Sediment loss from water erosion

Modeling sediment loss

Water erosion is the detachment and transport of soil particles by rainfall or irrigation water. When precipitation events occur, raindrops break the bond between soil particles and displace them. Sheet erosion takes place when the dislodged soil particles are moved by thin sheets of water flowing over the surface. Rill erosion occurs when the surface flow of water establishes paths and the flowing water detaches soil particles from the sides and bottoms of the rills that are formed. Ephemeral or concentrated-flow erosion follows when the topography of a landscape is such that rills enlarge and join with others to form channels. When concentrated-flow erosion is allowed to continue over time, it results in gully erosion, which is the most severe form of water erosion found on cropland.

The interaction between weather, soil properties, and farming practices (including irrigation) determines the rate of soil erosion. The amount of rainfall and the rainfall intensity are primary determinants of water erosion under rain-fed conditions. Irrigation induced erosion is primarily determined by the velocity of the water flowing through the furrows or basin and the volume and intensity of the water applied during sprinkler irrigation. The inherent potential for soil to erode is determined by the slope and topography of the land, the texture and structure of the soil, and the organic matter content in the soil. Soil texture refers to the proportions of particles of sand, silt, and clay in the soil. Water moves detached clay particles more readily than particles of silt or sand, but clay particle bonds are also stronger than those of silt and sand. Soil structure refers to how the soil particles are clustered in aggregates, which are held together by physical and chemical bonds. The shape, size, and arrangement of aggregates determine the pathways of infiltrating water and the volume of air space between aggregates. The more air space within a soil, the more room it has for infiltrating water. Reduced infiltration leads to more runoff, and thus more water erosion. Strong bonds and large aggregates provide more resistance to erosive forces. Organic matter enhances soil structure and increases water infiltration, thereby reducing the potential for water erosion. Plant cover and crop residue also reduce the potential for water erosion.

The EPIC model simulates sheet and rill erosion processes. The current version of EPIC includes six alternative water erosion prediction equations that represent different methods of accounting for erosion and net sediment delivery from the field. For this study, the Modified Universal Soil Loss Equation (MUSLE) was selected for reporting sediment delivery. MUSLE accounts for the amount of eroded soil that leaves the field through the processes of sheet and rill erosion. MUSLE does not include soil loss that can occur through ephemeral gully or gully erosion processes or erosion of furrows or basins during gravity irrigation events.

MUSLE is a modification of the Universal Soil Loss Equation (USLE). USLE is an estimate of sheet and rill soil movement down a uniform slope using rainfall energy as the erosive force acting on the soil (Wischmeier and Smith 1978). Depending on soil characteristics (texture, structure, organic matter, and permeability), some soils erode easily while others are inherently more resistant to the erosive action of rainfall.

MUSLE is similar to USLE except for the energy component. USLE depends strictly upon rainfall as the source of erosive energy. MUSLE uses storm-based runoff volumes and runoff peak flows to simulate erosion and sediment yield (Williams 1995). The use of runoff variables rather than rainfall erosivity as the driving force enables MUSLE to estimate sediment yields for individual storm events. The water erosion model uses an equation of the form:

$$\mathrm{Y} = \mathrm{X} \times \mathrm{EK} \times \mathrm{CVF} \times \mathrm{PE} \times \mathrm{SL} \times \mathrm{ROKF}$$

where:

Y = sediment yield in tons per hectare
EK = soil erodibility factor
CVF = crop management factor that captures the relative effectiveness of soil and crop management systems in preventing soil loss
PE = erosion control practice factor (including management practices such as terraces, contour farming, and stripcropping)
SL = slope length and steepness factor
ROKF = coarse fragment factor

For estimating MUSLE, the energy factor, X, is represented by:

$$X = 1.586 \times \left(Q \times q_p\right)^{0.56} \times WSA^{0.12}$$

where:
Q = runoff volume in millimeters
q_p = peak runoff rate in millimeters per hour
WSA = watershed area in hectares

Runoff volume is estimated using the SCS curve number method. Peak flow was estimated using a modification of the rational method which relates rainfall to peak flow on a proportional basis. The rational equation is:

$$q = C \times i \times A$$

where:
q = peak flow rate
C = runoff coefficient representing watershed characteristics
i = rainfall intensity for the watershed's time of concentration
A = watershed area

See Williams (1995) for details on the erosion and sediment yield equations used in EPIC.

Irrigation induced erosion was estimated for furrows and flat surfaces using flow as the driving force. For furrows, erosion is a function of irrigation application rate, flow velocity (calculated using Manning's equation), the soil erodibility factor, and sediment concentration. Erosion from flat surfaces was calculated with the MUSLE using the irrigation application volume and irrigation runoff rate to estimate the energy component.

To estimate MUSLE, the drainage area must be specified. For this study, the drainage area was set equal to 1 hectare (2.47 a). A 1-hectare drainage area was used to be consistent with other modeling assumptions tailored to the NRI sample point, such as uniform field slope, uniform precipitation, homogeneous soils, and management activities assumed to be evenly applied throughout a field.

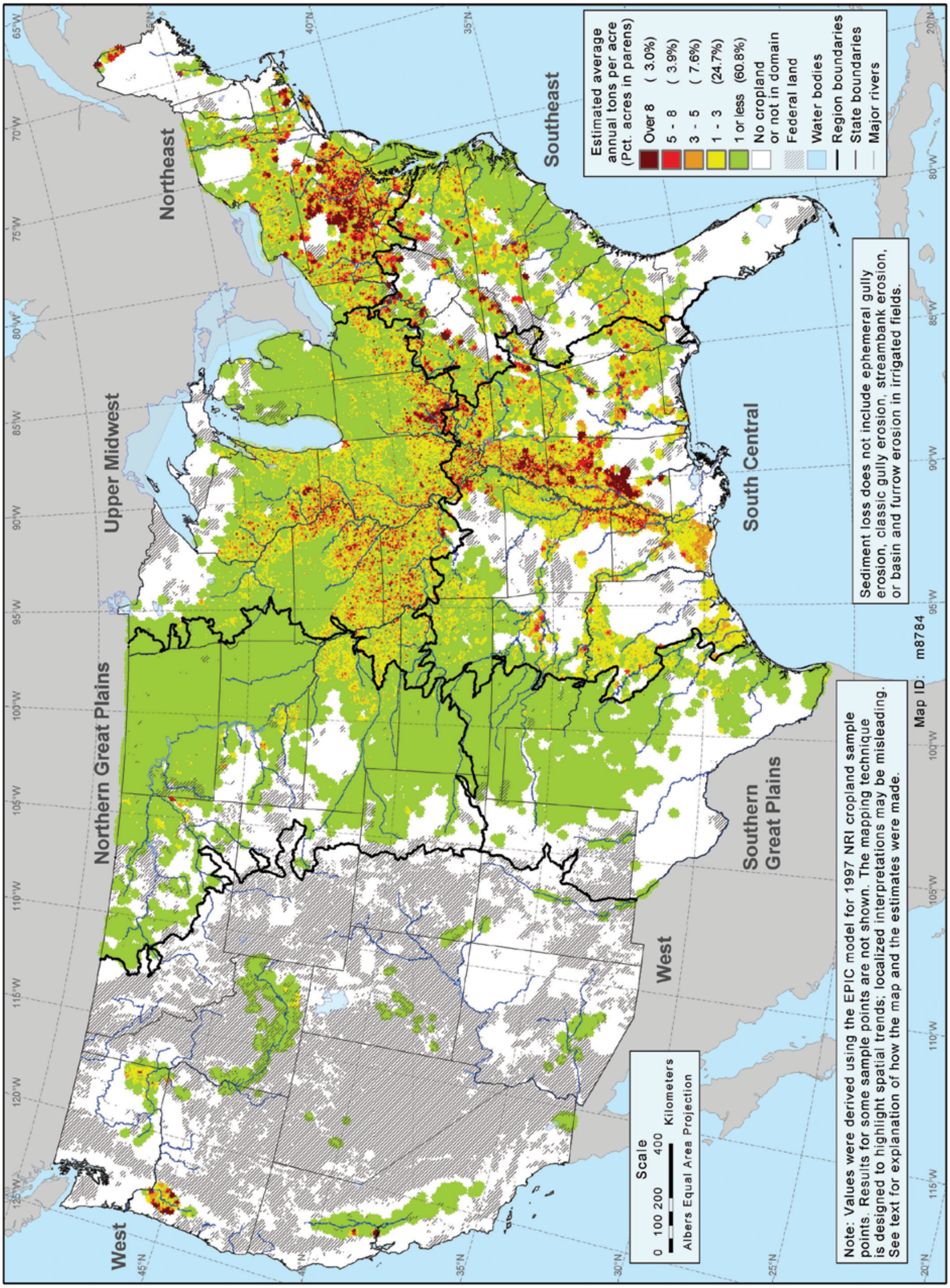
MUSLE produces estimates of sediment yield by calculating the tons of soil lost through sheet and rill erosion processes on a daily basis and summing these daily estimates to obtain the total tons of sediment yield per acre per year. MUSLE includes sheet and rill erosion that occurs when precipitation is sufficient to result in surface water runoff. It is possible for a light rainfall to cause some sheet and rill erosion, but not result in surface water runoff from the field; MUSLE does not include this source of sheet and rill erosion. This estimate of sediment yield is referred to throughout this report as sediment loss.

EPIC requires that only one of the six water erosion prediction equations be chosen as the driving equation that changes the soil profile and soil properties over time as erosion occurs. For this study, MUST, the theoretical erosion and sedimentation equation, was used as the driving equation. MUST is an equation developed on the basis of sediment concentrations (Williams 1995). Similar to MUSLE, MUST provides better estimates of nitrogen and phosphorus losses with sediment than use of USLE or MUSLE as the driving erosion equation. MUST differs from MUSLE in that the drainage area is not a factor in the equation.

Model simulation results for sediment loss

Model simulations on the cropland acres included in this study show that sediment loss from sheet and rill erosion processes on cropland varies depending on the region of the country (reflecting climatic and hydrologic factors), the crop type and related farming practices, the presence of conservation practices, and characteristics of the soil. Map 9 shows the cropland areas of the country that have the highest potential for sediment loss. The most vulnerable cropland acres—shown in dark red and red on the map—had average sediment loss estimates greater than 5 tons per acre per year and represent about 7 percent of the cropland acres. Another 8 percent of the acres had average sediment loss estimates between 3 and 5 tons per acre per year, shown in orange on the map. These acres are mostly collocated with the most vulnerable acres. About 25 percent of the cropland acres had average sediment loss estimates between 1 and 3 tons per acre per year, usually found in broad areas surrounding the most vulnerable acres. The remaining 60 percent of the cropland acres had average sediment loss estimates less than 1 ton per acre, shown on the map in green. These least vulnerable acres tend to correspond to areas shown in map 7 where surface water runoff is less than about 3 inches per year.

Map 9 Estimated average annual per-acre sediment loss (MUSLE)



The most vulnerable areas with respect to sediment loss on a per-acre basis tend to be concentrated in five areas of the country:

- an area in central and southeastern Pennsylvania and northern Maryland associated primarily with the Lower Susquehanna Basin and Potomac River Basin
- an area that follows the Ohio River from southern Illinois through western Pennsylvania
- an area along the lower Mississippi, primarily the eastern part of the drainage area
- an area that extends along the upper Mississippi, including the northern drainage area of the Missouri River in northern Missouri and southwest Iowa
- the Willamette River Basin in the Northwest

Per-acre sediment loss estimates

The average sediment loss rate for all cropland acres represented in the study was 1.5 tons per acre per year (table 22). Sediment loss per acre was greatest in the Northeast and the South Central regions, where sediment loss estimates averaged about 3 tons per cropland acre per year. Sediment loss per acre was lowest in the Great Plains regions and the West, averaging less than 0.6 tons per cropland acre per year.

The crops associated with the highest average sediment loss estimates were generally corn silage, corn, and cotton; although, average estimates by crop varied substantially from region to region (table 22; fig. 9). Averaged over all regions, corn silage had the highest sediment loss rate at nearly 6 tons per acre, and had the highest average sediment loss rate of all crops in most of the regions. Alfalfa hay had the lowest sediment loss rate (nearly zero), followed by spring wheat. All crops grown in the Northeast region had the highest per-acre sediment loss estimates of any region.

Most irrigated crops had about the same sediment loss estimates as non-irrigated crops in the same region (table 23). The largest differences occurred for wheat and barley acres in the West region and corn and cotton acres in the South Central region. Sediment loss estimates for these crops averaged about 2 tons per acre per year less for irrigated crops than for non-irrigated crops. Lower sediment loss for irrigated acres is generally expected because irrigation water is usually applied during the growing season when the ET rate is high, antecedent soil moisture is relatively low, and crop cover and surface residues provide some protection of the soil surface from the forces of erosion. Higher sediment loss estimates for irrigated acres than for non-irrigated acres, when it occurs, is due to more overall water inputs on irrigated acres in arid areas as well as climatic and soil type differences between irrigated and non-irrigated acres within a region.

Tons of sediment loss

When the acres of cropland are taken into account, three-fourths of the total tons of sediment loss for all cropland is associated with two regions—the Upper Midwest region and the South Central region (table 22; map 10). With average sediment loss estimates above the national average, the total sediment loss from cropland acres in these two regions was disproportionately high, relative to the percent of cropland acres. The South Central region contains 15 percent of the cropland acres included in the study but accounts for 27 percent of the total tons per year of sediment loss from cropland. Similarly, the Upper Midwest region contains 38 percent of the cropland acres but accounts for 48 percent of the total sediment loss. Sediment loss in the Northeast region was also disproportionately high; the Northeast accounted for about 9 percent of the total sediment loss from cropland but accounted for only about 5 percent of the cropland acres.

In terms of total sediment loss, corn and soybeans accounted for about two-thirds of the total for all cropland (table 22). In the Northeast region, corn and corn silage accounted for most of the sediment loss in the region. Cotton accounted for the most sediment loss in the Southeast and the South Central regions; the average loss rate for cotton in the South Central region was nearly 7 tons per acre. Corn accounted for the most sediment loss in the Upper Midwest and the Northern Great Plains regions, although average per-acre sediment loss estimates for corn in those regions were not as high as in the Northeast or the South Central regions. In the Southern Great Plains and the West, winter wheat accounted for more total sediment loss than other crops.

Effects of soil properties on sediment loss

Soil properties such as hydrologic soil group and soil texture have a pronounced influence on the potential for sediment loss to occur. The mix of hydrologic soil groups and soil textures varies throughout the

Table 22 Sediment loss (MUSLE) estimates–by region and by crop within regions (average annual values)

Region	Crop	Acres (1,000s)	Tons per acre per year	Tons per year (1,000s)
By region				
Northeast	All crops	13,642	3.2	43,467
Northern Great Plains	All crops	72,397	0.5	33,628
South Central	All crops	45,350	2.8	125,565
Southeast	All crops	13,394	1.6	21,520
Southern Great Plains	All crops	32,096	0.4	11,506
Upper Midwest	All crops	112,581	2.0	218,991
West	All crops	9,018	0.6	4,944
All regions	All crops	298,478	1.5	459,622
By crop within region*				
Northeast	Corn	2,943	5.2	15,304
	Corn silage	1,482	11.0	16,347
	Grass hay	2,369	1.4	3,208
	Legume hay	4,052	<0.1	4
	Oats	362	3.5	1,282
	Soybeans	1,305	2.8	3,707
	Winter wheat	853	2.8	2,423
Northern Great Plains	Barley	3,243	0.2	756
	Corn	15,466	0.8	13,091
	Corn silage	810	1.4	1,100
	Grass hay	2,443	0.1	249
	Legume hay	6,152	<0.1	32
	Oats	1,255	0.6	731
	Spring wheat	18,916	0.4	7,260
	Sorghum	1,595	0.6	909
	Soybeans	9,562	0.7	6,734
	Winter wheat	12,748	0.2	2,714
South Central	Corn	5,956	3.6	21,333
	Cotton	5,487	6.9	37,837
	Grass hay	3,347	1.4	4,529
	Legume hay	1,630	<0.1	1
	Peanuts	880	1.7	1,541
	Rice	3,004	2.9	8,624
	Sorghum	2,729	1.7	4,698
	Soybeans	14,083	2.2	31,555
	Winter wheat	7,896	1.7	13,598

Table 22 Sediment loss (MUSLE) estimates–by region and by crop within regions (average annual values)—Continued

Region	Crop	Acres (1,000s)	Tons per acre per year	Tons per year (1,000s)
Southeast	Corn	3,028	1.4	4,197
	Corn silage	412	6.7	2,746
	Cotton	2,422	2.4	5,832
	Grass hay	2,000	1.2	2,380
	Legume hay	1,183	<0.1	2
	Peanuts	479	1.8	861
	Soybeans	2,419	1.0	2,372
	Winter wheat	1,216	2.3	2,787
Southern Great Plains	Corn	2,665	0.6	1,588
	Cotton	7,316	0.4	3,083
	Legume hay	677	0.0	0
	Oats	503	0.6	310
	Peanuts	484	0.6	295
	Sorghum	4,895	0.4	1,826
	Winter wheat	15,037	0.3	4,289
Upper Midwest	Corn	47,941	2.6	126,254
	Corn silage	1,947	4.4	8,495
	Grass hay	4,044	0.5	2,034
	Legume hay	9,233	<0.1	4
	Oats	1,388	2.2	3,019
	Spring wheat	815	0.2	184
	Sorghum	1,604	2.0	3,155
	Soybeans	40,049	1.7	69,565
	Winter wheat	5,147	1.2	6,096
West	Barley	958	1.0	914
	Corn silage	297	0.5	140
	Cotton	1,631	0.2	282
	Legume hay	1,847	<0.1	21
	Potatoes	329	0.2	63
	Rice	599	0.3	164
	Spring wheat	772	0.5	401
	Winter wheat	2,118	1.3	2,812

* Estimates for crops with less than 250,000 acres within a region are not shown. However, acres for these minor crops are included in the calculation of the regional estimates.

Figure 9 Sediment loss estimates (MUSLE)–by crop within regions

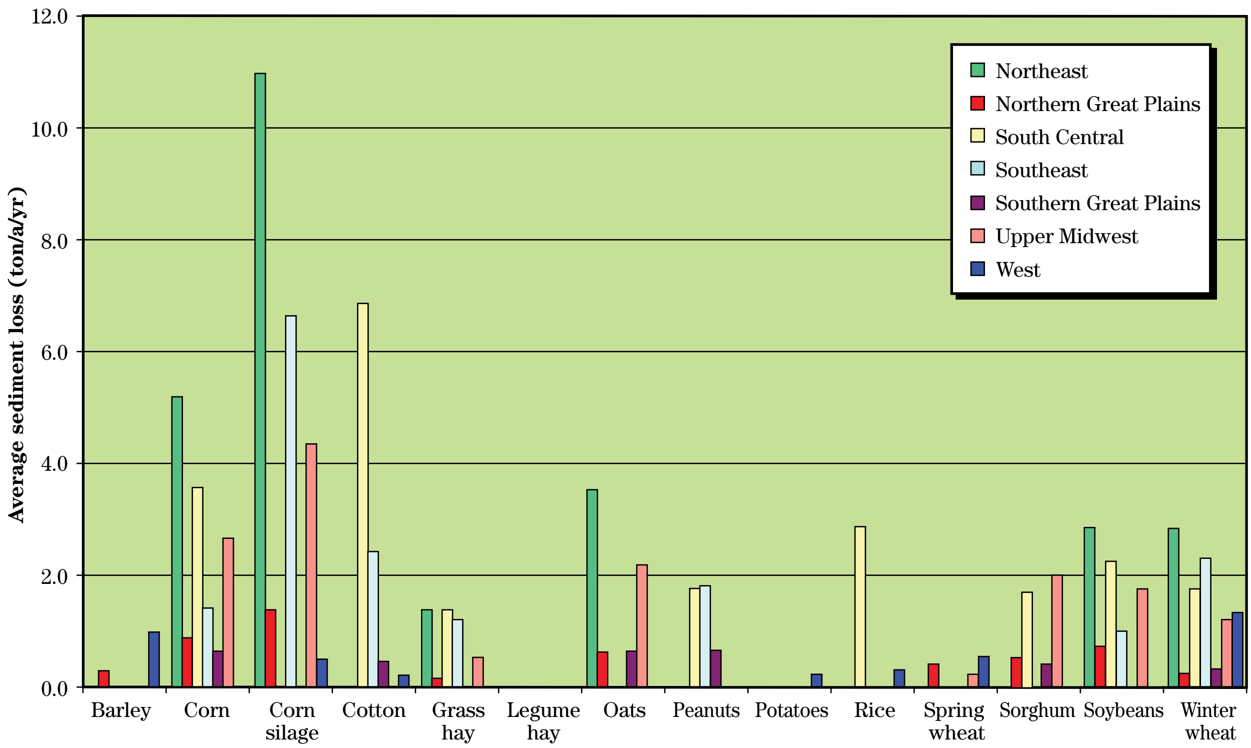
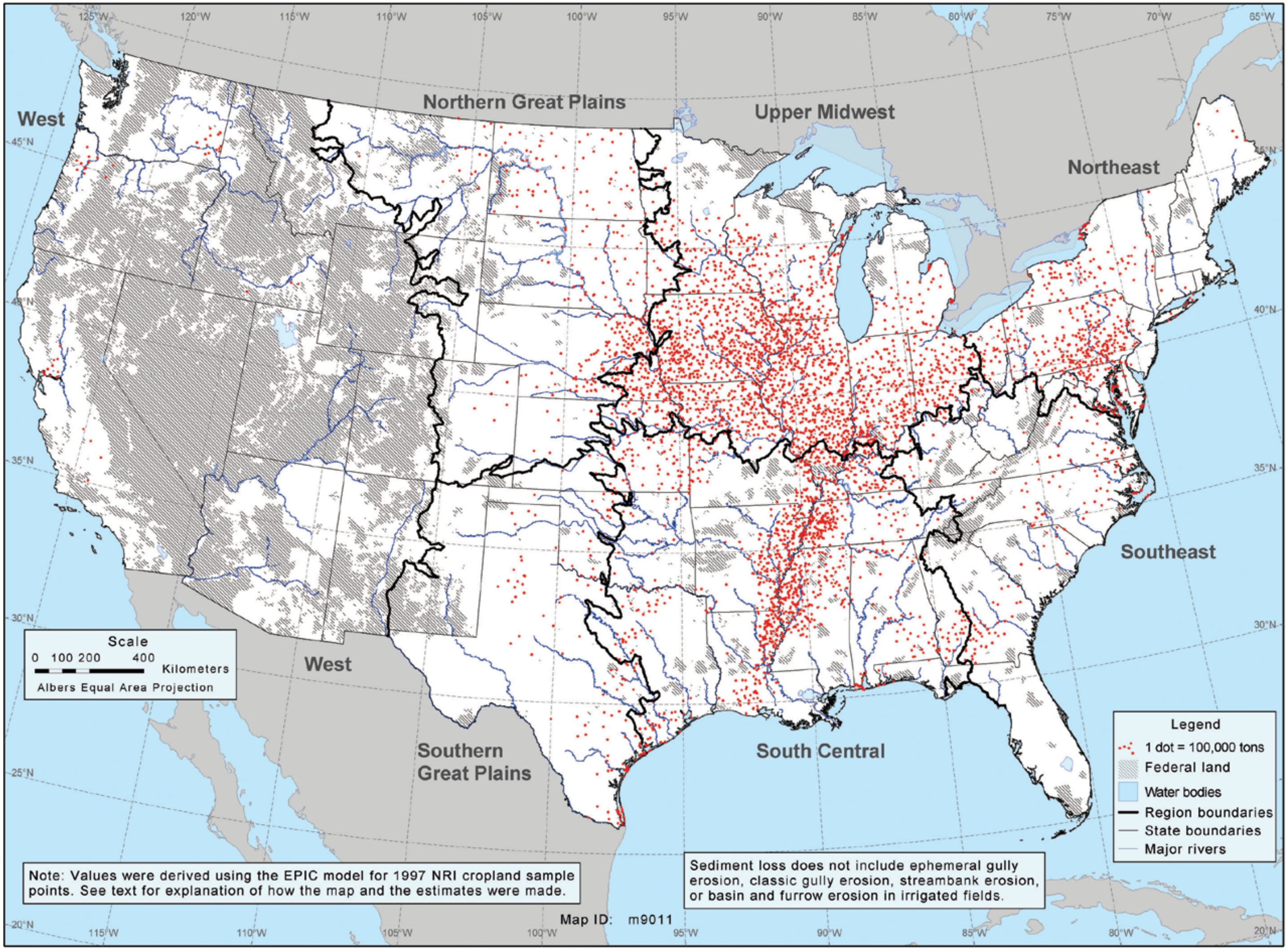


Table 23 Comparison of sediment loss estimates (MUSLE) for irrigated crops to estimates for non-irrigated crops (average annual values)

		Non-irrigated crops		Irrigated crops	
Region	Crop*	Acres (1,000s)	Tons per acre per year	Acres (1,000s)	Tons per acre per year
Northern Great Plains	Corn	8,785	0.9	6,680	0.8
	Legume hay	4,816	<0.1	1,336	<0.1
	Soybeans	8,578	0.7	984	1.2
	Winter wheat	12,086	0.2	662	0.1
South Central	Corn	5,285	3.8	671	2.0
	Cotton	3,983	7.6	1,505	5.1
	Rice	0	NA	3,004	2.9
	Soybeans	10,498	2.3	3,585	2.0
	Winter wheat	7,341	1.7	554	1.8
Southeast	Cotton	2,115	2.4	307	2.7
Southern Great Plains	Corn	672	1.5	1,993	0.3
	Cotton	4,486	0.4	2,831	0.5
	Legume hay	263	<0.1	414	<0.1
	Peanuts	159	0.9	325	0.5
	Sorghum	3,748	0.4	1,147	0.3
	Winter wheat	13,046	0.3	1,991	0.1
Upper Midwest	Corn	46,424	2.7	1,517	1.6
	Soybeans	39,409	1.7	641	1.4
West	Barley	357	2.4	601	0.1
	Corn silage	0	NA	297	0.5
	Cotton	0	NA	1,631	0.2
	Legume hay	159	0.1	1,688	<0.1
	Potatoes	0	NA	329	0.2
	Rice	0	NA	599	0.3
	Spring wheat	197	1.8	575	0.1
	Winter wheat	1,066	2.1	1,052	0.5

* Irrigated crops with more than 250,000 acres in a region are included in the table. These 26 crop-region combinations represent 92 percent of the irrigated acres included in the study.
NA = not applicable.

Map 10 Estimated average annual tons of sediment loss (MUSLE)



country, contributing to the variability in the spatial distribution of sediment loss shown in map 9. As shown in figure 10, which presents average annual sediment loss estimates for all model simulations included in the study, the lowest sediment loss estimates were for hydrologic soil group A, which tend to be well-drained soils with high infiltration estimates. However, hydrologic group A soils represent less than 10 percent of the soils in all regions and only about 4 percent of all cropland acres included in the study. Soils in hydrologic soil group B, which is the dominant hydrologic soil group in most regions and represents the majority of cropland acres, had sediment loss estimates at or below the average of about 1.5 tons per acre per year for all soil texture classes. In contrast, average sediment loss estimates for hydrologic soil groups C and D exceeded the average of 1.5 tons per acre per year for nearly all soil textures. Hydrologic soil groups C and D represent 26 and 15 percent, respectively, of the cropland acres included in the study. The highest sediment loss estimates occurred for medium textured soils for all but hydrologic soil group B, for which fine textured soils had a slightly higher average sediment loss rate than medium textured soils. Medium textured soils are the dominate soil texture class in most regions, representing 51 percent of the cropland acres included in the study.

Example of spatial variability of sediment loss

Model results showed that sediment loss can sometimes vary substantially from field to field, even within relatively small geographic areas. This variability is primarily due to local variability in soil properties, terrain characteristics, crops grown, and agricultural practices. Two specific examples of how sediment loss varies within a local area are shown in figure 11. The diversity of soil types represented in the model simulations for these two Iowa watersheds was discussed in a previous section (fig. 4). The Lower Iowa watershed has a more diverse collection of soils with more representation of hydrologic group C soils than the Floyd watershed; hydrologic group C soils have slower infiltration rates and tend to result in more surface runoff than group A or B soils. The two watersheds also have slightly different climates. The Lower Iowa watershed has higher annual precipitation (36 in/yr) than the Floyd watershed (29 in/yr). Surface water runoff for the Lower Iowa watershed averaged 5.4 inches per year, whereas surface water runoff for the Floyd watershed averaged only 3.2 inches per year.

As a result of these factors, as well as management related factors, the average annual sediment loss rate for the Lower Iowa watershed (3.7 ton/a/yr) was over twice as high as sediment loss for the Floyd watershed (1.6 ton/a/yr). Within the Lower Iowa watershed, model simulations show that sediment loss estimates varied dramatically among the soils represented, ranging from 0.1 to 17.2 tons per acre per year. Although less pronounced, significant variation among soils also occurred in the Floyd watershed, where sediment loss estimates ranged from 0.5 to 4.3 tons per acre per year for different soils.

Figure 11 also demonstrates the importance of minor soils in the assessment and treatment of soil erosion problems. Each watershed had three dominant soils that accounted for 10 percent or more of the cropland acreage, indicated by the red bars in figure 11. However, the highest sediment loss estimates in both watersheds were associated with the minor soils. In the Lower Iowa watershed, the seven soils with the highest sediment loss estimates—all greater than 7 tons per acre—accounted for 34 percent of the total sediment loss for the watershed, but only represented 12 percent of the cropland acres. In the Floyd watershed, the two soils with the highest sediment loss estimates (4.3 and 3.9 ton/a) represented only 7 percent of the cropland acres but accounted for 19 percent of the total sediment loss for the watershed.

Effects of tillage practices on sediment loss

Sediment loss estimates reported in this study accounted for conservation tillage currently practiced on cropland acres (table 11). As conservation tillage practices have a direct influence on sheet and rill erosion processes, the sediment loss estimates reported here would have been much higher had these tillage effects not been taken into account. To assess the effects that conservation tillage had on sediment loss estimates, the subset of model runs where all three tillage systems—conventional tillage, mulch tillage, and no-till—were present within a URU was defined to be the domain for examining the effects of tillage (table 12 and related discussion). This tillage comparison subset of model runs included eight crops and represented about 70 percent of the cropland acres covered by the study.

For the 208 million acres in the tillage comparison subset, the tillage-effects baseline sediment loss averaged 1.7 tons per acre per year (table 24), slightly higher

Figure 10 Average per-acre sediment loss estimates (MUSLE)–by hydrologic soil group and soil texture group

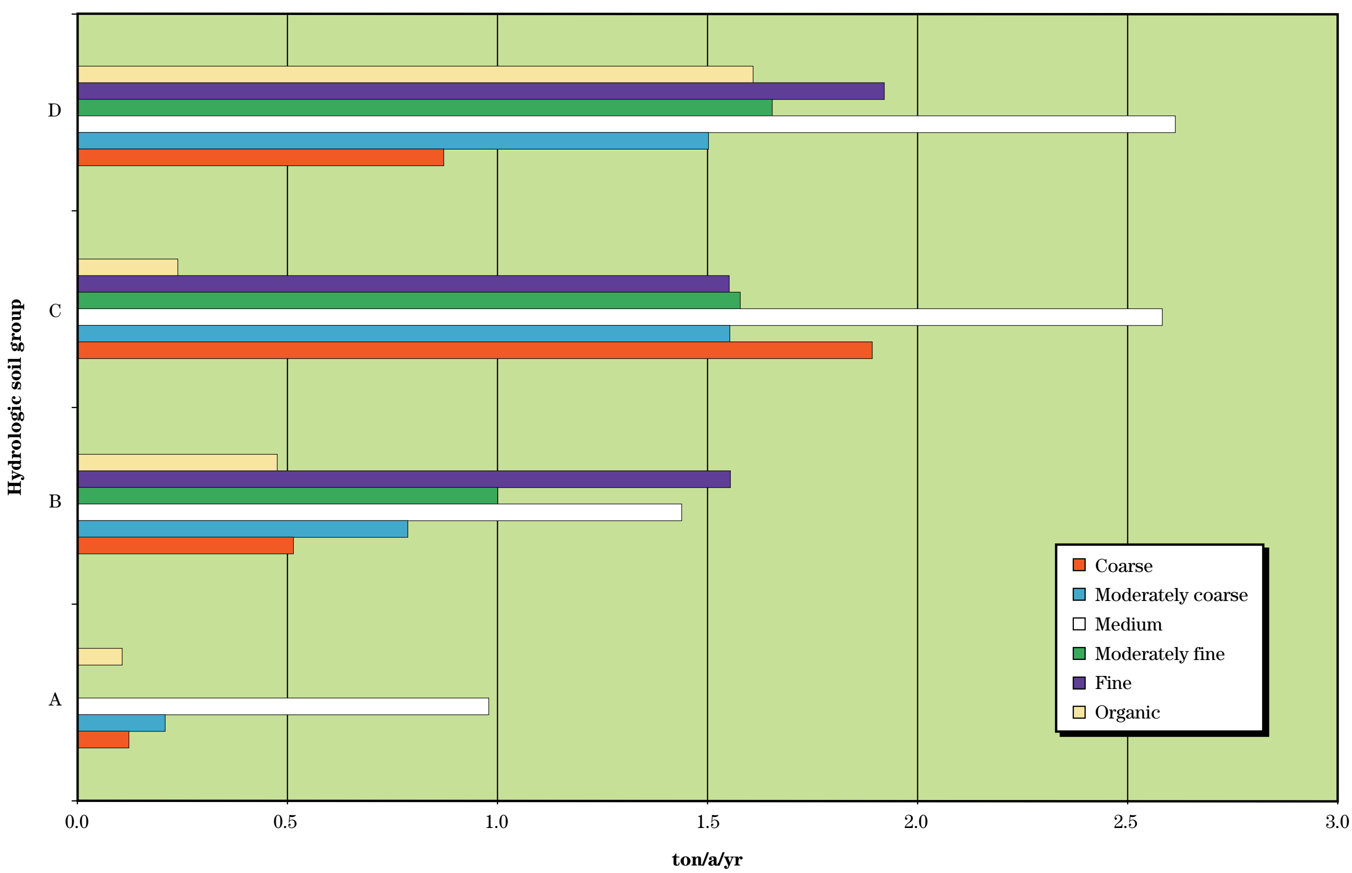
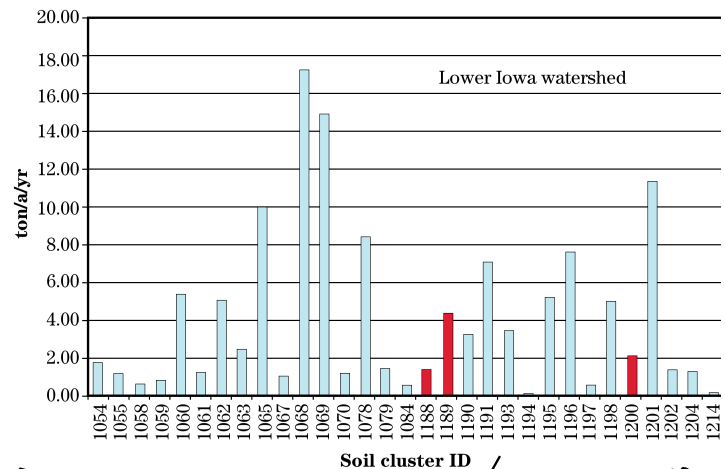
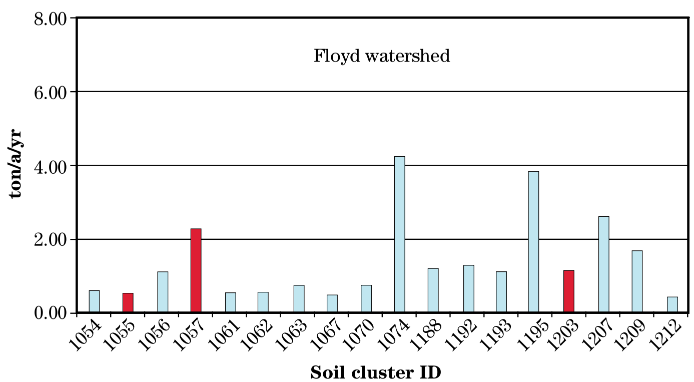


Figure 11 Variability in sediment loss estimates (MUSLE) within two IA watersheds

Soil cluster	Representative soil	Texture group	Hydrologic soil group	Soil cluster	Representative soil	Texture group	Hydrologic soil group
1054	Fairhaven	Medium	B	1189	Lagoda	Medium	B
1055	Kossuth	Moderately fine	B	1190	Sharpsburg	Moderately fine	B
1056	Alton	Moderately fine	C	1191	Adair	Medium	C
1057	Galva	Moderately fine	B	1192	Kenyon	Medium	B
1058	Hoopeston	Moderately coarse	B	1193	Marshall	Moderately fine	B
1059	Coland	Moderately fine	B	1194	Sparta	Coarse	A
1060	Tama	Medium	B	1195	Huntsville	Medium	B
1061	Coppock	Medium	B	1196	Downs	Medium	B
1062	Shelby	Moderately fine	B	1197	Village	Medium	B
1063	Turlin	Medium	B	1198	Lineville	Medium	C
1065	Fayette	Medium	B	1200	Humeston	Medium	C
1067	Nodaway	Medium	B	1201	Lamoni	Fine	C
1068	Gara	Medium	C	1202	Wabash	Moderately fine	D
1069	Lindley	Medium	C	1203	Terril	Medium	B
1070	Colo	Moderately fine	B	1204	Floyd	Medium	B
1074	Ida	Medium	B	1207	Monona	Medium	B
1078	Adair	Moderately fine	C	1209	Racine	Medium	B
1079	Lamont	Moderately coarse	B	1212	Spicer	Moderately fine	B
1084	Dickinson	Moderately coarse	B	1214	Chelsea	Coarse	A
1188	Ely	Medium	B				





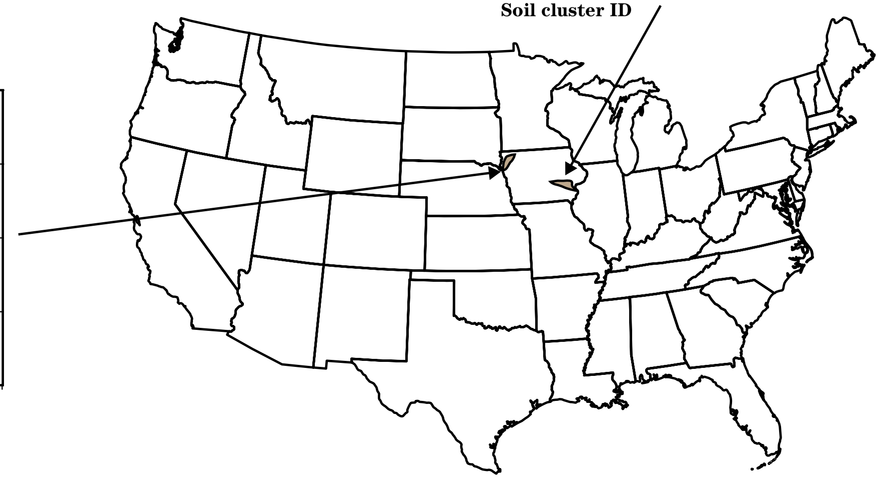


Table 24 Effects of tillage practices on estimates of sediment loss (ton/a/yr)

	Acres in tillage comparison subset (1,000s)	Sediment loss				Change relative to the tillage-effects baseline			Change relative to conventional tillage	
		Tillage-effects baseline	Conventional tillage	Mulch tillage	No-till	Conventional tillage	Mulch tillage	No-till	Mulch tillage	No-till
By region										
Northeast	6,034	5.5	7.1	5.0	1.6	1.6	-0.6	-3.9	-2.1	-5.5
Northern Great Plains	56,551	0.5	0.7	0.5	0.2	0.2	-0.1	-0.4	-0.2	-0.6
South Central	24,879	2.3	3.4	2.4	0.4	1.1	0.1	-1.9	-1.0	-3.0
Southeast	4,442	2.0	3.1	2.1	0.6	1.1	0.2	-1.4	-1.0	-2.5
Southern Great Plains	17,746	0.3	0.4	0.2	0.1	0.0	-0.1	-0.3	-0.2	-0.3
Upper Midwest	96,330	2.2	3.3	2.2	0.5	1.1	0.0	-1.7	-1.1	-2.8
West	1,661	1.8	2.1	1.3	0.8	0.3	-0.5	-1.0	-0.8	-1.3
By crop										
Barley	3,256	0.4	0.5	0.3	0.2	0.1	-0.1	-0.3	-0.2	-0.3
Corn	71,016	2.4	3.3	2.3	0.6	0.8	-0.2	-1.8	-1.0	-2.6
Corn silage	4,082	6.1	7.1	5.8	2.2	0.9	-0.3	-3.9	-1.2	-4.9
Oats	2,078	1.5	1.8	1.2	0.7	0.3	-0.4	-0.8	-0.6	-1.1
Spring wheat	18,074	0.4	0.5	0.3	0.1	0.1	-0.1	-0.3	-0.2	-0.4
Sorghum	7,697	1.1	1.3	0.9	0.2	0.3	-0.1	-0.8	-0.4	-1.1
Soybeans	62,967	1.7	3.0	2.1	0.3	1.3	0.4	-1.4	-0.9	-2.7
Winter wheat	38,473	0.7	1.0	0.5	0.2	0.3	-0.2	-0.5	-0.5	-0.8
All crops and regions	207,642	1.7	2.5	1.7	0.4	0.8	0.0	-1.3	-0.8	-2.1

Note: The subset used for this analysis includes only those URUs where all three tillage systems were present. The tillage-effects baseline results represent the mix of tillage systems as reported in the Crop Residue Management Survey for 2000 (CTIC 2001). Tillage-effects baseline results reported in this table will differ from results reported in table 22 because they represent only about 70 percent of the acres in the full database. Results presented for each tillage system represent sediment loss rates as if all acres had been modeled using a single tillage system.

than the 1.5 tons per acre per year estimate for the full set of NRI sample points included in the study. Table 12 shows the extent to which each of the three tillage systems are represented in the tillage-effects baseline. Model simulation results showed that sediment loss would have averaged nearly 2.5 tons per acre per year if conventional tillage had been used on all acres, indicating the tillage practices currently in use have reduced sediment loss by about 32 percent. Sediment losses for mulch tillage were similar to the tillage-effects baseline, suggesting that the mix of tillage systems in current use is roughly equivalent to mulch tillage being used on all acres, on average. Simulation of full implementation of no-till resulted in average sediment loss of less than 0.5 tons per acre annually, representing a decrease of 76 percent compared to the tillage-effects baseline and a decrease of 83 percent when compared to conventional tillage use on all acres.

The effects of tillage on sediment loss varied by both region and crop (table 24), depending on the extent to which the various tillage systems are currently practiced and differences among regions in soil characteristics, management activities, and climatic factors that affect sediment loss. In all comparisons, however, sediment loss estimates assuming mulch tillage on all acres were very close to sediment loss rate estimates for the tillage-effects baseline. These comparisons also indicate that full adoption of no-till on the eight crops would further reduce sediment loss by 1 to 4 tons per acre per year in all but the two Great Plains regions. The largest gains would occur in the Northeast region and for corn and corn silage acres in most regions. Model simulations further show that full adoption of no-till would result in less than 1 ton per acre per year of sediment loss in all regions except the Northeast and for all crops except corn silage.

Effects of three conservation practices on sediment loss

In addition to accounting for conservation tillage practices, sediment loss estimates accounted for the presence or absence of three conservation practices reported in the NRI database—contour farming, stripcropping, and terraces (table 13 and related discussion). For comparison to the results for the model runs that included conservation practices, an additional set of model runs were conducted after adjusting model settings to represent no practices. The difference between the no-practices scenario and the conservation-practices baseline scenario (consisting of the original model runs for NRI sample points with conservation practices) is used here to assess the extent to which conservation practices reduced the sediment loss estimates. These estimates of the effects of the three conservation practices are independent of the effects of tillage, as both scenarios retained the same tillage practices as used in development of the NNLSC database.

For the 31.7 million acres modeled with conservation practices, sediment loss estimates averaged 1.5 tons per acre per year (table 25), coincidently equal to the estimate for the full set of NRI sample points included in the study. Had conservation practices not been accounted for in the model simulations, sediment loss estimates on these acres would have averaged 3.3 tons per acre per year. These model simulations suggest, therefore, that the conservation practices reported by the NRI reduce sediment loss by about 54 percent, on average, for acres with one of more of the three practices.

Overall, the largest reduction—4.1 tons per acre per year—occurred for contour farming in combination with stripcropping. These acres had the highest sediment loss estimate for the no-practices scenario than any of the other categories—6.6 tons per acre per year. Contour farming alone reduced sediment loss estimates by 2.6 tons per acre per year for the acres included in the simulation, which had the second highest sediment loss rate for the no-practices scenario—5.5 tons per acre per year. The most prevalent practice set—contour farming and terraces—reduced sediment loss estimates from 2.8 tons per acre per year without practices to 1.0 ton per acre per year, on average. In terms of percent reductions relative to the no-practices scenario, contour farming in combination with one or more of the other two practices reduced sediment loss estimates by over 60 percent. Terraces only or stripcropping only was generally associated with acres that had lower sediment loss estimates without practices (about 2 ton/a/yr on average), and thus, resulted in sediment loss reductions of only about 1 ton per acre per year on average.

The effects of conservation practices varied considerably by region (table 25). The largest reductions occurred in regions with the highest sediment loss estimates—the Northeast and Upper Midwest regions. The percentage reductions were in the neighborhood of 50 percent for each of the regions on average, except

Table 25 Effects of three conservation practices on estimates of sediment loss (ton/a/yr)

Region	Conservation practices	Number of NRI sample points	Acres (1,000s)	Sediment loss			
				Conservation-practices base-line scenario	No-practices scenario	Difference	Percent difference relative to no-practices scenario
All regions	Contour farming only	3,728	5,965	3.0	5.5	-2.6	-46
	Contour farming and stripcropping	1,183	1,764	2.5	6.6	-4.1	-62
	Contour farming and terraces	7,883	14,728	1.0	2.8	-1.8	-66
	Contour farming, stripcropping, and terraces	31	64	0.8	2.5	-1.7	-69
	Stripcropping only	1,308	2,930	1.1	2.0	-0.8	-42
	Terraces only	3,268	6,285	1.2	1.9	-0.7	-37
	All practices	17,401	31,737	1.5	3.3	-1.8	-54
Northeast	Contour farming only	338	485	5.0	8.4	-3.4	-40
	Contour farming and stripcropping	454	595	3.4	8.2	-4.8	-58
	Stripcropping only	423	526	4.0	7.2	-3.2	-45
	All practices	1,215	1,606	4.1	7.9	-3.9	-49
Southeast	Contour farming only	275	456	2.5	4.5	-2.0	-44
	Contour farming and terraces	132	234	0.9	3.1	-2.2	-71
	Terraces only	52	92	1.4	3.0	-1.5	-52
	All practices	459	782	1.9	3.9	-2.0	-51
South Central	Contour farming only	110	172	3.8	7.7	-3.9	-51
	Contour farming and terraces	1,173	1,963	1.2	3.5	-2.4	-67
	Terraces only	1,169	1,974	1.8	2.9	-1.1	-37
	All practices	2,452	4,109	1.6	3.4	-1.8	-53
Upper Midwest	Contour farming only	2,625	4,239	3.1	5.9	-2.8	-47
	Contour farming and stripcropping	702	1,106	2.1	5.9	-3.8	-65
	Contour farming and terraces	3,621	5,293	1.9	5.3	-3.5	-65
	Stripcropping only	156	231	2.9	5.1	-2.2	-43
	Terraces only	637	985	2.5	4.0	-1.5	-38
	All practices	7,741	11,853	2.4	5.5	-3.1	-56

Table 25 Effects of three conservation practices on estimates of sediment loss (ton/a/yr)—Continued

				Sediment loss			
Region	Conservation practices	Number of NRI sample points	Acres (1,000s)	Conservation-practices base-line scenario	No-practices scenario	Difference	Percent difference relative to no-practices scenario
Northern Great Plains	Contour farming only	268	365	0.8	1.5	-0.7	-50
	Contour farming and terraces	1,370	3,553	0.3	0.6	-0.4	-58
	Stripcropping only	602	1,945	0.2	0.2	0.0	-18
	Terraces only	213	495	0.6	0.8	-0.3	-32
	All practices	2,453	6,357	0.3	0.6	-0.3	-49
Southern Great Plains	Contour farming only	104	235	0.3	0.6	-0.3	-53
	Contour farming and terraces	1,585	3,681	0.2	0.8	-0.5	-70
	Stripcropping only	80	149	0.1	0.1	0.0	-27
	Terraces only	1,122	2,677	0.4	0.7	-0.2	-35
	All practices	2,891	6,743	0.3	0.7	-0.4	-56
West	Terraces only	72	58	0.6	0.8	-0.2	-24

Note: Results for conservation practices and combinations of practices based on less than 20 NRI sample points are not shown in the regional breakdowns, but these data are included in the aggregated results for all regions.

for the West where the percentage reduction averaged 24 percent. Conservation practices in the West region, however, were represented by only 72 NRI sample points, all with terraces only, and may not be representative of conservation effects in this region because of the partial coverage of cropland acres in the study.

Assessment of critical acres for sediment loss

Acres with the highest estimates of sediment loss are identified here as critical acres. Since not all conservation practices were taken into account in the model simulations, these sediment loss estimates actually represent the potential for sediment loss. To the extent that buffers, field borders, and cover crops, for example, are present, the estimates of sediment loss reported here would be overstated and possibly some critical acres misidentified.

Some regions of the country have been shown in this study to have a much higher potential for sediment loss than other areas of the country. Moreover, as shown in map 9 and in the example for the two Iowa watersheds, sediment loss estimates often varied considerably within relatively small geographic areas. Estimates of the average sediment loss by region and by crops within regions mask much of this underlying variability. Table 26 demonstrates the extent of both regional and local variability by presenting the percentiles of sediment loss estimates for each region. The fifth and tenth percentiles (representing the per-acre sediment loss threshold below which 5 percent and 10 percent of the acres, respectively, would have lower sediment loss estimates) are all below 0.2 tons per acre per year. Similarly, results for the 25th percentile show that in every region 25 percent of the acres had sediment loss estimates less than 1 ton per acre per year. The median, or 50th percentile, is close to or below 1 ton per acre per year for all but the South Central region. Thus, even in the Northeast and the South Central regions, which had the highest average sediment loss estimates, there are a substantial number of acres with very low potential for sediment loss. As shown by the median sediment loss estimate for all regions, half of the cropland acres included in the study had sediment loss estimates less than 0.6 tons per acre per year.

The bulk of the distribution of sediment loss estimates is below the mean value in all regions, as indicated by mean values that exceed median values. The most extreme example of this is for the Northeast region, where the mean sediment loss estimate of 3.2 tons per acre per year is over three times greater than the median estimate of 0.85 tons per acre per year (table 26). For some regions, the mean value equals or approaches the 75th percentile. This condition of disproportionality exists because of a minority of sample points with very high sediment loss estimates. These sample points are defined here as critical acres, which, if adequately treated with conservation practices, are likely to have the greatest effect on offsite impacts associated with sediment loss from farm fields.

Five categories of critical acres, representing different degrees of severity, are defined on the basis of national level results:

- acres where per-acre sediment loss is above the 95th percentile (5.963 ton/a/yr) for all acres included in the study
- acres where per-acre sediment loss is above the 90th percentile (3.915 ton/a/yr) for all acres included in the study
- acres where per-acre sediment loss is above the 85th percentile (2.900 ton/a/yr) for all acres included in the study
- acres where per-acre sediment loss is above the 80th percentile (2.315 ton/a/yr) for all acres included in the study
- acres where per-acre sediment loss is above the 75th percentile (1.847 ton/a/yr) for all acres included in the study

The regional representation of critical acres is shown in table 27 for each of the five categories. Over 90 percent of the acres with per-acre sediment loss estimates in the top 5 percent were in three regions—the Upper Midwest region (46% of critical acres), the South Central region (30% of critical acres), and the Northeast region (18% of critical acres.). As the criterion for critical acres expanded from the top 5 percent to the top 25 percent, the representation of critical acres in other regions expanded somewhat, while the share of critical acres in the Northeast region fell to 7 percent. In the South Central region, half of the cropland acres were designated as critical acres in the top

Table 26 Percentiles of sediment loss estimates (ton/a/yr)

Region	Acres	Number of NRI sample points	Mean	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile
Northeast	13,641,900	11,282	3.186	0.000	0.000	0.001	0.850	4.345	9.731	13.515
Northern Great Plains	72,396,500	36,035	0.465	<.001	0.016	0.079	0.230	0.472	0.982	1.864
South Central	45,349,900	27,465	2.769	0.002	0.156	0.900	1.849	3.378	5.941	8.725
Southeast	13,394,400	8,955	1.607	<.001	0.002	0.088	0.604	1.730	3.794	6.930
Southern Great Plains	32,096,000	14,495	0.358	0.007	0.017	0.069	0.193	0.422	0.835	1.387
Upper Midwest	112,580,900	74,691	1.945	0.000	0.019	0.481	1.117	2.464	4.634	6.792
West	9,018,400	5,644	0.548	0.000	0.000	0.016	0.103	0.359	1.511	2.044
All regions	298,478,000	178,567	1.540	<.001	0.007	0.146	0.608	1.847	3.915	5.963

Note: Percentiles are in terms of acres. The 5th percentile, for example, is the threshold below which 5 percent of the acres have lower sediment loss estimates.

Table 27 Critical acres for sediment loss

		Per-acre loss in top 5 percent nationally		Per-acre loss in top 10 percent nationally		Per-acre loss in top 15 percent nationally		Per-acre loss in top 20 percent nationally		Per-acre loss in top 25 percent nationally	
Region	Acres	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Northeast	13,641,900	2,604,900	17.5	3,749,100	12.6	4,382,600	9.8	4,890,400	8.2	5,465,700	7.3
Northern Great Plains	72,396,500	105,600	0.7	693,900	2.3	2,152,000	4.8	2,982,600	5.0	3,686,800	4.9
South Central	45,349,900	4,472,100	30.0	9,262,400	31.0	13,849,600	30.9	18,477,900	31.0	22,677,100	30.4
Southeast	13,394,400	803,800	5.4	1,281,900	4.3	2,147,100	4.8	2,739,200	4.6	3,195,400	4.3
Southern Great Plains	32,096,000	11,100	0.1	54,700	0.2	267,500	0.6	410,600	0.7	621,100	0.8
Upper Midwest	112,580,900	6,844,100	45.9	14,624,100	49.0	21,681,600	48.4	29,765,200	50.0	38,174,700	51.2
West	9,018,400	65,900	0.4	181,700	0.6	283,000	0.6	322,500	0.5	798,500	1.1
All regions	298,478,000	14,907,500	100.0	29,847,800	100.0	44,763,400	100.0	59,588,400	100.0	74,619,300	100.0

Note: The top 5 percent corresponds to the 95th percentile in table 26. Other columns correspond to table 26 in a similar manner.

25 percent for sediment loss. In the Northeast region, 40 percent of the cropland acres were designated as critical acres in the top 25 percent for sediment loss.

These critical acres accounted for the bulk of the 459,622 thousand tons per year of sediment loss. The 95th percentile category, representing the 5 percent of acres with the highest per-acre losses, accounted for 34 percent of the total tons of sediment loss. The 25 percent of acres with the highest per-acre losses accounted for 76 percent of the total tons of sediment loss.

Percentile	Percent of total tons of sediment loss
95th	34.0
90th	49.6
85th	60.5
80th	68.9
75th	75.7

Wind erosion

Modeling wind erosion

Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the ground surface. The particles are lifted into the air and are either suspended and carried away by the wind or fall back to the surface and dislodge other soil particles. This process destroys the surface crust, creating a condition even more vulnerable to erosion. Soil grains too large to be lifted off the surface move along the surface and are deposited in areas protected from the wind. Wind strength, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Plant cover and crop residue greatly reduce the potential for wind erosion. The shape, size, and arrangement of aggregates are also important in wind erosion; strong bonds and large aggregates provide more resistance to erosive forces. Organic matter enhances soil structure, increases water infiltration, and thereby reduces the potential for wind erosion.

Wind erosion is estimated in EPIC using the Wind Erosion Continuous Simulation (WECS) model, which incorporates the daily distribution of wind speeds as the force driving erosion (Williams 1995). In essence, the equation estimates potential wind erosion for a smooth bare soil as a function of wind speed, soil particle size, and the ratio of soil water to water holding capacity in the top 10 millimeters (0.4 in) of the soil. Potential erosion is then adjusted downward to account for inherent soil properties, field characteristics, and management practices using four factors:

- soil erodibility
- surface roughness
- vegetative cover
- unprotected distance across the field in the wind direction

Model simulation results for wind erosion

Wind erosion, both on a per-acre basis and as total tons, was largely restricted to two regions—the Northern Great Plains and Southern Great Plains (maps 11 and 12). These two regions accounted for 89 percent of the total tons of wind erosion estimated for cropland acres included in this study (table 28). Low wind erosion rates—usually less than 1 ton per cropland acre per year—occurred in the Upper Midwest and South Central regions, accounting for about 10 percent of the total. The Northeast, Southeast, and West regions accounted for less than 1 percent of the total wind erosion.

The most vulnerable cropland acres for wind erosion—shown in dark red and red in map 11—occur mostly in northwestern Texas, central Kansas, Northeast Colorado, and parts of Nebraska, representing about 3 percent of cropland acres included in the study. Model estimates of wind erosion rates for these acres averaged over 8 tons per acre per year. Another 3 percent of cropland acres had average wind erosion rates ranging between 3 and 8 tons per acre per year and are found in the same areas as the most vulnerable acres. About 10 percent of the cropland acres had average wind erosion rates between 1 and 3 tons per acre per year; the preponderance of these acres is also found in the Great Plains states.

Summary of wind erosion results by region and crop

Wind erosion rates in the Southern Great Plains averaged over 5 tons per acre per year and accounted for 55 percent (165 million tons per year) of the total wind erosion (table 28). The majority of this wind erosion was on cotton acres (101 million ton/yr), where the average annual wind erosion rate was 14 tons per acre per year. Wind erosion rates in this region were also high for peanuts (9.2 ton/a/yr), corn (6.2 ton/a/yr) and sorghum (5.3 ton/a/yr).

Wind erosion rates in the Northern Great Plains were much lower, averaging 1.4 tons per acre per year for cropland acres. Corn accounted for over half of the total wind erosion in this region, averaging 3.6 tons per acre per year. Wind erosion rates in this region were also high for corn silage (4.0 ton/a/yr) and sorghum (3.5 ton/a/yr).

Wind erosion rates on irrigated crops were close to the rates for non-irrigated crops for most crops in most regions (table 29). Irrigated corn acres in the Southern Great Plains region, however, had much higher wind erosion rates than non-irrigated corn acres in that region, averaging 8 tons per acre per year for irrigated corn acres and 1 ton per acre per year for non-irrigated corn acres. Corn in the Northern Great Plains region similarly had higher wind erosion rates for irrigated acres than for non-irrigated acres, differing by about 2.2 tons per acre per year. These higher rates for irrigated corn represent acreage in the more arid areas within each region where corn usually cannot be produced without irrigation.

Effects of soil properties on wind erosion

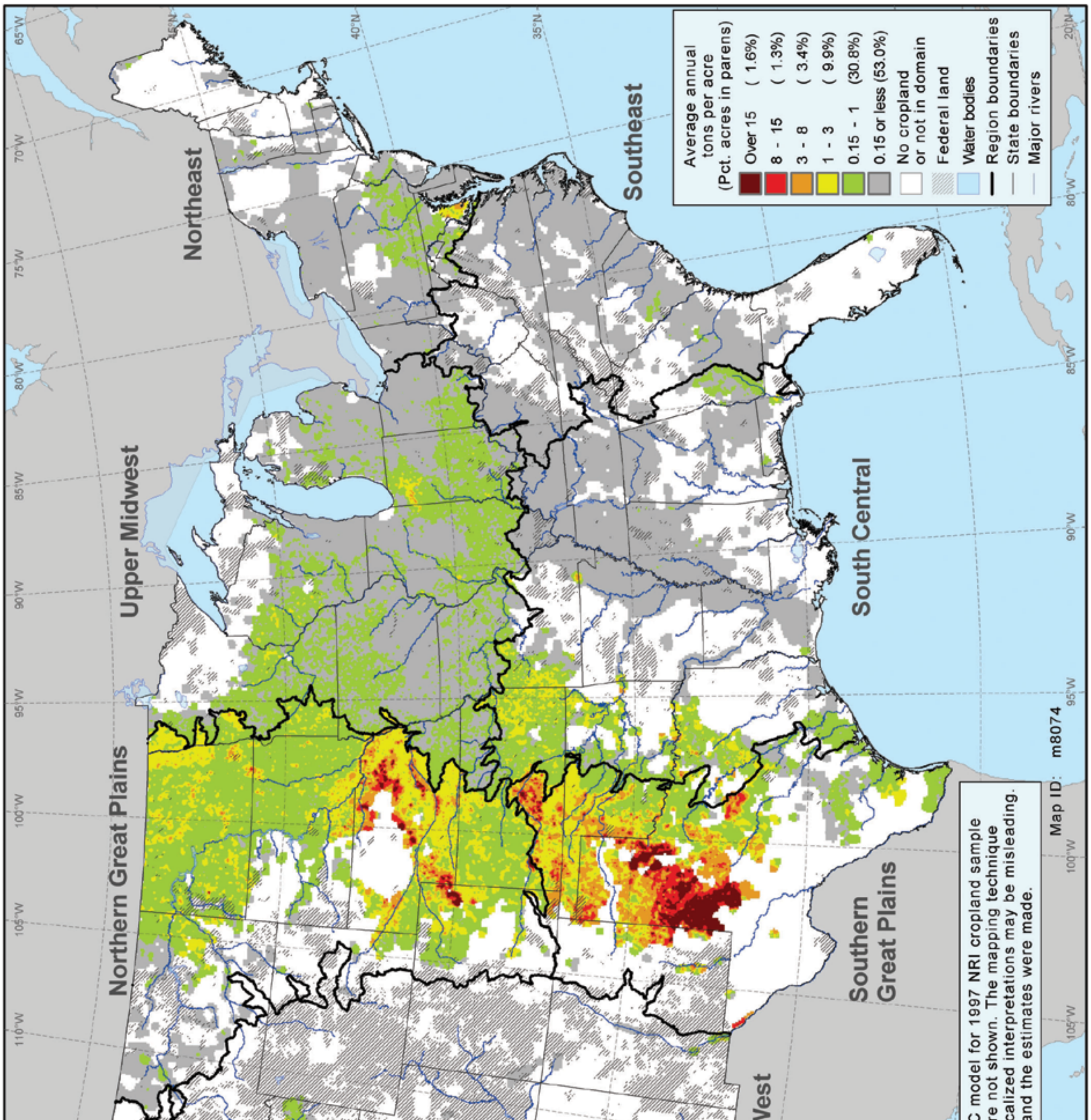
Model simulation results showed that soil texture and hydrologic soil group had a pronounced effect on wind erosion estimates (fig. 12). On average, coarse textured soils had much higher wind erosion rates than other soil texture groups, followed by moderately coarse textured soils. The highest wind erosion rate was for coarse textured soils in the hydrologic soil group A—about 7 tons per acre per year. Coarse and moderately coarse textured soils represent about 30 percent of the cropland acres in the Southern Great Plains, partly explaining the high erosion rates obtained for that region. A higher proportion of coarse and moderately coarse soils occur in the Southeast region, but climatic factors are not conducive to wind erosion in the Southeast.

Effects of tillage practices on wind erosion

These estimates of wind erosion rates include the mitigating effect of conservation tillage practices. Although the effects of tillage on wind erosion rates are significant, they are more modest than observed for sediment loss when aggregated at the regional level. To assess the effects that conservation tillage had on wind erosion estimates, the subset of model runs where all three tillage systems—conventional tillage, mulch tillage, and no-till—were present within a URU was defined to be the domain for examining the effects of tillage (table 12 and related discussion). This tillage comparison subset of model runs included eight crops—barley, corn, corn silage, oats, spring wheat, sorghum, soybeans, and winter wheat—and represented about 70 percent of the cropland acres covered by the study. Results on the effects of tillage on wind erosion estimates are shown in table 30.

For the 208 million acres in the tillage comparison subset, the tillage-effects baseline wind erosion rate averaged 0.8 tons per acre per year, slightly lower than the 1.0 tons per acre per year estimate for the full set of NRI sample points included in the study. On average, accounting for tillage effects reduced wind ero-

Map 11 Estimated average annual per-acre wind erosion rate



Map 12 Estimated average annual tons of wind erosion

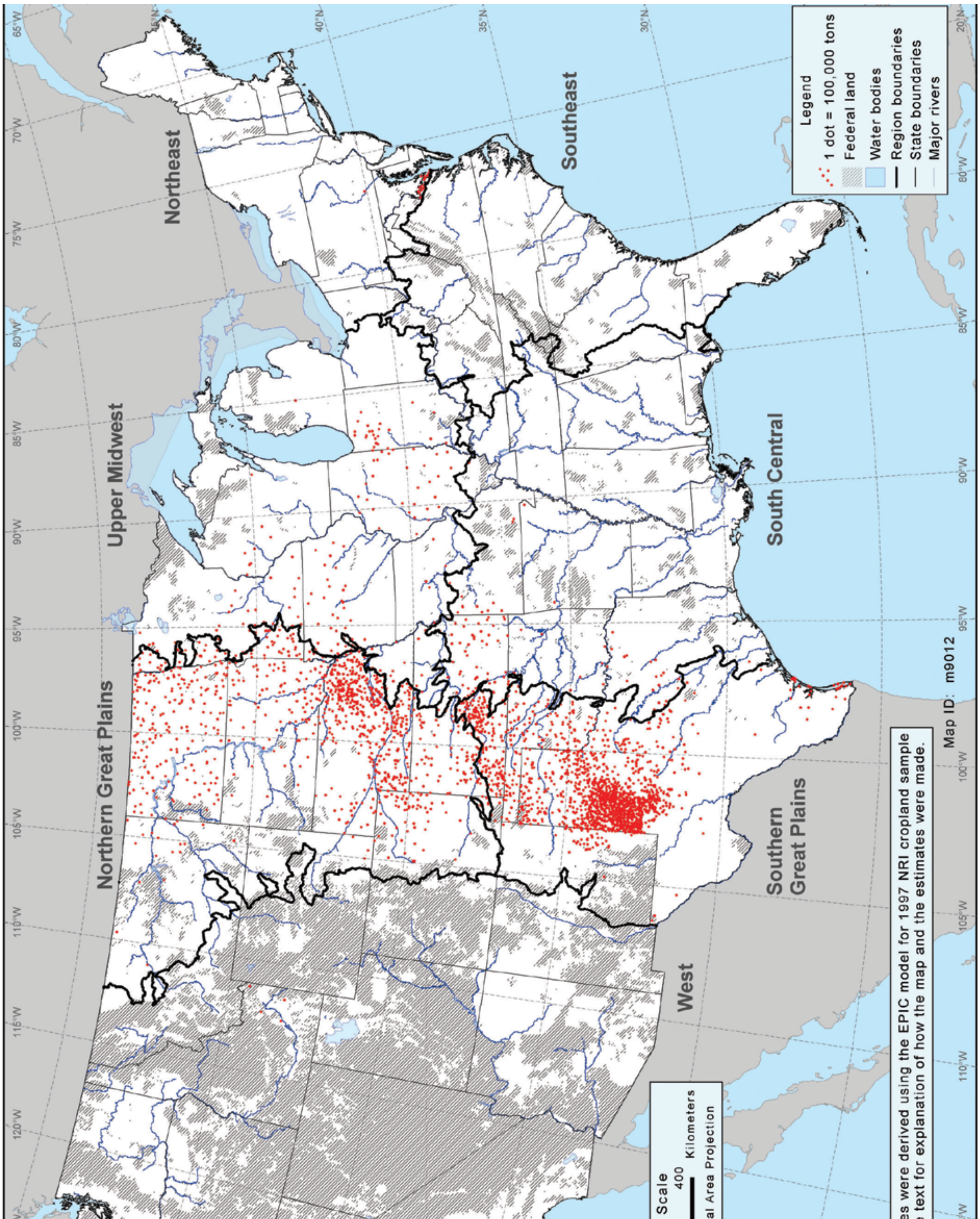


Table 28 Wind erosion rate estimates–by region and by crop within regions (average annual values)

Region	Crop	Acres (1,000s)	Tons per acre per year	Tons per year (1,000s)
By region				
Northeast	All crops	13,642	0.1	1,076
Northern Great Plains	All crops	72,397	1.4	103,286
South Central	All crops	45,350	0.3	11,511
Southeast	All crops	13,394	<0.1	201
Southern Great Plains	All crops	32,096	5.1	165,092
Upper Midwest	All crops	112,581	0.2	18,695
West	All crops	9,018	0.1	528
All regions	All crops	298,478	1.0	300,389
By crop within region*				
Northeast	Corn	2,943	0.2	454
	Corn silage	1,482	0.2	326
	Grass hay	2,369	<0.1	2
	Legume hay	4,052	0.0	0
	Oats	362	<0.1	15
	Soybeans	1,305	0.2	233
	Winter wheat	853	<0.1	15
Northern Great Plains	Barley	3,243	0.8	2,698
	Corn	15,466	3.6	55,022
	Corn silage	810	4.0	3,253
	Grass hay	2,443	<0.1	45
	Legume hay	6,152	0.0	0
	Oats	1,255	1.1	1,336
	Spring wheat	18,916	0.8	15,449
	Sorghum	1,595	3.5	5,564
	Soybeans	9,562	1.4	13,391
	Winter wheat	12,748	0.4	5,567
South Central	Corn	5,956	0.3	1,572
	Cotton	5,487	0.1	796
	Grass hay	3,347	<0.1	2
	Legume hay	1,630	0.0	0
	Peanuts	880	0.6	547
	Rice	3,004	<0.1	117
	Sorghum	2,729	1.5	4,101
	Soybeans	14,083	0.2	3,075
	Winter wheat	7,896	0.2	1,245

Table 28 Wind erosion rate estimates–by region and by crop within regions (average annual values)—Continued

Region	Crop	Acres (1,000s)	Tons per acre per year	Tons per year (1,000s)
Southeast	Corn	3,028	<0.1	44
	Corn silage	412	<0.1	4
	Cotton	2,422	<0.1	84
	Grass hay	2,000	0.0	0
	Legume hay	1,183	0.0	0
	Peanuts	479	<0.1	11
	Soybeans	2,419	<0.1	48
	Winter wheat	1,216	<0.1	1
Southern Great Plains	Corn	2,665	6.2	16,598
	Cotton	7,316	13.9	101,472
	Legume hay	677	0.0	0
	Oats	503	0.4	202
	Peanuts	484	9.2	4,455
	Sorghum	4,895	5.3	26,157
	Winter wheat	15,037	1.0	14,312
Upper Midwest	Corn	47,941	0.3	13,339
	Corn silage	1,947	0.4	784
	Grass hay	4,044	<0.1	4
	Legume hay	9,233	0.0	0
	Oats	1,388	0.2	259
	Spring wheat	815	0.2	166
	Sorghum	1,604	0.3	507
	Soybeans	40,049	0.1	3,365
	Winter wheat	5,147	<0.1	123
West	Barley	958	0.1	108
	Corn silage	297	0.1	26
	Cotton	1,631	<0.1	50
	Legume hay	1,847	0.0	0
	Potatoes	329	0.5	160
	Rice	599	0.0	0
	Spring wheat	772	0.1	104
	Winter wheat	2,118	<0.1	71

* Wind erosion rate estimates for crops with less than 250,000 acres within a region are not shown.
However, acres for these minor crops are included in the calculation of the regional estimates.

Table 29 Comparison of wind erosion rates for irrigated crops to rates for non-irrigated crops (average annual values)

		Non-irrigated crops		Irrigated crops	
Region	Crop*	Acres (1,000s)	Tons per acre per year	Acres (1,000s)	Tons per acre per year
Northern Great Plains	Corn	8,785	2.6	6,680	4.8
	Legume hay	4,816	0.0	1,336	0.0
	Soybeans	8,578	1.3	984	2.2
	Winter wheat	12,086	0.4	662	0.4
South Central	Corn	5,285	0.2	671	0.4
	Cotton	3,983	0.2	1,505	0.1
	Rice	0	NA	3,004	<0.1
	Soybeans	10,498	0.3	3,585	0.1
	Winter wheat	7,341	0.2	554	0.1
Southeast	Cotton	2,115	<0.1	307	<0.1
Southern Great Plains	Corn	672	1.0	1,993	8.0
	Cotton	4,486	13.8	2,831	14.0
	Legume hay	263	0.0	414	0.0
	Peanuts	159	8.3	325	9.7
	Sorghum	3,748	5.6	1,147	4.3
	Winter wheat	13,046	1.0	1,991	0.8
Upper Midwest	Corn	46,424	0.3	1,517	0.4
	Soybeans	39,409	0.1	641	0.1
West	Barley	357	0.1	601	0.1
	Corn silage	0	NA	297	0.1
	Cotton	0	NA	1,631	<0.1
	Legume hay	159	0.0	1,688	0.0
	Potatoes	0	NA	329	0.5
	Rice	0	NA	599	0.0
	Spring wheat	197	0.1	575	0.2
	Winter wheat	1,066	<0.1	1,052	0.1

* Irrigated crops with more than 250,000 acres in a region are included in the table. These 26 crop-region combinations represent 92 percent of the irrigated acres included in the study.
NA = not applicable.

Figure 12 Average per-acre wind erosion rates–by hydrologic soil group and soil texture group

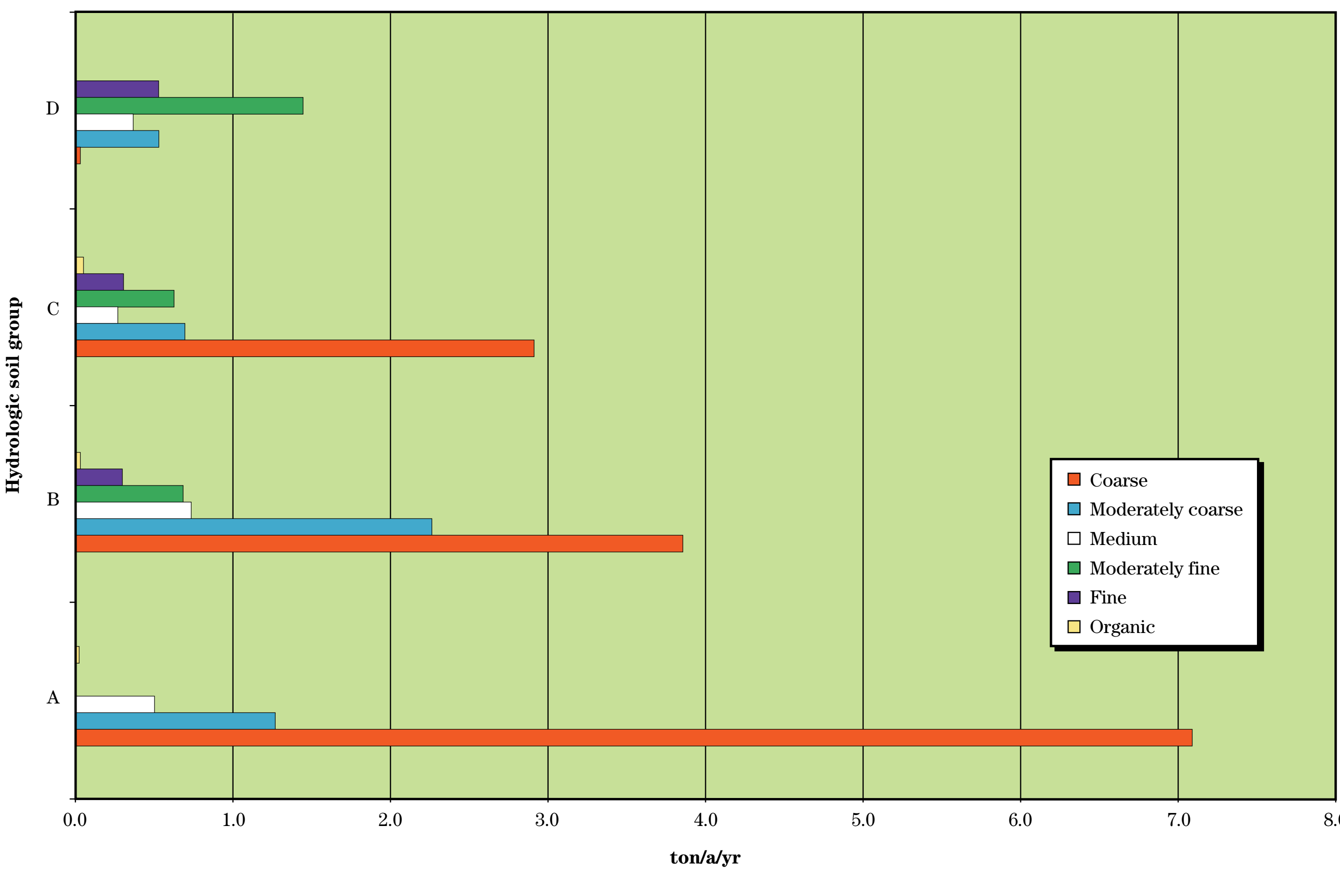


Table 30 Effects of tillage practices on estimates of wind erosion rates (ton/a/yr)

		Wind erosion rate				Change relative to the tillage-effects baseline			Change relative to conventional tillage	
	Acres in tillage comparison subset (1,000s)	Tillage-effects baseline	Conventional tillage	Mulch tillage	No-till	Conventional tillage	Mulch tillage	No-till	Mulch tillage	No-till
By region										
Northeast	6,034	0.15	0.21	0.12	0.03	0.06	-0.03	-0.12	-0.09	-0.18
Northern Great Plains	56,551	1.57	2.15	1.07	0.39	0.58	-0.50	-1.18	-1.08	-1.76
South Central	24,879	0.33	0.41	0.21	0.05	0.08	-0.12	-0.28	-0.20	-0.36
Southeast	4,442	0.01	0.01	0.01	0.00	0.00	0.00	-0.01	0.00	-0.01
Southern Great Plains	17,746	2.52	3.11	1.63	0.61	0.59	-0.89	-1.91	-1.48	-2.50
Upper Midwest	96,330	0.19	0.28	0.14	0.04	0.09	-0.05	-0.15	-0.14	-0.24
West	1,661	0.07	0.12	0.02	0.01	0.05	-0.05	-0.06	-0.10	-0.11
All regions	207,642	0.77	1.04	0.53	0.18	0.27	-0.24	-0.59	-0.51	-0.86

Note: The subset used for this analysis includes only those URUs where all three tillage systems were present. The tillage-effects baseline results represent the mix of tillage systems as reported in the Crop Residue Management Survey for 2000 (CTIC 2001). Tillage-effects baseline results reported in this table will differ from results reported in table 28 because they represent only about 70 percent of the acres in the full database Results presented for each tillage system represent wind erosion rates as if all acres had been modeled using a single tillage system.

sion rates overall by about 0.3 tons per acre per year compared to conventional tillage use on all acres, representing a reduction of 26 percent. The mitigating effect of tillage on wind erosion estimates occurred in all regions, although differences were small in regions with low wind erosion rates (table 30). In the Northern Great Plains and Southern Great Plains regions, where wind erosion rates are highest, accounting for tillage reduced wind erosion rates by about 0.6 tons per acre per year, on average, compared to conventional tillage use on all acres. This indicates that, had these tillage practices not been adopted, wind erosion rates would have been about 37 percent higher in the Northern Great Plains and 23 percent higher in the Southern Great Plains. Full adoption of mulch tillage in these two regions would further reduce wind erosion by 0.5 to 0.9 tons per acre per year. These model simulations further show that full adoption of no-till would reduce wind erosion rates by 1 to 2 tons per acre per year in the two Great Plains regions, on average, and bring the wind erosion rate to well below 1 ton per acre per year in all regions. These estimates of the effects of tillage may be understated in the Southern Great Plains region because the two crops with the highest wind erosion rates—cotton and peanuts—were not included in the analysis.

Assessment of critical acres for wind erosion

Acres with the highest wind erosion rates are identified here as critical acres. Erosion rate estimates reported in this study actually represent the potential for wind erosion as a source of soil loss from farm fields. Tillage practices were included in the assessment, but other conservation practices that are often used to help control wind erosion were not taken into account, such as windbreaks, buffers, field borders, cover crops, and stripcropping. Stripcropping was taken into account for sediment loss estimates by adjusting the P-factor, but this has no effect on wind erosion estimates in EPIC. To the extent that these practices are present, the potential for high wind erosion rates reported here would be overstated and possibly some critical acres misidentified.

Two regions of the country have been shown to have high wind erosion rates—the Southern Great Plains and Northern Great Plains regions. Even in those regions, however, high wind erosion rates were limited to a minority of the acres present. Table 31 demonstrates the extent of both regional and local variability by presenting the percentiles of wind erosion estimates for each region. Three-fourths of the cropland acres included in the study had wind erosion rates less than 0.6 tons per acre per year. For each region, the 75th percentile was nearly the same as the regional average wind erosion rate. Thus, there is a high degree of disproportionality in the wind erosion results, even in the Southern Great Plains and Northern Great Plains regions. A relatively small minority of sample points with very high wind erosion rates dominate the sample. These sample points are defined here as critical acres for wind erosion.

Five categories of critical acres, representing different degrees of severity, are defined on the basis of national level results:

- acres where per-acre wind erosion rates are above the 98th percentile (11.788 ton/a/yr) for all acres included in the study
- acres where per-acre wind erosion rates are above the 96th percentile (5.155 ton/a/yr) for all acres included in the study
- acres where per-acre wind erosion rates are above the 94th percentile (3.267 ton/a/yr) for all acres included in the study
- acres where per-acre wind erosion rates are above the 92nd percentile (2.489 ton/a/yr) for all acres included in the study
- acres where per-acre wind erosion rates are above the 90th percentile (1.983 ton/a/yr) for all acres included in the study

Higher thresholds are used to identify critical acres associated with wind erosion than are used to identify thresholds for critical acres associated with sediment loss and nutrient loss because the high wind erosion rates are limited to a much smaller subset of the cropland acres. Instead of the 95th percentile used for sediment loss, the 98th percentile is used for wind erosion, for example.

The regional representation of critical acres for wind erosion is shown in table 32 for each of the five categories. Most (86%) of the acres with per-acre wind erosion rates in the top 2 percent were in the Southern Great Plains, with the remainder in the Northern Great

Table 31 Percentiles of wind erosion estimates (ton/a/yr)

Region	Acres	Number of NRI sample points	Mean	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile
Northeast	13,641,900	11,282	0.079	0.000	0.000	0.000	0.001	0.041	0.256	0.422
Northern Great Plains	72,396,500	36,035	1.427	0.000	0.000	0.308	0.713	1.476	2.866	3.981
South Central	45,349,900	27,465	0.254	0.000	<.001	0.002	0.013	0.122	1.132	1.607
Southeast	13,394,400	8,955	0.015	0.000	0.000	0.000	0.001	0.015	0.038	0.060
Southern Great Plains	32,096,000	14,495	5.144	0.033	0.162	0.313	1.150	6.594	16.510	22.251
Upper Midwest	112,580,900	74,691	0.166	0.000	0.000	0.030	0.094	0.213	0.333	0.424
West	9,018,400	5,644	0.059	0.000	0.000	0.000	<.001	0.004	0.151	0.311
All regions	298,478,000	178,567	1.006	0.000	0.000	0.010	0.129	0.553	1.983	4.164

Note: Percentiles are in terms of acres. The 5th percentile, for example, is the threshold below which 5 percent of the acres have lower wind erosion rates.

Table 32 Critical acres for wind erosion

		Per-acre wind erosion rate in top 2 percent nationally		Per-acre wind erosion rate in top 4 percent nationally		Per-acre wind erosion rate in top 6 percent nationally		Per-acre wind erosion rate in top 8 percent nationally		Per-acre wind erosion rate in top 10 percent nationally	
Region	Acres	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Northeast	13,641,900	0	0.0	10,800	0.1	27,800	0.2	38,300	0.2	57,500	0.2
Northern Great Plains	72,396,500	812,000	13.6	2,288,200	19.2	5,299,100	29.6	9,801,100	41.0	14,135,800	47.4
South Central	45,349,900	25,900	0.4	138,200	1.2	284,300	1.6	478,500	2.0	1,265,100	4.2
Southeast	13,394,400	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Southern Great Plains	32,096,000	5,132,400	86.0	9,444,000	79.1	11,951,700	66.7	13,128,900	55.0	13,715,900	46.0
Upper Midwest	112,580,900	0	0.0	53,600	0.4	346,800	1.9	426,000	1.8	635,800	2.1
West	9,018,400	0	0.0	0	0.0	1,900	0.0	4,000	0.0	6,700	0.0
All regions	298,478,000	5,970,300	100.0	11,934,800	100.0	17,911,600	100.0	23,876,800	100.0	29,816,800	100.0

Note: The top 10 percent corresponds to the 90th percentile in table 31.

Plains. As the criterion for critical acres expands from the top 2 percent to the top 10 percent, the representation of critical acres in the Northern Great Plains expands to match that for the Southern Great Plains. In the top 10 percent category, the Northern Great Plains and the Southern Great Plains regions each had about 46 to 47 percent of the critical acres, with most of the remainder in the South Central region.

These critical acres accounted for the bulk of the 300,389 thousand tons per year of wind erosion. The 98th percentile category, representing the 2 percent of acres with the highest per-acre losses, accounted for 42 percent of the total tons of wind erosion. The 10 percent of acres with the highest per-acre losses accounted for 76 percent of the total tons of wind erosion.

Percentile	Percent of total tons of wind erosion
98th	42.3
96th	57.9
94th	66.2
92nd	71.8
90th	76.2