DIVISION S-6—SOIL AND WATER MANAGEMENT AND CONSERVATION

Corn and Soybean Cropping Effects on Soil Losses and *C* Factors[1]

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ABSTRACT

Greater soil losses are generally thought to occur with soybean (*Glycine max.* [L.] Merr.) cropping than with corn (*Zea mays* L.) cropping. However, runoff and soil losses from corn and soybean cropping systems have been measured simultaneously in only a few studies. The objectives of our study were to evaluate differences in soil and water losses between continuous corn and continuous soybean cropping for conventional, field cultivation, and no-till methods of tillage; and to evaluate differences between measured cropping and management (*C*) factors and those in Agricultural Handbook 537, USDA that are currently used in soil conservation planning. These objectives were accomplished by analyzing soil and water loss data from a 7-yr study conducted on a claypan soil in central Missouri. Cropping differences were evaluated for five seasonal periods based upon cultural operation dates and estimated amounts of canopy cover. Average annual soil loss from soybeans was significantly higher ($p < 0.01$) than that of corn for the conventional and no-till methods. Seasonal periods having the greatest cropping differences in soil loss were period F (rough fallow), period 12 (30 to 60 d after planting) and period 4 (fall harvest to spring tillage). Annual *C* factors for soybeans were about two times those of corn for all tillage methods. Measured *C* factors for all tillage methods were consistently lower than those presented in Agricultural Handbook 537, USDA.

Additional Index Words: **Universal Soil Loss Equation, erosion, runoff, conservation tillage, claypan soil**

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FARMERS AND SOIL CONSERVATIONISTS have felt for many years that soybean (*Glycine max.* [L.] Merr.) cropping increases soil loss relative to corn cropping. Conclusive experimental evidence is lacking, however, because of the time and expense required to conduct runoff and soil loss experiments in the field. Research to evaluate differences in runoff and soil loss between corn (*Zea mays* L.) and soybean cropping was initiated in the early 1940's. Both rainfall simulation (Van Doren and Stauffer, 1944) and natural rainfall (Van Doren et al., 1950) plots were used in the evaluations. Interpretation of these early results is hampered by a lack of statistical analysis, but trends generally support higher soil losses with soybean cropping. The oft-mentioned, prior cropping effect of soybeans on soil loss, when in rotation with corn, can be traced to Van Doren's research published in 1950 (see also Van Doren and Gard, 1950).

Recently, Oschwald and Siemens (1976) showed that soil losses in the spring prior to tillage were higher for soybeans than for corn. The rainfall simulation tests for the corn and soybean cropping treatments were conducted in successive years, however, which may have confounded the evaluation. Laflen and Moldenhauer (1979) analyzed 7 yr of water and soil loss data from natural rainfall erosion plots in Iowa and concluded that annual soil losses for corn following soybeans were significantly higher ($p \leq 0.10$) than those losses for soybeans following corn or corn following corn. Soil losses were greatest when corn followed soybeans for all seasonal periods studied, with significantly higher ($p \leq 0.10$) losses in period F (rough fallow) and period 3 (from 60 d after planting until harvest). However, Laflen and Colvin (1981) and Colvin and Laflen (1981) were unable to detect a prior cropping effect of soybeans on soil loss using simulated rainfall.

Because of the current interest in better understanding the effect of soybean cropping on soil loss, we analyzed 7 yr of soil and water loss data from natural rainfall erosion plots on a claypan soil in central Missouri to determine if continuous soybean cropping increased soil and water losses relative to continuous corn cropping. We also evaluated the effect of these crops on the cropping and management factor (*C*) used in the Universal Soil Loss Equation (Wischmeier and Smith, 1978).

MATERIALS AND METHODS

Soil and water loss measurements were obtained from rainfall erosion plots located in central Missouri, near Kingdom City (formerly McCredie). Data collected from these plots, which have been in continuous operation since 1941, were part of the more than 10 000 plot-year data base used to develop the Universal Soil Loss Equation (USLE). The plot site is within, and typically represents, the claypan soils area of central to eastern Missouri and southern Illinois (MLRA 113), an area of about 4 000 000 ha. The Mexico series (fine, montmorillonitic, mesic, Udollic Ochraqualf) has a claypan 200 to 280 mm below the soil surface that restricts drainage and root growth during wet periods. The sand, silt, and clay content of the tillage zone is 70, 710, and 220 g/kg, respectively. The soil carbon content of the 0- to 75-mm zone ranged from 14 to 21 g/kg among cropping and tillage treatments at the end of the study.

The 3.2 by 27.4 m plots (0.009 ha) were on a 3 to 3.5% slope. Sheet metal borders were used on the sides and an earthen dike at the upper end to define the runoff area of each plot. Runoff flowed into a collector, through a pipe, and into a calibrated, covered tank. After this tank filled (about 6 mm of runoff), runoff flowed through a multi-slot divisor where one ninth of the flow was collected in a second calibrated, covered tank. Total collection capacity was about 180 mm of runoff. After an event, runoff volumes were measured and the sediment thoroughly suspended before ob-

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Table 1. Precipitation and erosion index by crop year and seasonal period.

Crop year	Precipitation					Erosion index (*R*)				
	F	SB	12	3	4	F	SB	12	3	4
	mm					MJ mm/ha h				
					Continuous corn					
1971	38	104	49	231	273	51	259	267	368	551
1972	123	54	36	258	636	584	138	0	1605	982
1973	63	72	40	453	352	127	208	79	3001	448
1974	189	157	44	292	276	199	1015	223	1407	189
1975	136	63	107	424	266	742	116	1038	3441	629
1976	61	52	63	90	272	69	45	496	91	731
1977	152	32	111	366	332	391	77	341	1886	394
Avg. 1971–77	109	76	64	302	344(895)†	309	265	349	1686	561(3170)
Avg. 1941–77	109	106	106	316	272(909)	284	369	623	1484	734(3494)
					Continuous soybeans					
1971	104	85	58	151	297	205	373	125	184	609
1972	152	45	19	256	636	668	54	0	1605	982
1973	74	88	152	315	352	127	287	1628	1373	448
1974	191	155	44	224	344	199	1015	223	1296	300
1975	136	64	105	378	312	742	116	1038	3376	694
1976	92	23	62	89	272	87	27	496	91	731
1977	161	25	143	409	254	391	77	608	1762	251
Avg. 1971–77	130	69	83	260	352(894)	346	278	588	1384	574(3170)

† Numbers in parentheses are the sum of seasonal period values.

taining triplicate 1-L sediment samples for gravimetric analyses. Occasionally, a runoff event represented two or more rainfall events. Precipitation was measured in a single recording raingage located in a weather station adjacent to the plots.

The treatments evaluated were continuous corn and soybeans tilled by conventional, field cultivation, and no-till methods. All treatments except conventionally tilled soybeans were imposed either before or during 1970. Conventionally tilled soybeans were imposed in 1974. Conventional tillage for corn consisted of spring plowing in mid-April, disking and planting in mid-May, and chemical and mechanical weed control as needed. Harvest was generally completed in late October, with cornstalks being chopped in early November. Conventional tillage for soybeans consisted of spring plowing in mid-April, disking and planting in late May, and chemical and mechanical weed control as needed. Soybeans were generally harvested a week or two earlier than corn. Soybean residues were hand-spread uniformly over the plots after harvest. Cultural operations for field cultivation were performed on the same date as conventional tillage. Soil manipulation with the field cultivator on these small plots would be similar to that of a chisel plow. Our field cultivator had seven knives on 200-mm spacings. Primary tillage depth was 150 mm, similar to that for moldboard plowing. Secondary tillage depth was about 80 mm, similar to that for disking. A fluted coulter was used to prepare a narrow seedbed for no-till planting. Weeds on the no-till plots were controlled chemically. Farming was up and down slope on 0.76-m row spacings. All treatments were duplicated, except for conventional and no-till corn, which had six and seven replicates, respectively. Fertilizer was applied to corn at rates recommended for optimum production, except for some conventional and no-till plots that received variable nitrogen (N) fertilizer applications ranging from 90 to 360 kg/ha. Because variable N rate had no effect on soil and water losses, additional plots from the conventional and no-till corn treatments were included in our analyses. Corn and soybean varieties used were 'Pioneer 3369A' and 'Williams'[3], respectively.

Five seasonal periods, based on uniform ground cover and management effects, were selected for analyses (Wischmeier and Smith, 1965; Laflen and Moldenhauer, 1979). These periods are defined for conventional tillage as: Period F (rough fallow)—spring plowing to secondary disking and planting; Period SB (seedbed)—planting plus 30 d; Period 12 (rapid growth)—30 to 60 d after planting; Period 3 (reproduction and maturation)—60 d after planting until harvest; and Period 4 (residue)—harvest until spring plowing. Wischmeier and Smith (1978) in Agricultural Handbook 537, USDA (AH 537) defined seasonal periods according to the percentage of canopy cover rather than the number of days within a given time period. Based upon canopy measurements made on these plots in 1983 and 1984, canopy cover developed from about 10 to 75% during the 30- to 60-d period after planting. As a result, periods 1 and 2 defined in AH 537 were combined to form a single period (12). Our seasonal period definitions then closely correspond with those presented in AH 537. Although no-till did not have a rough fallow period, it was included so direct comparisons among the tillage treatments could be made. Runoff events for the crops were not always common to a given seasonal period because of the differences in cultural dates already discussed.

Sprinkler irrigation was used to apply supplemental water to the growing crops during June and July of each year. During the 1971 to 1973 period, the objective was to increase soil moisture and promote runoff. During these 3 yr, only one small runoff event occurred within 3 d of water application. After 1973, water was applied during periods of moisture stress to ensure adequate yield and dry matter production. Amounts added during 1971 to 1977 were 170, 130, 130, 20, 30, 100 and 10 mm, respectively.

The cover and management factor (C) in the USLE was computed by summing soil loss and rainfall erosivity over years for each of the seasonal periods (McGregor, 1978) and determining the C value from the following equation:

$$C_p = A_p/R_pKLSP \qquad [1]$$

where

C_p = cover and management factor for period P,
A_p = total soil loss per unit area for period P (kg/ha),
R_p = total rainfall erosivity for period P (MJ mm/ha h),
K = soil erodibility factor (kg ha h/ha MJ mm),
LS = slope length and steepness factor, and
P = support practice factor.

[3] Varieties are listed for the benefit of the reader only and do not imply endorsement or preferential treatment by the USDA.

Table 2. Water and soil losses for conventional tillage by crop year and seasonal period.

Crop year	Water loss					Soil loss				
	F	SB	12	3	4	F	SB	12	3	4
	mm					kg/ha				
					Continuous corn					
1971	0.0	10.4	3.0	0.0	15.9	0	1 064	205	0	65
1972	13.1	0.0	0.0	0.0	253.7	39	0	0	0	1 370
1973	4.9	1.6	0.0	95.8	127.7	47	24	0	1 304	443
1974	2.9	64.2	0.0	1.7	79.1	39	11 075	0	52	472
1975	23.4	2.9	26.7	37.2	71.0	488	1 027	2 685	974	693
1976	0.0	0.0	19.4	0.0	33.9	0	0	489	0	308
1977	49.3	0.0	0.7	22.2	140.1	193	0	4	111	464
Avg. 1971–77	13.4	11.3	7.1	22.4	103.1(157.3)†	115	1 884	483	349	545(3 376)
Avg. 1975–77	24.2	1.0	15.6	19.8	81.7(142.3)	227	342	1 059	362	488(2 478)
					Continuous soybeans‡					
1975	37.6	3.0	60.7	24.9	67.1	2 024	1 291	14 861	1 185	1 675
1976	0.0	0.0	23.1	0.0	29.0	0	0	1 084	0	779
1977	38.6	0.0	14.2	36.1	98.0	239	0	915	200	791
Avg. 1975–77	25.4	1.0	32.7	20.3	64.7(144.1)	754	430	5 620	462	1 082(8 348)

† Numbers in parentheses are the sum of seasonal period values.
‡ Soybean cropping by conventional tillage was not initiated until May of 1974.

The K value of the Mexico series measured from fallow plots at this site over a 10-yr period from 1961 to 1969 was 43 kg ha h/ha MJ mm. The LS factor was calculated from AH 537 to be 0.31. The P factor is 1.0 by definition. Upon substitution of these values in Eq. [1], we have:

$$C_p = 0.075\ (A_p/R_p)\,. \qquad [2]$$

Soil loss (A_p) was measured from the specified cropping and tillage treatments. Rainfall erosivity (R_p) was computed by the method of Wischmeier and Smith (1958) using data from the recording raingage. Rainfall erosivity from the sprinkler irrigations was not included. The annual C value was computed from the equation:

$$\text{annual } C \text{ value} = (\Sigma_{P=F}^{4}\, C_p\, R_p)/\Sigma_{P=F}^{4}\, R_p)\,. \qquad [3]$$

One-way analysis of variance procedures were performed on event and 7-yr average annual soil and water losses using the general linear model in SAS (Goodnight et al., 1982). Soil loss data were logarithmic transformed before analysis to make the experimental errors more normally distributed.

RESULTS

Precipitation Characteristics

Average annual precipitation during the 7-yr study period was 895 mm, 14 mm below the 37-yr average annual measured at the plot site (Table 1). Average seasonal precipitation for continuous corn for periods SB and 12 was 72 mm below normal compared to the long-term data, while average seasonal precipitation for period 4 was 72 mm above normal. Differences in seasonal precipitation for continuous corn and soybeans reflect the differences in cultural operation dates previously described.

Average annual rainfall erosivity for the 1971 to 1977 period was 3170 MJ mm/ha h, compared to 3494 MJ mm/ha h for the long term (Table 1). Erosivity in period 12 for continuous corn was 44% below normal. About 71% (2247 MJ mm/ha h) of the average seasonal rainfall erosivity occurred during periods 3 and 4 for continuous corn, compared to 63% (2218 MJ mm/ha h) for the long term. These two periods coincide with maximum ground cover and protection against raindrop impact. Seasonal precipitation and rainfall erosivity during the study period were not significantly different (p <0.05) from the long term as measured by the U-test (McGuinness and Brakensiek, 1964).

Soil and Water Losses

Soil losses from conventionally tilled soybeans were higher than those of conventionally tilled corn for the 1975 to 1977 period (Table 2). Average annual soil losses for soybeans and corn were 8348 and 2478 kg/ha, respectively, which were significantly different (p <0.01). Higher soil loss with soybeans was the result of higher sediment concentration because average annual water loss differed by only 1.8 mm.

Several large runoff events occurred during the 1975 to 1977 period when cropping comparisons for conventional tillage could be made. On 23 April 1975, 95 mm of rainfall occurred on plowed ground (period F) having a rainfall erosivity of 742 MJ mm/ha h. Water losses for soybeans and corn were 37.6 and 23.4 mm, respectively, and were significantly different (p <0.05). Soil loss from soybeans was four times that of corn; 2024 kg/ha versus 488 kg/ha. This finding suggests that a difference in soil physical properties existed between the soybean and corn-cropped plots. Another large event occurred on 16 June 1975, 32 d after planting (period 12). A total of 81 mm of rainfall was recorded with an erosivity of 919 MJ mm/ha h. Water loss for soybeans was 55.9 mm compared to 26.7 mm for corn (p <0.01). Soil loss for soybeans (13 530 kg/ha) was almost five times that of corn (2685 kg/ha). Canopy cover measurements were not obtained during this study, but based upon recent data from this plot site, our best estimate of canopy cover for this event is 18% for corn and 15% for soybeans. A difference in cultivation dates did exist between the crops. Corn was cultivated 10 d prior to the event while soybeans were not cultivated until after the event. We know that some consolidation of the loose cultivated soil occurred prior to the runoff event because rainfall events occurred on 9 and 14 June that produced 20 mm of rainfall (119 MJ mm/ha h erosivity). Manner-

Table 3. Water and soil losses for field cultivation by crop year and seasonal period.

Crop year	Water loss F	Water loss SB	Water loss 12	Water loss 3	Water loss 4	Soil loss F	Soil loss SB	Soil loss 12	Soil loss 3	Soil loss 4
	mm					kg/ha				
					Continuous corn					
1971	0.0	12.2	4.6	0.0	15.7	0	883	73	0	49
1972	14.5	0.0	0.0	0.0	211.8	88	0	0	0	1100
1973	7.6	0.5	0.0	74.7	98.6	52	0	0	632	364
1974	2.5	47.5	0.0	0.0	49.3	16	4233	0	0	275
1975	30.2	0.0	30.0	38.1	41.9	1347	0	1748	870	354
1976	0.0	0.0	17.8	0.0	17.3	0	0	240	0	115
1977	34.0	0.0	0.3	7.6	128.8	155	0	0	48	259
Avg. 1971–77	12.7	8.6	7.5	17.2	80.5(126.5)†	237	731	294	221	359(1842)
					Continuous soybeans					
1971	4.6	8.9	0.0	0.0	14.7	0	393	0	0	186
1972	21.3	0.0	0.0	0.0	237.5	245	0	0	0	2468
1973	4.6	0.0	46.7	9.7	98.0	0	0	553	5	338
1974	11.2	51.8	1.3	4.1	53.3	0	2697	31	15	382
1975	45.7	1.5	55.4	20.8	58.4	1941	330	9174	387	798
1976	0.0	0.0	33.0	0.0	39.1	0	0	1025	0	453
1977	29.7	0.0	13.7	44.7	147.8	234	0	424	155	821
Avg. 1971–77	16.7	8.9	21.4	11.3	92.7(151.0)	346	489	1601	80	778(3294)

† Numbers in parentheses are the sum of seasonal period values.

ing and Johnson (1969) measured soil losses from corn and soybeans both before and after cultivation on a fertile silt loam soil in Indiana. Total soil losses from 127 mm of rainfall were about 10% lower after cultivation. We feel that the effect of cultivation on time to initiation of runoff and infiltration rates would not entirely account for observed differences in soil loss between corn and soybeans. It is also important to note that differences in cultivation dates for these crops do exist for field conditions, which these plots were emulating.

Table 3 shows water and soil losses from corn and soybeans for field cultivation. Field cultivation for corn reduced the 7-yr average annual water loss by 30.8 mm (19.6%) as compared to conventional tillage. Water losses for soybeans, however, were higher than those from conventional tillage (1975–77 period). Over 60% of the water loss occurred during period 4. Both the absolute and relative soil losses for corn and soybeans were reduced by field cultivation as compared to conventional tillage. However, average annual soil loss was still significantly higher ($p < 0.10$) for soybeans than corn, 3294 vs. 1842 kg/ha, respectively. Some of the 79% increase in soil loss with soybeans can be attributed to increased water loss, but most of the difference was because of higher sediment concentrations. About 60% of the average annual soil loss occurred during periods SB and 12.

No-till was quite effective in reducing soil losses for both crops (Table 4). However, average annual soil loss for soybeans was still significantly higher ($p < 0.01$) than that for corn. Average annual water loss for soybeans was 6.5 mm less than that for corn; thus, soil detachment and transport were higher for soybean cropping.

It is interesting to note the differences in soil loss for period 4 among the three tillage treatments. Analysis of soil samples collected at the end of the study showed significant ($p < 0.01$) cropping and tillage effects on the carbon (C) content of the 0- to 75-mm soil surface. Organic C for corn was 16, 17, and 21 g/kg, respectively, for the conventional, field cultivation, and no-till treatments. Corresponding organic C levels for soybeans for these three tillage treatments were 14, 16, and 18 g/kg, respectively. Because residue cover after harvest would be similar for a given crop, lower soil losses for no-till during period 4 partially reflect the beneficial effect of the buildup in organic C and the known effects of such a buildup on aggregate size and stability (Browning and Milam, 1941; Strickling, 1950).

Water loss from no-till corn was 10 mm greater than that from conventional corn. As previously mentioned, period F was included with no-till so direct comparisons could be made among the tillage treatments. In our study, the 10-mm difference occurred during period F. The increased microrelief and soil drying that occurred after plowing reduced runoff more than the residue cover associated with no-till.

C Factors

The measured annual *C* factors for continuous soybeans among the various tillage methods were about two times those of continuous corn (Table 5). The largest difference in seasonal *C* factors between crops occurred for conventional tillage during period 12, when the *C* factor for soybeans was six times that of corn. *C* factors during period SB were higher for continuous corn than continuous soybeans, a finding that we cannot fully explain. Perhaps it is related to the below normal rainfall erosivity that occurred during period SB; and, if so, suggests the presence of an interaction between rainfall erosivity and cropping effects on soil loss. The *C* factors for periods F, 12, and 4 were higher for soybeans than for corn while those for the three tillage methods followed the order of conventional > field cultivate > no-till.

No *C* factors for continuous soybeans are given in AH 537, but estimated values were obtained from a corn following soybean rotation (Table 5 of AH 537; lines 109, 115, 120). The seasonal *C* factors and those

Table 4. Water and soil losses for no-till by crop year and seasonal period.

Crop year	Water loss					Soil loss				
	F	SB	12	3	4	F	SB	12	3	4
	mm					kg/ha				
					Continuous corn					
1971	0.0	13.0	10.0	0.0	26.9	0	156	125	0	61
1972	39.4	0.4	0.0	0.1	228.9	144	0	0	0	262
1973	12.3	6.1	0.0	77.7	112.4	28	26	0	263	17
1974	27.3	61.4	0.0	2.0	68.4	13	719	0	11	136
1975	35.2	0.0	45.1	42.4	75.8	377	0	773	200	5
1976	0.0	0.0	25.3	0.0	33.3	0	0	77	0	77
1977	56.0	0.0	2.5	15.9	153.6	100	0	0	0	24
Avg. 1971-77	24.3	11.6	11.8	19.7	99.9(167.3)†	95	129	139	68	83(514)
					Continuous soybeans					
1971	3.8	12.2	1.0	0.0	23.4	0	261	0	0	59
1972	20.3	0.0	0.0	0.3	234.7	0	0	0	0	813
1973	4.6	0.3	80.0	25.4	105.2	0	3	1221	237	0
1974	13.2	52.1	2.3	18.3	69.8	0	601	8	77	209
1975	67.1	0.0	52.6	47.5	65.5	1014	0	1928	163	85
1976	0.0	0.0	30.0	0.0	31.0	0	0	98	0	167
1977	35.8	0.0	12.2	37.3	80.3	0	0	42	87	278
Avg. 1971-77	20.7	9.2	25.4	18.4	87.1(160.8)	145	124	471	81	230(1051)

† Numbers in parentheses are the sum of seasonal period values.

from the continuous corn treatments were used with the rainfall erosivity (EI) distribution for area 16 in Table 6 of AH 537 to compute the predicted annual *C* factors shown in Table 5. Predicted annual *C* factors ranged from two to over seven times the measured values among our six treatments. These differences are due to two factors. First, the EI distribution measured during our 7-yr study was somewhat different than that given in Table 6 of AH 537. When our measured *C* factors are weighted with the EI distribution given for area 16 in Table 6 of AH 537, measured annual *C* factors for conventional, field cultivation, and no-till corn increased from 0.08 to 0.12, 0.04 to 0.06, and 0.01 to 0.02, respectively. Using this same adjustment approach, the measured annual *C* factors for conventional, field cultivation, and no-till soybeans increased from 0.18 to 0.25, 0.08 to 0.09, and 0.02 to 0.03, respectively. The second and, obviously, most important reason why predicted annual *C* factors were higher than those measured is that seasonal *C* factors in AH 537 are higher than those we measured (see Table 5 for a comparison). Differences between measured values and those from AH 537 were the smallest during period 4. It appears that *C* factors from AH 537 are too high for periods F, 12, and 3. Similar results have been found on natural rainfall erosion plots in Mississippi (McGregor and Mutchler, 1983). Perhaps the steady improvement over recent years in crop and fertilizer management practices is partially responsible for recently measured *C* factors being smaller than those given in AH 537. Another explanation could be related to a potential bias in the representativeness of some published soil loss data (Burwell and Kramer, 1983). They reported that soil losses from short-term studies (often 5 yr or less) are more apt to be published when treatment differences are large, generally from high runoff and soil loss years. The *C* factors developed from this type of data could be too high if there is an interaction between rainfall erosivity and soil loss.

Period 4 *C* factors were obtained from Table 5-C of AH 537 because cornstalks were chopped after harvest and the soybean residue was hand-spread to give maximum soil cover. Stalk chopping and residue spreading cause a several-fold reduction in *C* factors for period 4 (compare values in Tables 5 and 5-C of AH 537). The C factors in AH 537 are adjusted only in period 4 for the beneficial effects of these residue man-

Table 5. Measured *C*-factors by tillage method and seasonal period compared to those in Agricultural Handbook 537, USDA (AH 537).

Tillage method	Measured *C* factors						Table 5 origin	AH 537 *C* factors†					
	F	SB	12	3	4	Annual		F	SB	12	3	4	Annual
						Continuous corn							
Conventional	0.03	0.54	0.10	0.02	0.08	0.08	Line 1	0.31	0.55	0.43	0.20	0.03	0.28
Field cultivation	0.06	0.21	0.06	0.01	0.05	0.04	Line 41	-‡	0.14	0.12	0.09	0.03	0.09
No-till	-	0.04	0.03	<0.01	0.01	0.01	Line 27	-	0.05	0.05	0.05	0.02	0.04
						Continuous soybeans							
Conventional§	0.14	0.44	0.60	0.02	0.15	0.18	Line 109	0.40	0.72	0.54	0.25	0.15	0.39
Field cultivation	0.08	0.13	0.21	<0.01	0.10	0.08	Line 115	-	0.40	0.32	0.23	0.15	0.24
No-till	-	0.03	0.06	<0.01	0.03	0.02	Line 120	-	0.25	0.20	0.11	0.10	0.15

† *C* factors for periods F, SB, and 3 were obtained directly from Table 5 in AH 537. *C* factors for period 12 were obtained by weighting values for cropstages 1 and 2 from Table 5 with the EI distribution given for area 16 in Table 6 of AH 537. *C* factors for period 4 were obtained from Table 5-C in AH 537.

‡ *C* factor is insignificant or an unlikely combination of variables.

§ Measured *C* factors calculated from data collected during a 3-yr period from 1975 to 1977. All other measured *C* factors were calculated from data collected during a 7-yr period from 1971 to 1977.

agement practices. As a result, *C* factors for periods SB and 12 for no-till from AH 537 may be too high because no adjustment for residue management is made. We are not sure why AH 537 does not have these adjustments for periods other than 4, except perhaps that residue movement by wind during the overwintering period was expected to negate the beneficial effect of residue spreading. A similar effect of residue management on *C* factors for field cultivation would probably also be present, but perhaps minimized because spring tillage would reduce differences in soil cover that exist when residues are left in their natural state after harvest as opposed to chopping or spreading them to maximize soil cover.

It is also interesting to compare relative differences in corn and soybean C factors between measured values and those in AH 537. For conventional tillage, *C* factors in periods F, SB, 12, and 3 for soybeans from AH 537 are about 28% higher than those for corn. As can be seen in Table 5, measured *C* factors for soybeans in periods F and 12 for conventional tillage were over four times those of corn. As a result, the relative difference in measured annual *C* factors between corn and soybeans was considerably greater than that predicted from AH 537, indicating that adjustments of corn and soybean *C* factors in AH 537 may be needed to reflect actual cropping differences. For the conservation tillage treatments, relative differences between corn and soybean *C* factors in AH 537 for all seasonal periods were generally greater than those measured, opposite the results found for conventional tillage. In summary, considerable adjustment of the seasonal *C* factors in AH 537 would be required to more closely predict the annual *C* factors that we measured.

Implicit in our analyses of *C* factors is the assumption that the length-slope (*LS*) factor of 0.31 from AH 537 used to correct soil loss to unit plot conditions of 22.1-m length and 9% slope is correct for this set of plots. A second assumption is that the soil erodibility factor (*K*) was the same during the 1971 to 1977 period as it was during the 1961 to 1969 period when it was measured from fallow plots at this site. The soil erodibility factor can vary among years and measurement periods because of differences in antecedent soil moisture, surface sealing, tillage alterations in soil microrelief, and prior runoff event effects on soil loss. An analysis of differences in these factors between the 1971 to 1977 and 1961 to 1969 measurement periods is not possible, but they are thought to be minor. The soil erodibility factor has also been shown to be directly correlated with rainfall erosivity on some soils (Laflen, 1982). It can be deduced from this finding that lower than normal EI during the study period might have resulted in a lower *K* value than the one used to compute measured *C* factors. Because an evaluation of both the *K* value and *C* factor is not possible with our data, measured *C* factors might be too low for lower than normal EI periods if the *K* value used is associated with normal EI. Periods SB, 12, and 4 had lower than normal EI (see Table 1). Differences between AH 537 *C* factors and those we measured were the smallest for these periods. For periods F and 3, where EI during the 1971 to 1977 period was about 12% higher than the long term, *C* factors from AH 537 for conventional tillage were about 10 times those we measured. Obviously, it is difficult to assess the ambiguity of the *K* value and *C* factor on our results. It should be remembered, however, that seasonal EI during the study period was not significantly different ($p < 0.05$) from the long term.

DISCUSSION

Our discussion will focus on residue, soil, and canopy factors associated with these two crops, how they differ, and the influence that these differences probably had on soil and water losses. A 7.8 Mg/ha corn yield produces about two and one-half times more residue than a 2.1 Mg/ha soybean yield (Larson et al., 1978). Corn residue also decomposes at a slower rate than soybean residue during the first 0.5 yr of decomposition (Ghidey et al., 1984). These two factors would have combined to give our corn-cropped plots more cover and protection against raindrop detachment during the November to April overwintering period. The beneficial effects of soil cover in reducing erosion losses have been well documented (Mannering and Meyer, 1963; and Meyer et al., 1970). Differential amounts of residue cover also affect the number and severity of freezing and thawing and wetting and drying cycles that occur in soils (Slater and Hopp, 1949; and Chepil, 1954). Because of the additional residue cover with corn cropping, the near soil surface would have been better protected and would have undergone less weathering and aggregate breakdown when compared to the soil protected by soybean residue. As shown in Table 5, the effects of differential residue cover and soil protection on measured *C* factors are great for corn and soybean cropping, with *C* factors in period 4 for soybeans being about two times those of corn. For field cultivation and no-till, the residue factor remains important even when the canopy shades most of the soil surface.

With conventional tillage, moldboard plowing inverts the soil and buries nearly all the residue. As shown in Table 5 for period F, the measured *C* factor for soybean cropping is about five times that of corn cropping. This cropping difference in measured *C* factors is believed related largely to soil microrelief conditions that existed after plowing. An inverse relationship generally exists between microrelief and soil loss because runoff ponds in the low areas causing much of the sediment to deposit during transport. Our corn-cropped plots are believed to have had greater soil microrelief for two reasons. First, they were often plowed at greater than optimum moisture content because the additional residue cover retarded soil evaporation in the spring relative to that for soybeans. Thus, the soil compacted more upon shearing and inversion, which promoted clod formation (Baver et al., 1972). The second factor relates to differences in root morphology within the plow layer. The brace roots of a corn plant tend to encapsule and hold tightly the underlying soil. These roots appear to remain physically intact during the overwintering period; thus, they impart strength to the soil to inhibit soil shattering during inversion. Apparently, the effect of these, and perhaps other factors, was greater microrelief for the corn-cropped plots with an ensuing decrease in the amount of sediment transported.

The prior discussion has focused on the effect of these crops on the interrill erosion process where soil detachment is primarily by raindrop impact. However, rill erosion, where the soil is detached by concentrated flow, is a serious problem on many soils. Differences in residue mass incorporated into the soil have been found to affect the tendency of a soil to rill (Van Liew and Saxton, 1983). The increased amount of corn residue within the plow layer strengthens the soil and decreases the amount of rill erosion. Little rilling occurred on the runoff plots; thus, it would have been only a minor factor in our study. However, rilling differences between corn and soybean cropping may be very important on highly eroding soils, such as those in the deep loess hills region of western Iowa and northwestern Missouri.

Our finding of higher *C* factors for corn during period SB is difficult to explain because we anticipated higher values for soybeans for several reasons. First, secondary tillage (disking or shallow chiseling) was not expected to mask all of the microrelief effects that were evidently present during period F. Secondly, the stability of soil aggregates developed with soybean cropping was expected to be less than that developed with corn cropping because of differences in residue mass and decay rates affecting the aggregation process of the soil. For soybean cropping, this factor would have enhanced surface seal formation, decreased infiltration, and increased soil loss. The event of 16 June 1975 occurred 2 d after period SB ended. Canopy cover for corn and soybeans was estimated to be <20% (see Results section). Soil loss for conventionally tilled soybeans from this event was five times that of corn. It is possible that some of the difference in soil loss between corn and soybeans could be attributed to a soil aggregation factor. Because EI in period SB during our study was about 28% below normal, the low EI might have made detection of cropping effects on soil loss difficult.

During period 12, differences in canopy morphology, and the relation of the ground cover to erosional zones for these crops, have to be considered to explain some of the differences in *C* factors. Cultivation generally forms a ridge from the row position to the quarter row and a furrow halfway between the rows. Large differences in soil strength exist within the interrow microtopography (J.M. Bradford, USDA-ARS, unpublished data), with erosional zones having lower strength than depositional zones. The amount of canopy shading the erosional zones within the one fourth to one half row is undoubtedly quite important in explaining soil loss differences between corn and soybean cropping during this period. A soybean canopy would not begin to shade the one fourth row area until cover was near 50%. A corn canopy, on the other hand, would begin to shade the one fourth row area about 30 d after planting when six leaves have fully emerged. More research is needed to better understand how canopy cover interacts with erosional zones within the interrow area.

Period 3 *C* factors were quite low because of the near total canopy cover that existed during much of the period. Lower erosion rates often occurred with soybeans after complete canopy closure because the short, dense canopy was very effective in reducing raindrop energy. However, higher soil losses often occurred for soybeans after senescence of the plant tissue. At senescence, soybean leaves yellow and drop to the soil surface. The leaves dry rapidly, curl, and concentrate adjacent to the standing stems. This condition of lower cover for soybeans existed for about one-third of period 3. The timing of the rainfall events to these changing canopy conditions obviously becomes important for single event soil loss. On a seasonal basis, *C* factors were similar for both corn and soybean cropping.

SUMMARY

Soil and water losses from continuous corn and soybean cropping were measured during five seasonal periods on a fertile claypan soil in central Missouri over a 7-yr period. Each of the crops was evaluated by conventional, field cultivation, and no-till tillage methods. We found that:

1. Cropping had little effect on average annual water loss. Water losses were generally lower from field cultivation than from the conventional and no-till treatments.
2. Average annual soil losses from soybean cropping were higher than from corn cropping for all tillage methods. The largest cropping difference was found for conventional tillage.
3. Annual *C* factors for soybean cropping were about twice those of corn cropping for all tillage methods.
4. Measured seasonal *C* factors for corn and soybean cropping were consistently lower than those presented in Table 5 of AH 537 for all tillage methods.

Our study also showed the importance of maintaining soybean residue cover to maximize soil loss reduction. We found that no-till soybean cropping reduced average annual soil loss by 85% when compared to conventional tillage. Field cultivation with soybean cropping, however, reduced average annual soil loss by only 37% when compared to conventional tillage. Land cropped to soybeans with some conservation tillage methods can have insufficient residue cover for adequate erosion control.

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