	0.03	0.31	0.01	0.32	0.01
October	3.58	0.63	0.10	0.59	0.07	0.63	0.06
November	3.82	0.59	0.06	0.47	0.01	0.51	0.01
December	3.66	0.63	0.08	0.43	0.01	0.51	0.01
Annual	33.70	5.16	0.69	4.13	0.21	4.37	0.22

montmorillonitic, thermic Udic Pellusterts) soils. Watershed areas ranged from 16.3 to 20.8 acres, with average slopes ranging from 1.88% to 3.21%. The 3-year crop-rotation consisted of cotton, grain sorghum, and oats (*Avena sativa* L.). A winter cover of oats occurred on each watershed every third year. Oats were planted about October 15 and harvested about June 1 each year. Table 6 presents both observed and simulated runoff and sediment yields for the cover crop period (October-June). EPICs prediction efficiency averages 93% for runoff and 83% for sediment.

To accommodate leguminous, cereal grain, and fallow cover between corn crops, a 16.3-acre watershed with 2.24% slope for a 20-year simulation without crop rotation was assumed. Three simulations were performed using identical weather generated by EPIC. Table 7 provides simulated average monthly and annual rainfall, runoff, and sediment yield for the three simulated cover conditions. Based on these results, cool-season cover crops appear to provide a distinct soil erosion protection value, even on Vertisols formed on slopes averaging less than 4.0%.

Revised universal soil loss equation. The USLE has been revised to accurately estimate soil loss from both crop and rangeland. This revision incorporates technology developed since the 1978 version of the USLE *(67)*. The result is the revised universal soil loss equation (RUSLE) *(32)*. The basic structure of the USLE has been retained, but the algorithms used to calculate the individual factors have been changed significantly. One important change is in the computerization of the technology. This allows computation of the soil-loss ratio by 15-day intervals rather than by longer crop stage periods as in the USLE. This improves estimates of the factors affecting the soil loss ratio, such as surface roughness, crop growth, and residue decomposition. Another change is in use of a time-variant soil erodibility factor, which reflects winter freeze-thaw effects and the consolidating effect of moisture extraction by a growing crop during the summer months. New slope-length and steepness relationships were developed from plot data and detachment theory *(30, 31, 33)*. The relationships consider the relative susceptibility of the soil to rill versus interrill erosion. Separate relationships were developed specifically for the freeze-thaw-affected dry-farmed cropland region of the Pacific Northwest.

The cover-management factor is perhaps the most important factor of either the USLE or the RUSLE because it represents conditions that can be managed most easily to reduce erosion. The soil-loss ratio (SLR), which is weighted by the annual erosivity distribution to produce the cover-management factor, is calculated as a product of four subfactors by Laflen et al. *(22)*, as follows:

$$SLR = PLU \times CC \times SC \times SR \quad [4]$$

where PLU is prior land use, CC is crop canopy, SC is surface or ground cover, and SR is the surface roughness. The soil-loss ratio is far more sensitive to surface cover than to other factors. The effect of surface cover on soil erosion is given by a negative exponential relationship:

$$SC = e^{-bm} \quad [5]$$

where m is the fraction of the land area covered by plant material and b is a regression coefficient. Laflen et al. *(24)* and Laflen and Colvin *(21)* found b values ranging from 3.0 to 7.0 for row crops, while Dickey et al. *(11)* found b values of 2.4 to 3.2 in a rainfall-simulation study on small grains. In the Pacific Northwest, where much of the annual erosion is in the form of rills caused by snowmelt or rainfall on thawing soil, data from runoff plots on a Palouse silt loam (fine-silty, mixed, mesic Pachic Ultic Haploxeroll) near Pullman, Washington (Table 8), indicates a b-value greater than 5. Slopes at this study site ranged from 19% to 26% and soil losses from bare fallow plots often exceed 65 tons/acre/year. Winter wheat and spring dry peas (*Pisum sativum* L.) provide residue cover ranging from 11% to 96%. However, recommendations for b-values for use in RUSLE are 2.5 with interrill erosion (such as rangeland) and 3.5 for cultivated cropland conditions *(41)*. The data set presented herein suggests that specific technology associated with the RUSLE model is important for managing crop residues to control severe soil erosion of the Pacific Northwest.

Conclusion

Wise use of cover crop technology is essential to accomplish sustainable agriculture objectives. Sustainable agriculture must control soil erosion by both wind and water. Some 20% of the 420 million acres of cultivated cropland in the United States also requires soil productivity restoration. Use of cover crops in conservation tillage systems may offer sustainable solutions to best accomplish both goals. An assessment of more than 50 years of cover crop research in soil erosion control suggests their essential role on the nation's cultivated landscape.

Dominating Ultisol, Alfisol, and Mollisol soil orders received extensive cover crop attention in soil erosion control and restoration studies. We associate most of these research

Table 8. Relationship of RUSLE's surface cover (SC) subfactor to percent crop residue cover on a Palouse silt loam soil.*

Tillage	*Cropping System*	*Surface Residue (%)*	*Surface Cover (SC) Subfactor*
Conventional†	Fallow	0	1.0
Conventional‡	Summer fallow/winter wheat	11	0.57
Conventional‡	Wheat§/winter wheat	42.5	0.22
No-till seeded	Spring peas/winter wheat	58.0	0.073
No-till seeded	Wheat§/winter wheat	96.5	0.0050

*Data set includes 1978/1979 through 1983/1984 winter erosion seasons
†Tillage to maintain bare fallow conditions
‡Tillage representative of the Palouse Soils Resource Area *(11, 53, 58)*
§Rotating spring and winter wheat

activities with a long-term conservation tillage evaluation. Cover crops are best adapted to conservation tillage efforts for Ultisols and Alfisols. However, different research approaches were more discretely associated with soil resource areas within soil orders. We attribute this to cover crop species adaptation to climate and soil formation processes. Because of the xeric and boreal climate association of Mollisols, meadow rotations serve as the best vegetative cover. Conservation tillage technology has only recently approached a threshold to capitalize on the beneficial functions of cover crops for soil erosion control. Because of fragmentation of research efforts, as well as the short-term economic policy structure of American agriculture, cover crop use is prohibitive on much of the nation's landscape. Cover crop discouragement on Ultisols was exhibited only recently in the Conservation Reserve Program of the 1985 Food Security Act.

Hydrologic models that include vegetative parameters for soil conservation purposes may enhance the importance of cover crops for soil erosion control. Current model development for agroecosystems has also experienced a long-term evaluation process. Those models that appear most applicable for managing cover or meadow crops for soil erosion control herein are the USLE, WEQ, EPIC, and RUSLE. This model diversity is similar to the different cover crop management requirements for the nation's diverse soil family and series association. These soil erosion control tools may serve to stimulate best management of our most important renewable natural resource—crop vegetation—in an economical and environmental manner.

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