Predicting Crop Residues Needed to Control Soil Erosion on Farmland

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Traditionally, residues remaining after harvest have been left on the land either for erosion control or for soil building processes. With the current emphasis on nonpoint source pollution and energy shortages, the production and use of crop residues are considered important in maintaining environmental quality and producing energy. Crop residues removed from the land will affect, to varying degrees, soil erosion and the fertilizer requirements of subsequent crops. On certain classes of agricultural land, all crop residues are needed for erosion control; on other soils, residues are not as critical. Consequently, criteria are needed to determine the amount of residue that can be removed from a given area without increasing soil erosion beyond tolerable limits. Although nutrients removed in residues will surely have to be replaced with fertilizers, this study does not address that issue.

Control of soil loss by wind and water erosion imposes additional costs in farming, and certain types of soils and terrain require more erosion protection than others. That erosion control is necessary is recognized by even the casual observer, but effecting control is much more complex than is envisioned by those not directly involved in land management and erosion control processes. Of high priority is the development of management methods that identify erosion control needs before crop residue resources are removed for energy use. Effective partitioning of crop residues between on-farm and off-farm uses will become more and more important as the value of crop residue increases. Here, we discuss a method for determining the amounts of incorporated crop residues needed to keep soil erosion below tolerable limits for several cropping systems in the major land resource areas of six southern states—Alabama, Georgia, Mississippi, North Carolina, South Carolina, and Virginia.

Computation of Residue Requirements for Erosion Control

"Residue needed" is defined as the amount of plant material that must be retained on cropland to keep soil loss by water erosion within tolerable limits (1). "Available residue" is defined, therefore, as the amount excess to "residue needed." Wind erosion control in relation to crop residue management has been discussed by Skidmore *et al.* (4). Residues produced in excess of those needed for both wind and water erosion control depend not only upon the sequence of crops grown but also upon the amount of residue produced, soil erodibility, tillage methods, conservation practice, amount and intensity of rainfall, land slope, and acceptable erosion tolerable standards.

Residues produced (RP) by crops may be partitioned between residues that need to be retained on the land (RN) and residues that are available for removal (RA) without increasing soil loss above tolerable limits, as given in equation:

$$RP = RN + RA \qquad (1)$$

The RA may be calculated from the equation:

$$RA = (1\text{-}A/T)F, \qquad (2)$$

Where A is soil loss as computed from the Universal Soil Loss Equation (USLE), T is the soil loss tolerance value, and F is a coefficient defined as the reduction of soil loss per unit of residue incorporated into the soil. The usefulness of equation 2 depends upon three boundary conditions: (1) RA is dependent on A/T values from 0 to near 1. Calculated values of RA should be compared with RP because RA cannot, by definition, exceed RP, (2) and when A/T = 1, RA = 0; all residues that are produced will be needed, and (3) when A/T exceeds 1, RA becomes negative. The logic of equation 1 suggests that negative values of RA are meaningless because RN does not exceed RP. One cannot utilize residues that do not exist. By applying these boundary conditions, the amount of residue RN that should remain on the land for erosion control can be expressed in terms of known measureable quantities. Consequently, the RN can be computed directly from equation 3:

$$RN = RP - (1\text{-}A/T)F \qquad (3)$$

A more general form of this equation may be written as equation 4:

$$RN = f[RC] - (1\text{-}A/T)F \qquad (4)$$

which allows determining residues produced after crop remains have been laying on the soil surface for a known time after harvest. In equation 4, RC is defined as the residue remaining at the time of observation and f is a decay correction factor expressed as the inverse fraction of the undecomposed residues. Although this equation increases the flexibility of determining available residue at different times of the year, residue should normally be removed when amounts in the field are maximum. In our calculations we used 1.3 times RC to estimate RP, where RC is the amount of residue on the surface in the spring. The constant F is based upon the reduction of erosion due to the incorporation of residues into the soil. A single value of F has been derived from data by Wischmeier (10), in which relative values of soil loss ratios were reduced about 12% for each ton/acre of residue incorporated. When the F is expressed in metric units, the constant becomes 18,667 kg/ha (16,667 lb/acre). For every 0.1 decrease in the A/T ratio, between 1.0 and 0.0 the amount of residue available for removal is increased by 1,867 kg/ha. Taking A as the soil loss computed from USLE and T as the tolerance limit, RN can be computed for various soils. Since F is dependent on soil class, climate, type of residue, and tillage practice, it needs experimental evaluation for a range of soils, climatic conditions, and types of residue. Nevertheless, the application of this approach will be demonstrated by utilizing the best available data at this time.

Crop Information and Soil Loss Computations

Crop yields and area harvested for 1975 in the six states were obtained from the USDA Statistical Reporting Service (SRS) and cooperating state agencies (7). These data were compiled county by county for predominant field crops listed in table 1. Forage crops were not included in the study because they are either grazed or harvested for animal feed. Residue production was then calculated based on strawgrain ratios (2), for various crops (3), seed or grain yield, and area harvested by county.

Sources of crop and soil information given in figure 1 illustrate the sequence of calculations used to estimate the amount of residue that should remain on the farm to keep erosion at or below tolerable levels. If the amount of residue produced (RP) is known and the amount of residue needed (RN) can be estimated accurately, then the amount of residue available (RA) for removal is readily ascertained.

To determine expected RN, one must know the soil loss, A, and the soil loss tolerance, T. The factor A takes into account climate (rainfall), terrain features, soil erosivity, erosion control practices used, and the effect of crop cover protection afforded by the crop during the production of residues that will subsequently be used for erosion protection. These factors are taken into account in the Universal Soil Loss

Table 1. Area harvested in 1975 for several major crops and cropping sequences in six southern states

Row crop	Crop sequence	Row crop (acres x 1000)	Cropped land (%)
Corn-soybeans	Rotation	1,156	4.5
Soybean-small grain	Double crop	3,054	12.0
Soybeans	Continuous	5,934	23.3
Corn	Continuous	3,715	14.6
Cotton	Continuous	1,876	7.4
Sorghum	Continuous	180	0.7
Total		**15,915**	**62.5**

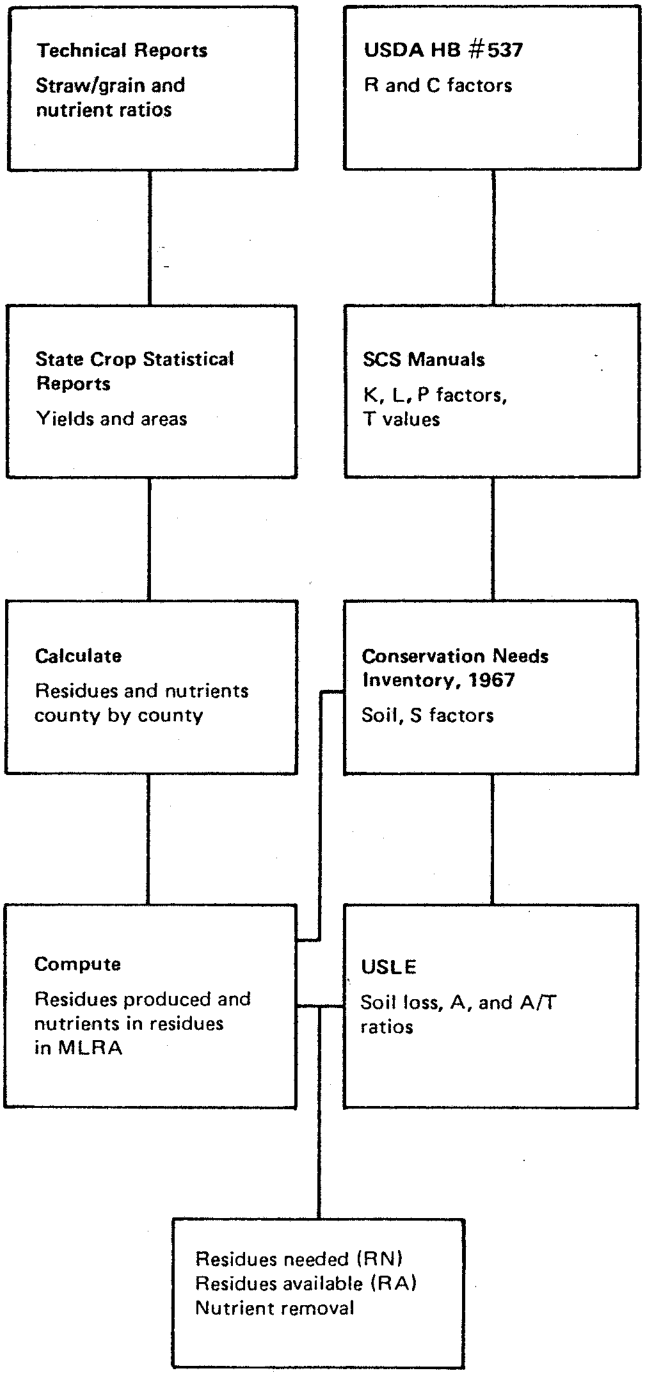

Figure 1. Sources of information for estimating needed and available crop residues for water erosion control

Equation, for the major field crops within each major land resource areas (MLRA) in each of the six southern states.

The USLE is A = RK(LS)CP, where A, the dependent variable, is the computed soil loss, R is the rainfall erosion index, K is the soil erodibility factor, (LS) is the topographic factor, C is the cover and management factor, and P is the support practice factor (8). Since C and P are ratios varying between 0 and 1, with R expressed in index units, and K is defined as soil loss rate per erosion index unit, A must be expressed as soil loss per unit area per year.

To solve this equation for each soil series within each MLRA, the area and slope data were obtained from the SCS "Conservation Needs Inventory of 1967" (5). Soil Conservation Service personnel assisted in defining the slope length, L criteria. Weighted average S values are given in table 2. For this study, soils having slopes greater than 7% were not considered to be in cultivated field crops. Values of R given in table 3 for each MLRA were determined from the MLRA map of the United States (9) and the R value map given in USDA Handbook 537 (11). The K and T factors for each soil series were obtained from SCS (6) and weighted average K values are presented in table 3 for MLRA within states. We used a P factor of 0.8 as a constant throughout the study because common practice is to plant across slopes as well as up and down slopes.

Results and Discussion

Land area in fiber and grain crops considered in this study encompassed about 16 million acres from a total of 25.5 million acres of cropped land (table 1). About 9.5 million acres is used for forage and pasture. Woodlands were not included.

Cropped acreage and percentage of total acreage for each state and MLRA given in tables 4 and 5, respectively, indicate the distribution of crops and the percentage of total cropped area in major row crops. In 1975, the soybean acreage in the single cropping systems was 160% of the corn acreage and corn acreage was 200% greater than cotton. Double-cropping soybeans with small grain is a practice gaining popularity in all states in the Southeast. Corn is the crop most frequently used in rotations with soybeans. Corn, soybeans, and small grains dominate the row crop agriculture in the Southeast. In 1975 about 2 million acres was in cotton and about 0.2 of a million acres was in sorghum. Consequently, crop residue use and erosion control practices will be associated with these crop management systems.

The field slope distribution shown in table 2 indicates that the steepest lands are in MLRA 136 in North Carolina and South Carolina, 134 in Mississippi, 129 in Alabama, and 148 in Virginia. In contrast, 90% of the land in MLRA 153 has slopes of less than 1%.

Soil loss computations using the USLE are based upon C factors given in table 6 and other factors for each crop sequence for each MLRA in each of the six southern states. The C factor calculations were based

Table 2. Field slope distribution of cultivated land in the major land resource areas in six southern states

State	MLRA	Field slope - percent						
		0 - 1	1 - 2	2 - 3	4 - 5	5 - 6	6 - 7	7 - 8
		Percent cultivated land						
Alabama	125	0	55	0	0	31	14	0
	128	0	46	0	0	9	45	0
	129	0	26	0	0	26	48	0
	133	0.3	47	1	0	46	5	0
	135	42	8	28	0	22	0	0
	136	0	58	0	0	9	33	0
Georgia	128	47	0	0	53	0	0	0
	129	29	0	0	71	0	0	0
	130	75	0	0	25	0	0	0
	133	40	0	47	0	0	13	0
	136	31	0	1	67	0	1	0
	137	31	0	37	5	0	27	0
	153	92	0	6	0	0	2	0
Mississippi	131	69	0	0	30	0	0	1
	133	48	0	0	30	0	0	22
	134	53	0	0	22	0	0	25
	135	57	0	0	30	0	0	13
	152	51	0	0	42	0	0	7
North Carolina	130	9	0	0	91	0	0	0
	133	68	0	11	19	0	0	2
	136	6	0	2	92	0	0	0
	137	21	0	3	76	0	0	0
	153	85	0	10	5	0	0	0
South Carolina	130	30	0	0	70	0	0	0
	133	68	0	10	22	0	0	0
	136	19	0	0	81	0	0	0
	137	20	0	19	61	0	0	0
	153	92	0	3	5	0	0	0
Virginia	133	57	0.3	0	43	0	0	0
	136	9	0	0	91	0.3	0	0
	148	1	16	0	1	82	0	0
	149	51	5	0	43	1	0	
	153	89	0	0	11	0	0	0

Table 3. Weighted average USLE factors for each MLRA in six southern states.

State	MLRA	S %	L (feet)	L S	R (index)	K T/A/yr	A T/A/yr
Alabama	125	2.94	317	0.68	250	0.32	18.3
	128	3.61	298	0.74	250	0.34	23.5
	129	4.44	320	0.90	350	0.31	36.2
	133	3.61	334	0.68	350	0.24	20.6
	135	2.52	299	0.44	350	0.32	16.5
	136	3.59	295	0.63	350	0.26	20.3
Georgia	128	2.59	316	0.44	300	0.31	16.5
	129	3.13	339	0.53	250	0.27	13.5
	130	1.75	281	0.30	300	0.23	7.2
	133	2.59	180	0.25	350	0.19	10.4
	136	3.08	334	0.52	300	0.26	15.3
	137	3.24	288	0.54	300	0.16	11.8
	153	1.22	248	0.20	350	0.16	4.0
Mississippi	131	1.96	285	0.33	350	0.30	13.8
	133	3.22	288	0.57	350	0.34	30.2
	134	3.16	278	0.56	350	0.37	35.0
	135	2.68	288	0.47	350	0.34	19.9
	152	2.68	303	0.46	350	0.26	15.7
North Carolina	130	3.73	364	0.63	200	0.22	8.4
	133	1.91	274	0.31	300	0.20	5.9
	136	3.80	366	0.63	250	0.28	15.1
	137	3.34	347	0.56	250	0.18	7.5
	153	1.35	261	0.22	350	0.21	4.7
South Carolina	130	3.16	338	0.47	300	0.47	11.8
	133	1.86	283	0.30	300	0.21	5.5
	136	3.43	351	0.58	250	0.28	12.1
	137	3.21	336	0.52	250	0.16	7.2
	153	1.21	258	0.20	350	0.20	4.6
Virginia	133	2.28	303	0.38	250	0.26	7.4
	136	3.73	364	0.63	175	0.28	9.3
	148	4.48	379	0.93	150	0.28	10.7
	149	2.38	307	0.40	250	0.25	6.8
	153	1.33	264	0.23	250	0.11	2.2

Table 4. Total cropped land in the major land resource areas of six southern states, percentage included in the study, and distribution among cropping systems

State	MLRA	Soybeans-small grain	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous cotton	Continuous sorghum	Total cropped	Cropped land in study
					thousands of acres				
Alabama	125	6.7	27.7	35.1	12.0	3.3	0.7	106.7	80
	128	26.1	109.7	194.4	0.0	163.2	3.2	637.5	78
	129	12.9	83.4	112.7	80.4	67.5	3.5	496.3	73
	133	74.3	362.7	447.9	237.5	96.1	27.2	1813.3	69
	135	14.2	43.5	66.6	0.0	28.5	2.8	233.7	67
	136	2.1	2.5	1.7	14.9	6.6	1.2	55.9	52
Georgia	128	1.9	24.3	42.7	0.0	8.9	1.2	81.1	97
	129	0.0	0.1	0.1	0.1	0.0	0.0	0.2	100
	130	0.0	0.4	0.7	6.9	0.0	0.0	8.0	100
	133	88.5	427.4	549.4	1193.7	122.1	30.5	3053.0	78
	136	26.2	75.6	88.1	23.2	21.6	9.2	270.1	90
	137	15.0	40.6	46.9	33.3	6.3	1.3	169.2	85
	153	3.5	59.3	81.1	308.1	2.0	1.4	494.5	92
Mississippi	131	131.5	1.0	1337.0	0.0	711.9	0.0	2480.4	88
	133	23.9	172.2	596.8	0.0	139.6	0.0	956.5	98
	134	29.3	82.0	604.1	0.0	230.3	0.0	976.0	97
	135	11.9	26.1	234.9	0.0	19.5	0.0	304.2	96
	152	0.6	2.1	8.3	0.0	0.0	0.0	11.7	94
N.C.	130	3.6	2.4	0.0	59.0	0.0	0.2	197.3	33
	133	66.9	251.3	308.4	460.2	88.1	6.5	1631.8	72
	136	160.2	160.2	76.1	272.3	20.0	66.7	1334.9	57
	137	9.6	21.4	22.5	8.0	31.2	1.6	121.8	77
	153	56.3	277.4	359.7	422.9	5.5	5.5	1373.1	82
S.C.	130	1.2	0.0	0.0	5.2	0.4	0.3	20.6	34
	133	127.6	380.1	448.1	93.3	84.2	2.7	1357.8	84
	136	63.7	75.1	48.9	0.0	11.7	12.1	391.0	54
	137	32.3	86.0	96.9	2.8	4.5	1.1	279.3	80
	153	23.2	145.1	191.6	109.1	1.7	0.6	580.6	81
Virginia	133	14.9	35.4	38.2	92.0	0.8	0.0	280.6	65
	136	38.2	38.9	20.6	81.5	0.0	0.0	367.0	49
	148	14.1	15.3	2.7	89.6	0.0	0.0	191.0	64
	149	72.5	72.6	36.5	81.5	0.0	0.0	357.6	74
	153	41.9	51.3	35.3	28.6	0.0	0.0	313.9	50

Table 5. Percentage of land cropped for several cropping systems in the major land resource areas in six southern states in 1975

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton	Total cropped acres
					%			
Alabama	125	6.3	26.0	32.9	11.2	0.7	3.1	106,700
	128	4.1	17.2	30.5	0	0.5	25.6	637,500
	129	2.6	16.8	22.7	16.2	0.7	13.6	496,300
	133	4.1	20.0	24.7	13.1	1.5	5.3	1,813,300
	135	6.1	18.6	28.5	0	1.2	12.2	233,700
	136	3.8	4.5	3.0	26.7	2.1	11.8	55,900
Georgia	128	2.4	30.0	52.6	0	1.5	11.0	81,120
	129	0	25.0	37.5	37.5	0	0	200
	130	0	5.0	8.4	86.6	0	0	7,990
	133	2.9	14.0	18.0	39.1	1.0	4.0	3,052,960
	136	9.7	28.0	32.6	8.6	3.4	8.0	270,170
	137	8.9	24.0	27.7	19.7	0.8	3.7	169,210
	153	0.7	12.0	16.4	62.3	0.3	0.4	494,510
Mississippi	131	5.3	0.04	53.9	0	0	28.7	2,480,450
	133	2.5	18.0	62.4	0	0	14.6	956,470
	134	3.0	8.4	61.9	0	0	23.6	975,960
	135	3.9	8.6	77.2	0	0	6.4	304,240
	152	5.1	18.2	71.3	0	0	0	11,700
North Carolina	130	1.8	1.2	0	29.9	0.1	0.1	197,260
	133	4.1	15.4	18.9	28.2	0.4	5.4	1,631,850
	136	12.0	12.0	5.7	20.4	5.0	1.5	1,334,900
	137	7.9	17.6	18.5	6.6	1.3	25.6	121,820
	153	4.1	20.2	26.2	30.8	0.4	0.4	1,373,090
South Carolina	130	5.8	0	0	25.3	1.6	1.8	20,590
	133	9.4	28.0	33.0	6.8	0.2	6.2	1,357,780
	136	16.3	19.2	12.5	0	3.1	3.0	391,030
	137	11.6	30.8	34.7	1.0	0.4	1.6	279,310
	153	4.0	25.0	33.0	18.8	0.1	0.3	580,580
Virginia	133	5.3	12.6	13.6	32.8	0	0.3	280,590
	136	10.4	10.6	5.6	22.2	0	0	367,040
	148	7.4	8.0	1.4	46.9	0	0	191,030
	149	20.3	20.3	10.2	22.8	0	0	357,580
	153	19.6	24.0	16.5	13.4	0	0	213,870

Table 6. Universal Soil Loss Equation C factors for the predominant cropping systems in six southern states

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton
Alabama	125	0.141	0.470	0.480	0.407	0.464	0.509
	128	0.141	0.470	0.480	0.407	0.464	0.424
	129	0.141	0.470	0.480	0.407	0.464	0.424
	133	0.145	0.457	0.461	0.450	0.454	0.408
	135	0.145	0.457	0.461	0.450	0.454	0.333
	136	0.141	0.470	0.480	0.456	0.464	0.424
Georgia	128	0.141	0.470	0.480	0.401	0.464	0.509
	129	0.141	0.470	0.480	0.407	0.464	0.350
	130	0.141	0.470	0.480	0.407	0.464	0.350
	133	0.134	0.471	0.477	0.454	0.449	0.350
	136	0.141	0.470	0.480	0.456	0.464	0.509
	137	0.134	0.471	0.477	0.454	0.449	0.424
	153	0.116	0.433	0.440	0.382	0.431	0.325
Mississippi	131	0.153	0.485	0.492	0.475	0.472	0.353
	133	0.145	0.457	0.461	0.450	0.454	0.408
	134	0.153	0.485	0.492	0.475	0.472	0.353
	135	0.145	0.457	0.461	0.450	0.454	0.408
	152	0.145	0.457	0.461	0.450	0.454	0.408
North Carolina	130	0.139	0.436	0.436	0.388	0.439	0.325
	133	0.116	0.433	0.440	0.382	0.431	0.325
	136	0.139	0.436	0.436	0.426	0.439	0.401
	137	0.116	0.433	0.440	0.415	0.431	0.403
	153	0.116	0.397	0.440	0.319	0.431	0.403
South Carolina	130	0.139	0.436	0.436	0.426	0.439	0.401
	133	0.116	0.445	0.440	0.394	0.426	0.329
	136	0.139	0.436	0.436	0.426	0.439	0.401
	137	0.116	0.445	0.440	0.428	0.426	0.329
	153	0.116	0.433	0.440	0.382	0.431	0.403
Virginia	133	0.122	0.413	0.456	0.331	0.433	0.413
	136	0.139	0.436	0.436	0.388	0.439	0.413
	148	0.122	0.413	0.456	0.331	0.433	0.413
	149	0.122	0.413	0.456	0.331	0.433	0.413
	153	0.122	0.413	0.456	0.331	0.433	0.413

upon the procedure suggested in USDA Handbook 537 (11). These C values were compared with SCS and USDA Handbook 282 (10) procedural values and are given in table 7. Only the C values for cotton were significantly different. The newer calculation procedure gives more accurate values because the factor for crop cover is based on accurate observations of crop cover.

Weighted average USLE factors given for each MLRA in six southern states in table 3 and for each state in table 8 show the magnitude and range for each factor used in the study. Slope, S, ranged between 1.2% and 4.4%. Weighted average soil loss A values ranged between 2.2 and 36. With tolerance, T, values of about 4, it is apparent that in MLRA 133 and 153 most of the A values were less than T values.

The importance of various cropping practices for reducing soil loss is indicated by data presented in table 9 for six cropping systems. The soybean-small grain double-cropping system substantially reduced soil loss below that for continuous cropping systems. For example, the percentage of cultivated land with soil loss less than or equal to the tolerance level shown in table 10 indicates a median value of 55% for the soybean-small grain double-cropping system, as compared with 17% for continuous soybeans. The lower A values in the soybean-small grain system are due primarily to lower C factors used in the USLE. Since R, K, and LS are fixed for a given soil, only C and P can be varied. When the factor P is fixed on a farm, the factor C becomes the remaining variable that can influence factor A based on the crop and the cropping practice. Consequently, if T is known with R, K, LS, and P as constants, a desired C value can be determined that can be used to develop cropping systems and residue management procedures that will keep soil loss at or below critical tolerance levels.

With RP known and RN determined, crop residues available, RA, were calculated for various crops for MLRA in six southern states (table 11). Georgia, North Carolina, and South Carolina produce the most available residues, primarily because of MLRA located in the broad, reasonably flat southeastern Coastal Plain where erosion and soil loss hazards are less than in lands at higher elevations in the southeast. Low sloping lands exist in parts of most all MLRA; consequently, if the indicated crop is grown, some residue can be removed without appreciable soil loss. The percentages of residues produced that are needed to keep soil loss at or below tolerance levels are largest in Alabama and Mississippi (table 12). The double-cropped soybean-small grain rotation had the lowest RN requirements because of winter residue cover and greater residue production. A large fraction of residues from the continuous cropping systems are needed for erosion control because the soil remains bare for a considerable fraction of the year.

This study has identified erosion hazards associated with several cropping systems. As expected,

Table 7. Comparison of C-values for South Carolina determined by procedure described in the USDA Handbook 537 with those determined by SCS and USDA Handbook 282 procedure

Cropping System	USDA Handbook 537	SCS - Values Handbook 282	Percent differences
Soybean - small grain	0.116	0.120	− 3
Soybean - corn	0.445	0.467	− 5
Continuous soybean	0.440	0.440	0
Continuous corn	0.394	0.415	− 5
Continuous sorghum	0.426	0.422	+ 1
Continuous cotton	0.329	0.505	−35

Table 8. Weighted average USLE factors for six southern states

State	S %	L feet	L S	R	K T/A/yr	A T/A/yr
Alabama	3.55	302	0.68	336	0.27	21.98
Georgia	3.02	272	0.30	338	0.19	9.11
Mississippi	2.84	294	0.50	350	0.34	26.24
North Carolina	2.23	295	0.37	305	0.22	7.86
South Carolina	2.05	292	0.34	306	0.21	6.70
Virginia	3.00	328	0.56	214	0.25	7.89

Table 9. Weighted average soil loss and soil loss tolerance for indicated crops in the major land resource areas of six southern states

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton	Soil loss tolerance
					tons/acre/year			
Alabama	125	5.8	19.5	20.5	16.9	19.8	21.2	4.2
	128	7.4	25.0	25.5	21.7	24.9	22.6	4.2
	129	11.7	38.7	39.7	33.5	38.2	35.0	4.2
	133	6.9	21.7	21.8	21.3	21.5	19.3	4.4
	135	5.9	18.6	18.7	18.3	18.5	13.5	3.8
	136	6.7	22.3	22.8	21.6	22.0	20.1	4.5
Georgia	128	4.9	16.4	16.8	14.2	16.2	17.8	4.0
	129	4.2	14.1	14.4	12.2	13.9	10.5	3.3
	130	2.4	8.1	8.2	7.0	7.9	6.0	4.1
	133	3.2	11.0	11.1	10.6	10.4	8.2	4.6
	136	4.9	16.4	16.7	15.9	16.2	17.8	4.1
	137	3.7	13.0	13.1	12.5	12.3	11.6	4.6
	153	1.2	4.4	4.4	3.9	4.4	3.3	4.8
Mississippi	131	4.9	15.6	15.9	15.3	15.2	11.4	4.5
	133	9.8	31.2	31.3	30.7	31.0	27.8	4.1
	134	12.0	37.0	38.6	37.2	37.0	29.0	4.0
	135	6.5	20.5	20.6	20.1	20.3	18.3	4.0
	152	5.2	16.2	16.3	16.0	16.1	14.5	4.3
North Carolina	130	3.1	9.8	9.8	8.7	9.9	7.3	4.0
	133	1.7	6.4	6.6	5.7	6.4	5.6	4.6
	136	5.7	17.9	17.9	17.5	18.1	16.5	3.6
	137	2.4	8.9	9.1	8.6	8.9	6.7	4.8
	153	1.5	5.0	5.6	4.1	5.5	5.1	4.4
South Carolina	130	4.3	13.6	13.6	13.3	13.7	12.5	4.2
	133	1.6	6.3	6.2	5.6	6.0	4.6	4.7
	136	4.9	15.3	15.0	15.4	15.4	14.1	3.8
	137	2.1	8.2	8.1	7.9	7.9	6.1	4.6
	153	1.3	5.0	4.9	4.3	4.8	4.5	4.6
Virginia	133	2.6	8.6	9.5	6.9	9.3	8.6	3.4
	136	3.7	11.5	11.5	10.3	11.6	10.9	3.3
	148	4.1	13.9	15.3	11.1	14.5	13.9	3.3
	149	2.7	9.0	9.9	7.2	9.4	9.0	3.3
	153	0.8	2.7	3.0	2.2	2.8	2.7	4.1

Table 10. Percentage of cultivated land with soil loss less than or equal to the tolerance level in the major land resource areas of six southern states for six cropping sequences

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton
				%			
Alabama	125	55.00	1.23	1.23	1.23	1.23	1.23
	128	43.42	0.55	0.55	0.55	0.55	0.55
	129	23.54	2.30	2.30	2.30	2.30	2.30
	133	45.13	2.42	1.31	2.42	2.42	2.42
	135	48.72	0.45	0.34	0.45	0.45	11.15
	136	57.08	0	0	0	0	0
Georgia	128	46.06	16.66	16.66	29.86	16.66	16.66
	129	32.59	21.44	21.44	21.44	21.44	28.73
	130	82.03	27.21	27.21	29.43	27.21	74.78
	133	85.57	29.49	29.49	29.63	29.63	39.01
	136	33.14	18.46	18.46	18.46	18.46	18.35
	137	67.64	22.01	22.01	22.01	22.01	13.40
	153	97.34	79.94	78.04	88.33	79.94	89.47
Mississippi	131	63.72	0.95	0.95	0.95	0.95	13.51
	133	47.88	1.00	1.00	1.00	1.00	1.28
	134	43.69	0.30	0.30	0.30	0.30	2.44
	135	57.44	14.73	14.73	14.73	14.73	15.25
	152	57.20	18.96	18.96	18.96	18.96	22.00
N.C.	130	78.15	9.46	9.46	9.46	9.46	9.46
	133	95.23	54.74	47.38	54.88	54.75	55.65
	136	12.91	3.26	3.26	3.26	3.26	3.34
	137	95.56	20.33	20.33	22.07	20.33	22.65
	153	97.00	57.93	50.06	58.42	52.55	57.93
S.C.	130	54.03	10.39	10.39	10.39	10.39	10.39
	133	97.60	42.34	42.34	54.79	53.19	60.86
	136	21.91	15.21	15.21	15.21	15.21	16.48
	137	95.89	17.38	18.60	18.60	18.60	37.83
	153	98.69	54.43	54.43	62.76	54.44	62.76
Virginia	133	74.01	18.19	5.80	18.71	5.80	18.19
	136	56.71	0.96	0.96	0.96	0.96	0.96
	148	16.49	5.03	5.03	5.93	5.03	5.03
	149	51.35	26.64	8.05	29.49	8.33	26.64
	153	27.47	21.51	0.22	21.51	0.22	21.51

Table 11. Crop residue available without exceeding soil loss tolerance levels in the major land resource areas of six southern states for six cropping sequences

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton	MLRA total	State total
					Tons				
Alabama	125	8264	471	134	257	10	52	9,188	
	128	26991	293	415	—	6	1414	29,119	
	129	7214	2804	2953	3300	82	2678	19,031	
	133	59828	4463	4324	4792	383	4846	78,636	
	135	13245	182	233	—	9	3166	95,471	
	136	2506	0	0	0	0	0	2,506	233,951
Georgia	128	2316	2507	2048	—	160	831	7,862	
	129	—	31	23	40	—	—	94	
	130	—	159	186	3684	—	—	4,029	
	133	180129	154887	167216	525117	9122	99785	1,136,256	
	136	21232	10298	8004	5466	1151	3139	49,290	
	137	23970	8472	7939	9855	214	2530	52,980	
	153	8093	62515	67459	425699	1063	4393	569,222	1,819,733
Mississippi	131	181918	0	10613	—	—	122856	315,387	
	133	20048	1452	4328	—	—	2490	28,318	
	134	27539	264	1788	—	—	3448	33,039	
	135	13801	0	0	—	—	1632	15,433	
	152	451	297	917	—	—	—	1,665	393,842
N.C.	130	4340	293	—	10905	17	—	15,555	
	133	163707	162728	115593	493814	3592	107959	1,047,393	
	136	37927	6254	2010	14857	3184	1165	65,397	
	137	19824	4953	4066	2308	430	15284	46,865	
	153	166175	248175	182007	573561	3509	5851	1,179,278	2,354,488
S.C.	130	1202	—	—	785	38	72	2,097	
	133	295138	196362	156298	80845	903	107413	836,959	
	136	32321	13923	7576	—	1831	2208	57,859	
	137	60285	16045	14076	687	157	2939	94,189	
	153	54313	108877	100978	117686	251	1958	384,063	1,375,167
Virginia	133	21297	7383	1583	35062	—	9	65,334	
	136	15338	1807	666	5103	—	—	22,914	
	148	7623	2910	255	28329	—	—	39,117	
	149	94172	19528	2730	62580	—	—	179,010	
	153	33445	98004	93	13380	—	—	144,922	451,297

Table 12. **Percentage of residues produced that are needed to keep soil loss at or below tolerance levels for six cropping systems in the major land resource areas in six southern states**

State	MLRA	Soybeans-small grains	Soybeans-corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton
				%			
Alabama	125	51	99	99	99	99	99
	128	62	99	99	—	99	99
	129	79	98	98	98	98	98
	133	62	99	43	99	99	98
	135	58	99	99	—	99	96
	136	45	100	100	100	100	100
Georgia	128	58	93	96	—	89	93
	129	—	60	75	72	—	—
	130	—	73	72	73	—	—
	133	19	73	73	71	71	66
	136	67	90	92	84	87	89
	137	33	84	84	80	82	80
	153	2	25	28	17	26	14
Mississippi	131	40	100	99	—	—	93
	133	62	99	99	—	—	99
	134	58	99	99	—	—	99
	135	46	100	100	—	—	95
	152	64	91	87	—	—	—
North Carolina	130	49	91	—	86	92	—
	133	7	56	60	47	54	46
	136	91	97	97	97	97	97
	137	12	80	80	79	80	78
	153	4	47	52	42	50	47
South Carolina	130	54	—	—	90	91	90
	133	4	63	65	52	59	47
	136	79	86	86	—	85	85
	137	12	84	84	83	83	75
	153	2	47	48	42	46	43
Virginia	133	48	88	96	84	—	99
	136	85	97	97	97	—	—
	148	78	89	90	87	—	—
	149	53	86	93	72	—	—
	153	73	1	99	82	—	—

erosion hazards were the most serious on the steep lands at the higher elevations. Computed soil loss data of this study are based only upon the effect of soil-incorporated residues. If crop residues had remained on the surface they would have been more effective in controlling soil loss. In fact, surface residues are about five times more effective in controlling soil loss than the same amount of incorporated residues (9). For this reason, a parallel series of calculations using coefficients derived from runoff data from residue-covered surfaces would add an important aspect to the concept for partitioning crop residues between those needed for on-farm erosion control and those that could be removed without increasing soil loss beyond tolerable limits. Although surface residue management is an efficient approach to erosion control, most residues produced are now incorporated into the soil as an integral part of crop management practices because agricultural technology and its applications are not yet sufficiently developed to cope with the inconvenience and effect of surface managed residues.

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