United States Department of Agriculture
Natural Resources Conservation Service

Conservation Resource Brief

Soil Erosion

February 2006 — Number 0602

Key Messages:

- Soil erosion directly or indirectly impacts soil quality, water use, water quality, air quality, plant management, animal management livestock unconfined, animal management livestock confined, wildlife aquatic, wildlife terrestrial, and energy management.
- In 1997, wind erosion rates exceeded "T" on more than 47 million acres of cultivated cropland annually.
- In 1997, sheet and rill erosion rates exceeded "T." on more than 63 million acres of cultivated cropland annually.
- Some of America's cropland continues to erode at unsustainable rates.
- In 2001, 103 million acres (about 28% of total cropland) were eroding at rates greater than "T."
- Of the 101 million acres of Highly Erodible Land, 2001 NRI data indicates that 55 percent continues to erode in excess of "T."
- Of the 268.6 million acres of Non-Highly Erodible Land, 2001 NRI data indicates that 18 percent continues to erode in excess of "T."

Contact:

NRCS Web site at www.nrcs.usda.gov.

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Helping People Help the Land

Description

Soil erosion involves the detachment and removal of soil material from one site by the forces of wind or flowing water and its transport to another location. The soil surface is susceptible to erosion when the live plant or residue cover is inadequate.

Soil erosion usually degrades soil quality. A soil of poorer quality is less able to withstand further erosion, thus creating a downward spiral of soil degradation. Organic matter and clay particles may be lost which have nutrients and pesticides attached, with consequent reductions in fertility and crop productivity, biological activity, aggregation and rooting depth. Other potential effects of erosion on soil quality include reduced infiltration, formation of soil surface crusts, changes in soil texture, and compaction. These changes in turn reduce the capacity of the soil to supply and cycle nutrients, filter and degrade toxic materials, store and supply moisture and sustain plant and biological productivity. They may also result in increased runoff, less biomass production and plant cover, and greater susceptibility to further erosion.

Water erosion results in the formation of rills and gullies and streambank cutting at the site of removal, and down-slope deposition and sedimentation of downstream channels and water bodies.

Wind blown sediment also can be deposited in channels and water courses with similar results. Air born soil particles can obstruct visibility along highways adjacent to agricultural areas subject to wind erosion.

Sediment transport often carries nutrients and pesticides into water used for livestock and human consumption, and for recreation.

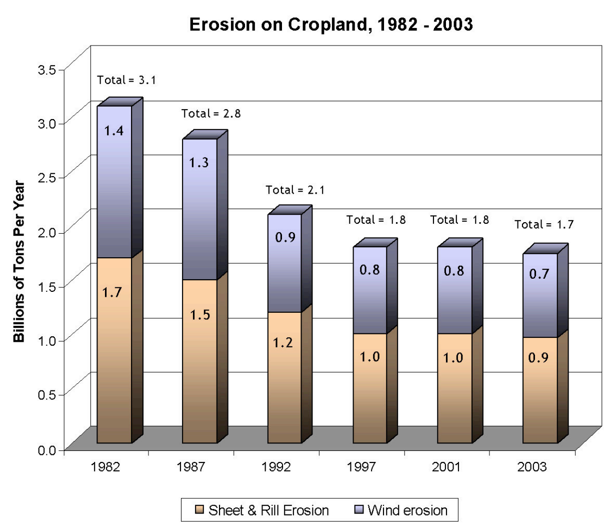


Figure 1–Erosion on Cropland, based on 1982-2003 NRI data.

Economic Effects of Soil Erosion

In addition to the detrimental environmental impact, soil erosion takes a huge toll on our nation's economy. Norfleet (2005) identified several components of on-site costs (e.g., lost nutrients, water runoff, and productivity) and off-site costs (e.g., water quality & quantity and air quality) associated with soil erosion. He suggests that the cost of keeping soil in place is worth at least $13.67 per ton or $27.5 billion for the 2 billion tons of soil eroded in 1997, which is equivalent to **$27.5 billion in 2004**. Total expenditures by the U.S. Army Corps of Engineers and other industry in 2003 for dredging a total of 233.8 million cubic yards was $887.3 million, equivalent to **$910.9 million in 2004** (USACE). If erosion were to continue at the 1982 rate for the next 50 years, Pierre Crosson (1998), estimates a 5.1 percent decrease in yield for corn and 3.4 percent for soybeans, or an average **loss in productivity of .1 and .07 percent per year, respectively**. Given that crop yields are projected to increase more slowly in percentage terms than food demand over the next several decades, even small degradation-induced losses of productivity raise concerns (Wiebe, 2003).

Conservation Connection

Residue management practices are among the most effective conservation efforts delivered by the agency to directly reduce water and wind erosion on cropland. Residue management and conservation tillage systems benefit air quality, soil quality, water quality and quantity, wetlands, wildlife, animal waste and bio energy.

Many alternative resource management systems can be created from the list of practices (Table 1) to solve soil erosion problems on cropland. In areas where crop residues are grazed, residue management must be integrated with grazing management. Producers can change crop rotations; add cover crops, contouring, strip cropping and terraces; or any combination of these practices, either with a conventional tillage system or with some form of residue management to create an integrated system to protect the resource base.

Table 1– Applied conservation practices that reduce soil erosion by wind and water on cropland, based on 2004 NRCS performance results system reports.[1]

Conservation Practice	Amount	Conservation Practice	Amount
Conservation Cover (ac)	961,268	Pasture and Hay Planting (ac)	307,172
Conservation Crop Rotation (ac)	3,399,526	Residue Management, Mulch Till (ac)	1,270,687
Contour Buffer Strips (ac)	5,642	Residue Management, No-Till/Strip Till (ac)	1,290,839
Contour Farming (ac)	445,934	Residue Management, Ridge Till (ac)	30,522
Cover Crop (ac)	320,227	Residue Management, Seasonal (ac)	950,628
Critical Area Planting (ac)	32,029	Stripcropping (ac)	25,231
Cross Wind Ridges (ac)	2,545	Surface Roughening (ac)	150,973
Cross Wind Trap Strips (ac)	4,842	Terrace (ft)	20,077,723
Diversion (ft)	658,591	Tree/Shrub Establishment (ac)	248,288
Field Border (ft)	6,227,965	Vegetative Barrier (ft)	4,600
Herbaceous Wind Barriers (ft)	2,835,460	Water and Sediment Control Basin (no)	13,123
Irrigation Water Management (ac)	685,924	Windbreak/Shelterbelt Establishment (ft)	15,323,919
Mulching) (ac)	18,279	Windbreak/Shelterbelt Renovation (ft)	287,826

[1] The performance amounts in Table 1 are conservation practices strictly applied in 2004. They are not the total existing amounts of "conservation applied on the land."

Residue management systems allow the producer to continue using the land as cropland. Due to either a decrease in income or incompatibility with the over-all farming enterprise, placing cropland into the conservation reserve program (CRP) or another permanent-cover type of land use is not as widely used as combining residue management systems with other conservation practices. Without livestock, fencing, water supply and forage equipment, forage production may be of little value to a cash grain farmer. All these considerations are part of the conservation planning process that tailors the system to the producer's needs while remedying natural resource problems. However, in severe situations it may be most practical to participate in land retirement or set aside programs such as CRP or convert the land use from cropland to permanent hay or pasture, wildlife land or woodland.

Figures 2a and 2b show the amount of cropland utilizing conservation tillage systems (no-till, mulch till, and ridge-till) over time. Total acres of conservation tillage systems rose steadily in the late 1980's to 37.2% of all planted acres in 1998 (Figure 2b). The implementation of Farm Bill Compliance standards containing residue management practices was largely responsible for much of this increased adoption. From 1998 through 2000, total acres in conservation tillage systems remained static at about 109 million acres (Figure 2a); however the actual percentage of conservation tillage adoption dropped from 37.2% of the 293.4 million acres of planted cropland to 36.7% of the 297.5 million acres of planted cropland. After about a 5.7% decline in 2002, total acres of conservation tillage increased by 8.5 percent to almost 113 million acres in 2004. This gain (largely due to added acres of no-till) is probably a result of increased adoption in the southeastern states, and it can also be attributed to increased use of genetically modified seed, which eliminates the need for mechanical weed control (personal communication, Mike Hubbs, National Agronomist, NRCS). Whereas the total acres in a conservation tillage system have fluctuated since 1980, no-till adoption has continued to steadily rise from 6% in 1990 to almost 23% of all planted acres in 2004.

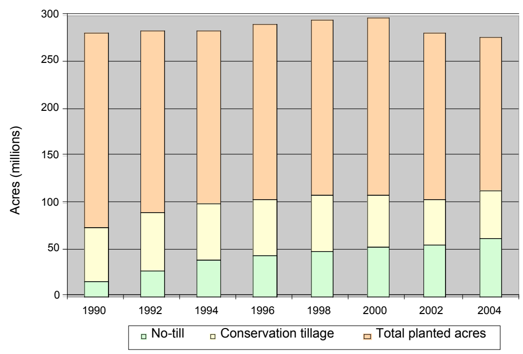


Figure 2a--Total planted acres and those with a conservation tillage system, of which no-till is a part

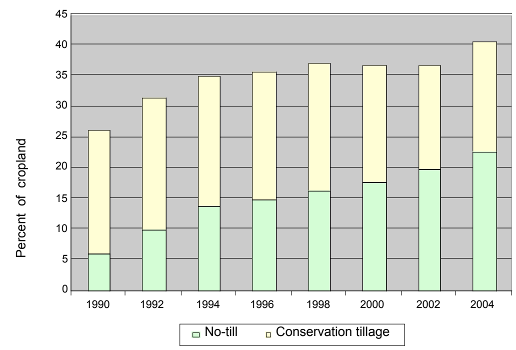


Figure 2b--Percentage of cropland with a conservation tillage system, of which no-till is a part

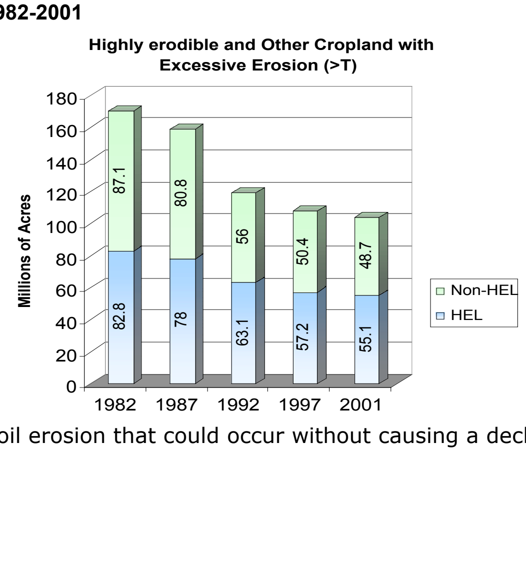
Source: Conservation Technology Information Center (http://www.ctic.purdue.edu/CTIC/CTIC.html)

Current Conditions and Trends

National

- From 1982 to 1997, there was significant progress to reduce soil erosion on all cropland (Figure 1). Sheet and rill erosion dropped by 41 percent during this time period. Wind erosion dropped by 43 percent. This translates to a savings of more than 1.2 billion tons of soil per year on cropland. Since 1997, reductions in erosion on cropland have stagnated (Figure 1).
- In 1997, there was 47 million acres of cultivated cropland with average annual wind erosion rates exceeding "T", and 63 million acres with annual sheet and rill erosion rates exceeding "T." [2] (USDA, 2000).

Figure 3–Total acres of cropland with excessive erosion on highly erodible and non-highly erodible cropland. Based on 1982-2001

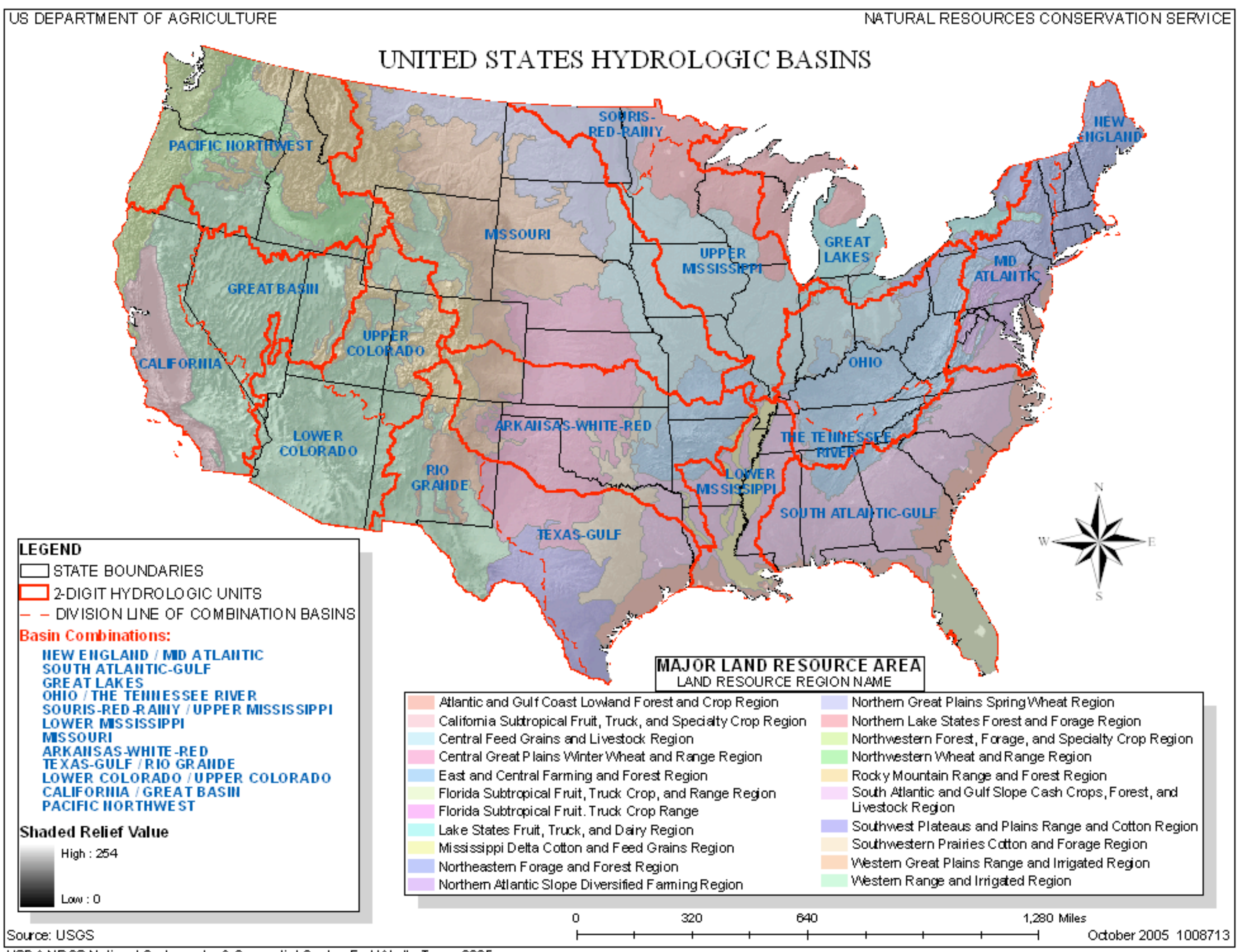


[2] The soil loss tolerance (T) value represents the average annual rate of soil erosion that could occur without causing a decline in long term productivity.

- The period from 1982 to 2001 experienced 39 percent decrease in total acres of excessively eroding cropland (Figure 3) (USDA, 2003).
- The period from 1982 to 1997 achieved a commendable 2.4 percent reduction per year. However, from 1997 to 2001, the average yearly decrease was .9 percent (Figure 3).
- In 2001 there were still more than 103 million acres (about 28 percent) of all cropland eroding at unacceptable rates (>T) (Figure 3) (USDA, 2003).
- From 1982 to 2003, as cultivated cropland was converted to other land uses such as CRP, the highly erodible cropland (HEL) acreage decreased by 27.8 percent and the non-highly erodible cropland (NHEL) decreased by 13.4 percent (Table 4).
- From 1982 to 2003, total soil loss on cultivated cropland (NHEL and HEL combined) decreased by 39.2 percent, from 462 to 281 million tons (Table 3). The erosion rate on all cultivated cropland decreased by 31.8 percent (Table 2). These reductions are probably the result of decreasing acres of HEL and the application of effective conservation practices during the time period.

Regional Findings, Cultivated Cropland

NRI 1982 – 2003 data across the Hydrologic Basins of the U.S. (Figure 4) were used to evaluate regional trends on cultivated cropland. The reductions in erosion rate (tons per acre) and total tons of soil loss are summarized in Table 2 and Table 3, respectively, for all cropland, non-highly erodible cropland (NHEL), and highly erodible cropland (HEL). Table 4 indicates the percent reduction in cultivated cropland from 1982 to 2003. The conversion of cropland to other land uses has resulted in significant reductions in erosion on cultivated cropland; thus, it must be factored into the overall analysis of soil erosion status in the U.S.



USDA NRCS National Cartography & Geospatial Center, Fort Worth, Texas 2005.

Table 2–Erosion Rates (Tons/Acre) and Percent Changed from 1982 to 2003 on Cultivated Cropland

U.S. Hydrologic Basin	All Cultivated Cropland			Non-Highly Erodible			Highly Erodible		
	1982	2003	Rate change (pct)	1982	2003	Rate change (pct)	1982	2003	Rate change (pct)
Arkansas-White-Red	7.6	5.0	**34.6**	4.5	3.4	**25.2**	12.6	8.0	**36.4**
California / Great Basin	3.2	2.1	**36.4**	1.7	1.0	**41.9**	16.6	13.8	**17.1**
Great Lakes	4.1	3.1	**23.3**	3.4	2.6	**22.6**	10.9	8.9	**18.3**
Lower Colorado / Upper Colorado	9.3	11.5	**23.8**	5.1	3.4	**33.1**	11.4	14.6	**28.7**
Lower Mississippi	5.9	3.8	**36.7**	3.9	3.2	**19.4**	19.9	9.7	**51.5**
Missouri	8.7	5.6	**35.4**	5.1	3.5	**31.9**	14.5	9.7	**32.9**
New England/ Mid Atlantic	5.9	5.1	**13.1**	2.7	2.6	**4.8**	10.6	9.7	**8.3**
Ohio/Tennessee River	6.1	3.5	**42.4**	3.6	2.2	**38.9**	13.6	8.9	**34.7**
Pacific Northwest	9.2	7.8	**15.5**	5.6	5.1	**9.2**	14.9	12.1	**18.7**
Souris-Red-Rainy / Upper Mississippi	7.9	5.5	**31.4**	6.3	4.3	**30.9**	16.1	11.8	**26.7**
South Atlantic-Gulf	5.9	4.1	**29.5**	3.7	3.4	**9.3**	14.1	9.5	**32.7**
Texas-Gulf / Rio Grande	16.6	11.7	**29.4**	7.4	6.4	**12.8**	29.4	20.2	**31.3**
USA Average	**8.0**	**5.5**	**31.8**	**4.9**	**3.6**	**25.9**	**15.8**	**11.0**	**30.6**

Table 3–Soil Erosion (10^6 tons) and Percent Reduced from 1982 to 2003 on Cultivated Cropland

U.S. Hydrologic Basin	All Cultivated Cropland			Non-Highly Erodible			Highly Erodible		
	Tons (million)		Erosion reduced (pct)	Tons (million)		Erosion reduced (pct)	Tons (million)		Erosion reduced (pct)
	1982	2003		1982	2003		1982	2003	
Arkansas-White-Red	302.0	153.7	**49.1**	109.5	67.6	**38.2**	192.6	86.1	**55.3**
California / Great Basin	30.0	12.4	**58.7**	13.9	5.4	**61.5**	16.1	7.0	**56.3**
Great Lakes	74.6	46.6	**37.5**	55.4	35.4	**36.1**	19.2	11.2	**41.5**
Lower Colorado / Upper Colorado	17.8	13.8	**22.4**	3.2	1.1	**64.5**	14.6	12.7	**13.4**
Lower Mississippi	134.7	73.7	**45.3**	78.0	56.4	**27.6**	56.7	17.2	**69.6**
Missouri	825.6	469.8	**43.1**	300.3	191.7	**36.2**	525.3	278.0	**47.1**
New England/ Mid Atlantic	53.7	31.4	**41.6**	14.8	10.2	**30.8**	38.9	21.1	**45.7**
Ohio/Tennessee River	188.2	88.6	**52.9**	84.4	45.1	**46.6**	103.8	43.5	**58.1**
Pacific Northwest	143.8	92.9	**35.4**	52.9	37.0	**30.0**	90.9	55.9	**38.5**
Souris-Red-Rainy / Upper Mississippi	661.6	415.3	**37.2**	434.2	281.4	**35.2**	227.4	133.9	**41.1**
South Atlantic-Gulf	141.3	59.6	**57.8**	70.2	42.0	**40.2**	71.1	17.6	**75.2**
Texas-Gulf / Rio Grande	432.0	235.3	**45.5**	111.8	79.5	**28.9**	320.1	155.7	**51.4**
USA Average	**461.9**	**280.8**	**39.2**	**216.9**	**147.3**	**32.1**	**290.7**	**159.9**	**45.0**

Table 4–Percent reduction of total cultivated cropland acreage from 1982 to 2003.

U.S. Hydrologic Basin	ALL	NHEL	HEL
Arkansas-White-Red	22.1	17.4	29.7
California / Great Basin	35.0	33.6	47.3
Great Lakes	18.4	17.4	28.4
Lower Colorado / Upper Colorado	37.3	47.0	32.7
Lower Mississippi	13.6	10.3	37.3
Missouri	11.9	6.3	21.1
New England/ Mid Atlantic	32.8	27.3	40.8
Ohio/Tennessee River	18.4	12.6	35.8
Pacific Northwest	23.5	22.9	24.4
Souris-Red-Rainy / Upper Mississippi	8.5	6.3	19.7
South Atlantic-Gulf	40.2	34.0	63.2
Texas-Gulf / Rio Grande	22.9	18.5	29.1
USA Average	17.5	13.4	27.8

Regional trends from 1982 to 2003 on cultivated cropland, Tables 2, 3, and 4:

- *The greatest progress has occurred on HEL* (reduced rate 30.6 percent, reduced tons 45 percent) compared to NHEL (reduced rate 25.9 percent, reduced tons 32.1 percent).
- From the data provided to date, it is not possible to determine the acreage of cropland still eroding at unacceptable rates (i.e., >T). However, throughout all of the Basins, all highly erodible cultivated cropland continues to erode on average at rates that exceed the maximum allowable T = 5, which is commonly assigned to deep soils. *The 2003 erosion rates on HEL range from 8.0 to 20.2 tons/acre.* *This indicates that more progress is needed to accomplish the national objective of long term sustainability of our soil resource on highly erodible cultivated cropland*.
- The upper Colorado/Lower Colorado Basin appears to be an exception to the general rule of progress being made in the other Basins. In the highly erodible category, despite an acreage reduction (32.7 percent) and a reduction in tons of soil loss (13.4 percent), *the rate of soil erosion on a per acre basis has increased 28.7 percent more than the rate that was reported in 1982*. This suggests that applied conservation practices on cultivated highly erodible cropland in the Upper Colorado/Lower Colorado Basin have not been totally effective and are not keeping pace with soil erosion. There may have been a significant focus to retire HEL cropland to CRP while other conservation measures were not as readily adopted; hence the overall increase in erosion rate on a per acre basis.

Conclusion: Significant soil erosion reductions on Highly Erodible Land were made by the Conservation Compliance and Sod Buster provisions of the 1985 and 1990 Farm Bills. However, the Conservation Compliance and Sod Buster provisions did not require the producer to reduce soil losses to the level considered to be sustainable (i.e., ≤ T) on much of the land designated as Highly Erodible because minimum treatment levels, defined as "Alternative Conservation Systems" typically resulted in soil losses nearly double the sustainable rate. This is reflected in the 1997 NRI data (USDA, 2000), which shows that the Conservation Compliance efforts have not reduced soil loss to less than 5 tons per acre per year in any region of the country designated as highly erodible. *The 2001 NRI published data indicate that about 55 percent of all Highly Erodible Land (55.1 million of a total of 101.1 million acres) continues to erode in excess of "T"* (USDA, 2003).

Also, the Compliance provisions were mainly concerned with lands designated as HEL, while Non-Highly Erodible Lands with excessive erosion rates were not required to be treated. *The 2001 NRI data indicate that about 18 percent of all Non-Highly Erodible Land (48.7 million of a total of 268.6 million acres) continues to erode in excess of "T"* (USDA, 2003).

Farmers across the country have made great strides to improve the resource condition, but there is still more to do. While land conversion and land retirement have had significant impact on soil loss reduction, these activities along with initiatives on buffers and filters may have slowed progress in some regions on adoption of practices to reduce erosion on the working lands.

Science and Technology Status

The farming industry continues to explore innovative approaches to new technologies. With the advent of precision farming and variable rate technology, the producer has the ability at the sub-field scale to program a specific amount of fertilizer and seed that will assure adequate residues for erosion control.

Soil compaction reduces infiltration. Consequently, surface water runoff increases and hazard of soil erosion ensues. In essence, 80% of the compaction that will occur happens with the first pass. In order to control compaction, one must control traffic. This means using the same wheel tracks for most operations, for each crop every year. This improves infiltration greatly on the cropped areas and thereby would reduce erosion.

Mulch tillage systems (systems with tillage across the entire field) require auto-steer technology using guidance from a Global Positioning System (GPS) to locate traffic lanes year after year. Auto-steer technology keeps all field operations in the same traffic lanes. Some systems are even capable of 1-inch accuracy. This technology allows controlled traffic with standard agricultural equipment and full-width tillage. Automatic steering and controlled traffic reduce compaction beneath the row, thereby increasing infiltration and reducing the hazard of erosion and the need for subsoiling.

Completed:
NRCS and the ARS have jointly developed, and continue to improve-upon, erosion prediction models for conservation planning. With regard to water erosion, the Revised Universal Soil Loss Equation, version 2 model (RUSLE2) is used in about 90 percent of NRCS field offices. RUSLE2 is used to generate documented estimates required in USDA farm bill programs. RUSLE2 and the internally contained Soil Conditioning Index (SCI) and Soil Tillage Intensity Rating (STIR) are required for determining eligibility and payment category for the Conservation Security Program. Increasingly, the private sector is using RUSLE2 and its precursor, RUSLE1, on highly disturbed lands. Many federal, state and local regulations require RUSLE1 and RUSLE2 technology. RUSLE2 implementation policy is contained in National Instruction 300–RUSLE2, Subpart A, and National Bulletin 450-3-3, dated 4/7/02. New versions are certified and made available on about a six month interval. Beyond the standard mix of rain-fed row crops, small grains and forage crops, a variety of specialty cropping systems including fruit and nut crops, nursery and sod farming, vegetable crops and tropical crops are also available in RUSLE2. In addition, irrigation water additions are accounted. Outputs include soil loss, detachment, and sediment deposition by segment and at the end of the slope. Both flat and standing crop residue pools are racked daily and by operation as is live biomass and canopy cover, surface roughness and a number of other parameters important to the erosion assessment process.

The NRCS has expanded the databases for use in all states and areas. RUSLE2 databases are now quite extensive, including Soils, climate, operations, vegetation, and practices used in all states and areas. Over 21,000 locally adapted crop management and tillage system scenarios are available for use with the model. ARS expects to complete the User Guide and Science Document by the end of December, 2005. Anticipated publication of peer-reviewed papers on RUSLE1 and RUSLE2 are planned for 2006 and 2007, depending on the time it takes to complete the journal review process.

Resource Investment

Soil Management

Program	Financial Assistance Funding 2002-2005	Technical Assistance Funding 2002-2005	% of FA	% of TA
Conservation Technical Assistance (CTA)	$0	$856,800,000		79%
Environmental Quality Incentives Program (EQIP)	$462,473,163	$101,790,731	48%	9%
Ground & Surface Water Conservation (GSWC)	$12,257,274	$1,419,291	1%	0%
Conservation Innovation Grants (CIG)	$1,422,435	$7,046	0%	0%
Conservation Security Program (CSP)	$56,875,908	$8,531,387	6%	1%
Resource Conservation & Development_ (RC&D)	$0	$19,995,961		2%
Wildlife Habitat Incentives Program (WHIP)	$2,095,013	$421,327	0%	0%
Agricultural Management Assistance (AMA)	$5,485,505	$1,281,059	1%	0%
Grassland Reserve Program (GRP)	$93,175,490	$24,124,509	10%	2%
Farm and Ranch Lands Protection Program (FRPP)	$320,755,450	$9,514,229	34%	1%
Conservation Reserve Program (CRP)	FSA Provides FA	$53,248,123		5%
Watershed Protection and Flood Prevention Program (WP&FPP)	$2,332,400	$999,600	0%	0%
Total	$956,872,638	$1,078,133,263	100%	100%

The RC&D program provides benefits for a multiple number of resource issues. Dollar amounts given reflect a percentage of total program funding for RC&D for FY 2002-2004. This figure is pro-rated based on data analysis conducted for the national program evaluation conducted in FY2004 & FY 2005. Soil management is captured under the land conservation element in the RC&D statute.

References

Crosson, Pierre (1998). *The on-farm economic costs of soil erosion. In Methods for Assessment of Soil Degradation*, edited by R. Lal, W.H. Blum, C. Valentine, and B.A. Stewart. Boca Raton, FL: CRC Press, pp. 495-511

Norfleet, M. Lee (2005). "Is topsoil dirt cheap? Estimating the cost of erosion." *Draft* Agronomy Technical Note No. 18, USDA, NRCS.

U.S. Department of Agriculture (2000). *Summary Report: 1997 National Resources Inventory (revised December 2000)*, Natural Resources Conservation Service, Washington, DC, and Statistical Laboratory, Iowa State University, Ames, Iowa, 89 pages. http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/report.pdf (verified 12/1/2005).

U.S. Department of Agriculture (2003). *2001 annual NRI–soil erosion.* U.S. Department of Agriculture, Natural Resources Conservation Service, National Resources Inventory. http://www.nrcs.usda.gov/technical/land/nri01/erosion.pdf (verified 12/1/2005).

U.S.A.C.E. *Actual Dredging Cost Data for 1963-2003, Long-Term Continuing Cost Analysis Data, U.S. Army Corps of Engineers Dredging Program, Summary of Corps and Industry Activities*. http://www.iwr.usace.army.mil/ndc/dredge/ddhisbth.htm (verified 8/8/2005)

Wiebe, Keith (2003). Linking land quality, agricultural productivity, and food security. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 823.