# SOIL EROSION ON CROPLAND IN THE UNITED STATES: STATUS AND TRENDS FOR 1982-2003

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**Abstract:** Soil erosion is a natural process. However, accelerated erosion, often driven by anthropogenic activities, impacts agriculture, the infrastructure, and the environment. Cropland is particularly prone to erosion because many farming practices remove the protective vegetative cover. The National Resources Inventory (NRI) provides nationally consistent estimates of soil erosion resulting from water (sheet and rill) and wind processes on the Nation's cultivated cropland, non-cultivated cropland, and land enrolled in the Conservation Reserve Program (CRP). The NRI is a statistical survey designed to assess natural resource conditions and trends on non-Federal land in the United States. The NRI is conducted by the U.S. Department of Agriculture's Natural Resources Conservation Service in cooperation with Iowa State University's Center for Survey Statistics and Methodology. Data from the 2003 Annual NRI, the most up-to-date NRI information available, indicate that average soil erosion rates on all cropland and CRP land have decreased more than 38 percent since 1982. In 2003, the soil erosion rate was estimated at 4.5 tons per acre per year, compared to 7.3 tons per acre per year in 1982. Total soil erosion on all cropland and land in CRP declined since 1982 as well. Between 1982 and 2003, total soil erosion dropped from an estimate of over 3 billion tons per year to 1.7 billion tons. This is a decrease of 43 percent. Possible reasons for this decline include better management of the soil resource, prompted by land stewardship incentives and conservation compliance provisions in Federal farm legislation; increased use of conservation practices, such as conservation tillage; and an overall decline in cultivated cropland acres. A noteworthy trend indicated by the NRI data is a relative flattening of the decline in both soil erosion rates and total erosion since 1997. Although gains are still being made in reducing erosion, further reductions may require new approaches to addressing the soil erosion issue.

## INTRODUCTION

Soil erosion is a natural process that contributes to the formation of fertile soils (e.g., in river deltas) and provides nutrients to water bodies for nourishing aquatic ecosystems. Accelerated soil erosion is a significant threat to soil quality and impacts agriculture, infrastructure, and the environment. Accelerated erosion is often driven by anthropogenic activities, such as cultivation of crops, urban development, deforestation, mining, etc. Cropland is particularly susceptible to erosion because many farming practices remove the protective vegetative cover. The United States Department of Agriculture (USDA) has estimated soil erosion and has addressed erosion issues since the 1930's. This paper discusses the impact of soil erosion and presents USDA data on soil erosion on cropland in the United States from 1982 to 2003.

## THE SOIL EROSION PROCESS AND ITS IMPACT

Erosion is the breakdown, detachment, transport, and redistribution of soil particles by forces of water (rain, concentrated flow, streams, glaciers, etc.), wind, or gravity (Lal *et al*., 2004). As falling raindrops impact the soil surface, they detach individual soil particles. When the topmost layers of soil become saturated, a film of water accumulates on the surface. This film captures the soil particles dislodged by raindrops and detaches additional soil particles as it moves down slope. Called "sheet erosion", this process removes a thin, fairly uniform layer of soil over the entire land surface. However, this type of erosion also carries away a high proportion of the lighter organic particles that are critical to soil fertility and health. Where sheet flow has increased thickness, flow is concentrated in small channels called rills. "Rill erosion" can remove considerable amounts of soil, because water becomes increasingly erosive when confined to these channels (Clark *et al*., 1985). Erosion caused by gullies, which are deep, often permanent, scours, can be severe enough to cause terrain deformation (Lal *et al*., 2004).

Wind erosion is the process of soil detachment and transport by forces generated by the wind. Regions of low precipitation, high temperatures, and elevated wind velocity are most prone to wind erosion. The risks of wind erosion are exacerbated by increased fetch as wind blows across long, bare fields. Soils of single-grain or weak structure and coarse-grained, loamy texture are particularly prone to wind erosion (Lal *et al*., 2004).

Soil erosion can negatively impact not only agriculture but also infrastructure and the environment. Soil erosion control practices historically have focused on preventing damage to farmland productivity as well as preserving land values. Accelerated erosion results in declining agricultural (biomass) productivity as organic matter is removed and effective root depth is decreased. Erosion also contributes to soil degradation and concomitant imbalances in the root zone, susceptibility to pests, and release of greenhouse gases (Lal *et al*., 2004). However, off-site effects of soil erosion may far exceed those experienced in the farm fields. As the soil is eroded, sediment, nutrients, pesticides, pathogens (bacteria and viruses), salts, and other pollutants are carried into the Nation's waterways and ultimately into the water supply. Wind erosion may cause sediment and pesticides, either in aerosol form or attached to soil particles, to be entrained in the atmosphere and deposited over vast areas.

The influx of sediment caused by erosion clogs drainage and irrigation ditches and canals, and navigational channels; degrades wildlife habitat and fisheries; infills water reservoirs; elevates water treatment costs; increases the need for dredging; and may indirectly contribute to flooding (Ribaudo *et al*., 1999). Siltation is the second leading cause of water quality impairment in the Nation's rivers and streams and the third leading cause in lakes (U.S. Environmental Protection Agency, 2002). Ribaudo (1989) estimated that sediment damage from agricultural erosion ranged between $2 billion and $8 billion per year. A survey of selected sediment damages to harbors, irrigation and agricultural drainage ditches, floodplain croplands, and water treatment facilities estimated annual damages at nearly $8 billion per year (Bernard and Iivari, 2000). Additional sediment damages to reservoirs, non-agricultural drainage ditches, pumping equipment, flooded buildings, and wildlife is estimated to be in excess of $10 billion annually (Iivari, 1996). McConnell (2001) puts the economic cost of soil erosion in the U.S. at $44 billion per year. This includes sediment damages and property damages, as well as on-site loss of productivity, lost nutrients, crop damages, increased energy demands, and replacement of water lost by erosion. Other references on the costs of soil erosion and erosion-related losses have been compiled by Sundquist (2005).

Nutrients, such as fertilizers and animal waste, fuel increased algal growth, which causes clogged pipelines, fish kills, reduced recreational opportunities, degraded aquatic ecosystems, and threats to human health. U.S. Environmental Protection Agency (EPA) studies have found that nutrient pollution is the primary cause of degraded water quality in lakes and is a significant cause of impairment in rivers (U.S. Environmental Protection Agency, 2002). Pesticide residues in surface water systems may harm aquatic organisms, damage fisheries, and pose a risk to human health. Additional costs are incurred for treatment of public water supplies in order to bring pesticide levels within health standards. Pesticides are the second leading cause of water quality impairment in estuaries (U.S. Environmental Protection Agency, 2002).

Some reports have identified agriculture as a leading contributor of non-point source water pollution in the United States (Pimental *et al.*, 1976; U.S. Environmental Protection Agency, 2002). However, with the establishment of soil conservation districts, widespread adoption of conservation tillage practices, implementation of measures outlined in recent Federal farm legislation, and increased participation in specific conservation programs, such as the Conservation Reserve Program (CRP) and Environmental Quality Incentives Program (EQIP), the agricultural sector has made significant advances in reducing soil erosion.

## METHOD FOR ESTIMATING SOIL EROSION ON U.S. CROPLAND

Soil erosion rates and total erosion on cropland in the United States were estimated using data from the National Resources Inventory (NRI). The NRI is a statistical survey designed to assess natural resource conditions and trends on non-Federal land in the United States. This non-Federal land—including privately owned land, tribal and trust land, and land controlled by State and local governments—comprises approximately 78 percent of the Nation's total land area. The NRI is conducted by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) in cooperation with Iowa State University's Center for Survey Statistics and Methodology. The NRI covers all 50 States, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations (Goebel, 1998; U.S. Department of Agriculture, 2000).

Data from the NRI have been utilized for a variety of decision-making processes, scientific assessments, program evaluations, and other studies of soil and environmental issues. Examples of how data from the NRI have been applied include:

- Formulating agricultural and environmental legislation and policies to protect soil, water, and other related natural resources.
- Developing conservation programs and allocating USDA financial and technical assistance.
- Evaluating the effectiveness of existing policies, programs, and legislation that address or affect erosion, sediment, water quality, land-use, pollution prevention, and other related environmental issues.
- Identifying and/or targeting critical areas needing special emphasis, additional resources, or efforts to control erosion, protect water quality, or protect other related natural resources.
- Providing scientific data for land use planning.

- Supplying data for protecting soil quality or soil health in order to sustain long-term productivity and environmental protection.
- Aiding in estimating sediment yields and trends from landscapes and watersheds.
- Enhancing the public's understanding of natural resources and environmental issues.

During the period from 1977 to 1997, the NRI was conducted every 5 years. Data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes were collected at more than 800,000 randomly selected sample sites. Beginning in 2000, the NRI started a multi-year progression to an annual inventory. For the Annual NRI, data are gathered for a subset (approximately one-fourth) of the 800,000 sample sites that were established for previous NRI's. The data collection process for the Annual NRI is cumulative; that is, after several years of data collection, the reliability levels of the data will approximate those of the previous five-year cycle. For more information on the NRI, see the NRI Web site at www.nrcs.usda.gov/technical/NRI/.

The first release of Annual NRI data was from data collected during the 2001 NRI. Conclusions in this paper are based on data from the 2003 Annual NRI, the most up-to-date NRI information available. For national-level results, information is available for 1982, 1987, 1992, 1997, and 2003, so that trends and changes in land use and resource characteristics over a span of more than 20 years can be examined and analyzed. Soil erosion data from the 2003 Annual NRI presented in this paper are available only for the 48 conterminous States. Data derived from the NRI are estimates and not absolutes. This means that there is some amount of uncertainty in any result obtained using NRI information. Data in the tables in this paper are followed (in parentheses) by the estimated standard error for each value.

Present NRI data only describe the magnitudes of wind erosion and sheet and rill forms of water erosion. Gully, stream bank, mass wasting, channel scour, and other miscellaneous forms of water erosion or gravity-affected erosion are not included. However, data from some erosion studies (USDA, 1989; Bernard and Iivari, 2000) show that sheet and rill erosion on agricultural lands is the largest source of sediment contributed to small streams. Erosion from stream banks, gullies, road banks, construction sites, and other miscellaneous locations accounted for about 22 percent of total erosion on private lands (USDA, 1989). The NRI provides estimates of on-site erosion rates and does not estimate off-site sediment yield.

## SOIL EROSION DATA FROM THE NRI, 1982-2003

The NRI estimates soil erosion on cultivated cropland, non-cultivated cropland, and land enrolled in the Conservation Reserve Program. Cropland is a land cover/use category in the NRI that includes areas used for the production of adapted crops for harvest. The subcategories of cultivated and non-cultivated cropland are utilized in the NRI. Cultivated cropland comprises land in row crops or close-grown crops as well as other cultivated cropland, such as hayland or pastureland that is in a rotation with row or close-grown crops. Non-cultivated cropland includes permanent hayland and horticultural cropland. CRP land includes land under a CRP contract.

NRI data show that between 1982 and 2003, total cropland acres declined, primarily due to a decrease in acres of cultivated cropland (Table 1). Some of this decline may be attributed to enrollment of land in the Conservation Reserve Program, initiated in 1985. In the same time interval, acres of non-cultivated cropland have increased.

Table 1 Acreage of Cultivated Cropland, Non-cultivated Cropland, and CRP Land by Year (millions of acres)

| Year | Cultivated Cropland | Non-cultivated Cropland | All Cropland | CRP Land | Total—All Cropland and CRP |
|---|---|---|---|---|---|
| 1982 | 375.7 (1.1) | 44.1 (0.4) | 419.7 (1.1) | 0.0*(n/a) | 419.7 (1.1) |
| 1987 | 362.0 (1.1) | 43.6 (0.4) | 405.6 (1.2) | 13.8 (0.1) | 419.4 (1.2) |
| 1992 | 334.5 (1.1) | 46.9 (0.4) | 381.3 (1.0) | 34.0 (0.1) | 415.4 (1.0) |
| 1997 | 326.4 (1.1) | 50.0 (0.5) | 376.4 (1.0) | 32.7 (0.0) | 409.0 (1.0) |
| 2003 | 310.1 (1.2) | 57.8 (0.9) | 367.9 (1.2) | 31.4 (0.1) | 399.3 (1.2) |

*CRP established in 1985
Estimated standard errors are shown in parentheses.

Data from the 2003 Annual NRI indicate that average soil erosion rates on the total of all cropland and CRP have decreased significantly since 1982. In 2003, the soil erosion rate was estimated at 4.5 tons per acre per year, down from 7.3 tons per acre per year in 1982 (Table 2), a drop of more than 38 percent. In that same time interval, water erosion rates declined over 37 percent, from 4.0 to 2.5 tons/acre/year; corresponding wind erosion rates fell more than 39 percent.

Although not directly comparable to NRI data, estimates of historical erosion rates provide interesting and useful information on the magnitude of the soil erosion problem. Prior to 1930, it was common for soil in some areas to erode at rates in excess of 30 to 40 tons per acre per year (Trimble, 1974; Franzmeier, 1990; National Research Council, 1993; Trimble, 1999). The Dust Bowl catastrophe of the 1930's prompted farmers to implement conservation practices such as contouring and terracing. As a result, estimates of average erosion rates on U.S. cropland fell to under 15 tons per acre per year (Pimental, *et al.*, 1976). Trimble (1999) gathered 140 years' of information about sediment buildup and erosion around Coon Creek Basin in Wisconsin and concluded that, overall, erosion in the watershed has been declining steadily, down to six percent of what it was in the 1930's. Many other references with historical soil erosion information have been compiled by Sundquist (2005).

Between 1982 and 2003, total soil erosion on all cropland and CRP land in the United States decreased from over 3 billion tons per year to 1.7 billion tons (Table 3). This is a decrease of nearly 43 percent. There are several likely reasons for this decline. Land stewardship incentives and conservation compliance provisions of the 1985, 1990, 1996 and 2002 Farm Bills led to better management of the soil resource. The Conservation Reserve Program, established by the 1985 Farm Bill, provided a mechanism and incentive for setting aside up to 34 million acres of highly erodible cropland that are now planted to permanent grass and/or trees. Increased use of conservation practices, such as conservation tillage and other Best Management Practices, has had a significant impact on reducing soil erosion. The use of conservation tillage has increased from 1 percent of the planted land in 1963 to nearly 41 percent in 2004 (Uri, 1998; Conservation Technology Information Center, 2005). Finally, changes in land use, specifically, a decline in cultivated cropland acres, has affected national total erosion levels.

Table 2 Average Annual Rates of Soil Erosion on Cropland and Land in CRP, 1982-2003 (tons/acre/year)

| | 1982 | 1987 | 1992 | 1997 | 2003 |
|---|---|---|---|---|---|
| Cultivated Cropland | | | | | |
| Water Erosion | 4.4 (0.0) | 4.0 (0.0) | 3.4 (0.0) | 3.1 (0.0) | 3.0 (0.0) |
| Wind Erosion | 3.6 (0.1) | 3.5 (0.0) | 2.9 (0.0) | 2.5 (0.0) | 2.4 (0.0) |
| Total | 8.0 (0.1) | 7.5 (0.1) | 6.3 (0.0) | 5.6 (0.0) | 5.4 (0.0) |
| | | | | | |
| Non-cultivated Cropland | | | | | |
| Water Erosion | 0.6 (0.0) | 0.7 (0.0) | 0.6 (0.0) | 0.6 (0.0) | 0.6 (0.0) |
| Wind Erosion | 0.4 (0.1) | 0.4 (0.0) | 0.3 (0.0) | 0.2 (0.0) | 0.3 (0.0) |
| Total | 1.0 (0.1) | 1.1 (0.0) | 0.9 (0.0) | 0.8 (0.0) | 0.9 (0.0) |
| | | | | | |
| All Cropland | | | | | |
| Water Erosion | 4.0 (0.0) | 3.6 (0.0) | 3.1 (0.0) | 2.8 (0.0) | 2.6 (0.0) |
| Wind Erosion | 3.3 (0.0) | 3.2 (0.0) | 2.6 (0.0) | 2.2 (0.0) | 2.1 (0.0) |
| Total | 7.3 (0.1) | 6.8 (0.0) | 5.7 (0.0) | 5.0 (0.0) | 4.8 (0.0) |
| | | | | | |
| Land in CRP | | | | | |
| Water Erosion | --* (n/a) | 2.0 (0.1) | 0.6 (0.0) | 0.4 (0.0) | 0.4 (0.0) |
| Wind Erosion | --* (n/a) | 6.7 (0.6) | 0.6 (0.0) | 0.3 (0.1) | 0.5 (0.1) |
| Total | --* (n/a) | 8.7 (0.6) | 1.2 (0.1) | 0.7 (0.1) | 0.9 (0.1) |
| | | | | | |
| All Cropland and CRP | | | | | |
| Water Erosion | 4.0 (0.0) | 3.6 (0.0) | 2.9 (0.0) | 2.6 (0.0) | 2.5 (0.0) |
| Wind Erosion | 3.3 (0.0) | 3.3 (0.0) | 2.4 (0.0) | 2.1 (0.0) | 2.0 (0.0) |
| Total | 7.3 (0.1) | 6.9 (0.1) | 5.3 (0.0) | 4.7 (0.0) | 4.5 (0.0) |

*CRP established in 1985
Estimated standard errors are shown in parentheses.

The 2003 data show that the decline in total soil erosion has not been as dramatic since 1997, compared to the interval from 1982 to 1997. However, it is important to note that gains are still being made in this area. The significant reductions in soil loss that were made between 1982 and 1997 were not only sustained but slightly improved upon in the period between 1997 and 2003.

## CONCLUSIONS

Results from the 2003 Annual NRI show that both soil erosion rates and total erosion on all cropland and land in CRP declined considerably between 1982 and 2003. Possible reasons for this decline include increased use of conservation practices, such as conservation tillage and other Best Management Practices, participation in land stewardship incentive programs, and implementation of conservation compliance provisions outlined in Federal farm legislation. A noteworthy observation is that the decline in soil erosion rates and total erosion from 1997 to 2003 is not nearly as steep as for the interval from 1982 to 1997. The significant gains in soil erosion control that were made between 1982 and 1997 were sustained in the period between 1997 and 2003 and were improved upon slightly. As more data are accumulated with each successive year of the Annual NRI, soil erosion components and issues may be examined at finer levels of detail, such as on a regional basis, with greater degrees of reliability, and possibly with a deeper extent of resource information to attempt to explain the flattening in this trend. Further reductions in soil erosion may require new approaches to addressing the erosion issue.

Table 3 Total Annual Erosion on Cropland and Land in CRP, 1982-2003 (millions of tons)

| | 1982 | 1987 | 1992 | 1997 | 2003 |
|---|---|---|---|---|---|
| Cultivated Cropland | | | | | |
| Water Erosion | 1,637.8 (10.5) | 1,436.9 (9.2) | 1,139.8 (8.1) | 1,010.1 (6.3) | 935.5 (7.4) |
| Wind Erosion | 1,367.5 (19.7) | 1,275.0 (18.3) | 972.5 (16.9) | 828.1 (15.2) | 757.6 (13.3) |
| Total | 3,005.3 (21.4) | 2,712.0 (19.9) | 2,112.3 (17.2) | 1,838.2 (15.1) | 1,693.0 (15.2) |
| | | | | | |
| Non-cultivated Cropland | | | | | |
| Water Erosion | 28.0 (1.1) | 28.5 (1.2) | 26.2 (0.8) | 28.9 (0.7) | 34.8 (0.9) |
| Wind Erosion | 16.8 (2.8) | 17.8 (2.0) | 11.8 (1.3) | 9.3 (1.0) | 18.3 (1.6) |
| Total | 44.8 (3.1) | 46.4 (2.1) | 38.0 (1.5) | 38.2 (1.1) | 53.2 (2.0) |
| | | | | | |
| All Cropland | | | | | |
| Water Erosion | 1,665.8 (10.5) | 1,465.4 (9.4) | 1,166.0 (8.1) | 1,039.0 (6.2) | 970.3 (7.3) |
| Wind Erosion | 1,384.3 (20.1) | 1,292.9 (18.5) | 984.3 (17.0) | 837.5 (15.1) | 775.9 (13.1) |
| Total | 3,050.1 (21.8) | 2,758.3 (20.4) | 2,150.3 (17.5) | 1,876.4 (15.2) | 1,746.2 (14.9) |
| | | | | | |
| Land in CRP | | | | | |
| Water Erosion | --* (n/a) | 27.7 (1.2) | 19.4 (0.8) | 12.1 (0.4) | 11.4 (0.4) |
| Wind Erosion | --* (n/a) | 92.9 (7.8) | 20.1 (2.1) | 10.3 (1.8) | 14.2 (2.0) |
| Total | --* (n/a) | 120.6 (8.0) | 39.5 (2.4) | 22.4 (1.8) | 25.6 (2.0) |
| | | | | | |
| All Cropland and CRP | | | | | |
| Water Erosion | 1,665.8 (10.5) | 1,493.2 (9.6) | 1,185.4 (8.4) | 1,051.0 (6.3) | 981.7 (7.3) |
| Wind Erosion | 1,384.3 (20.1) | 1,385.8 (19.8) | 1,004.4 (17.1) | 847.7 (15.6) | 790.2 (13.0) |
| Total | 3,050.1 (21.8) | 2,879.0 (23.0) | 2,189.8 (17.5) | 1,898.7 (15.4) | 1,771.8 (14.9) |

*CRP established in 1985
Estimated standard errors are shown in parentheses.

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