IMPROVING WATER QUALITY BY SOIL CONSERVATION AND MANAGEMENT PRACTICES[1]

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ABSTRACT: Recent concern for the deterioration of the quality of water in our Nation's streams and lakes has created interest in assessing the contribution of sediment and chemicals by agriculture. Evaluation of practices that will reduce agriculture's contribution has intensified. Research on four agricultural watersheds in western Iowa, in the Iowa and Missouri deep loess hills, showed that man influences river water quality markedly by his soil conservation and management practices. Studies made on these watersheds near Treynor, Iowa, 1964 through 1971, showed that sediment yield from sheet erosion averaged 24 tons per acre per year on the contoured-corn watershed. It was less than 1 ton per acre per year from the terraced-corn watershed and the pastured-grass watershed. Gully erosion averaged 450 tons per year from the outlet channels of the two contoured-corn watersheds but was negligible on the others. Measurements of nitrogen and phosphorus losses from these watersheds, 1969 through 1971, showed that only low levels of these chemicals are present in solution; nitrogen adsorbed on sediment was generally low but varied with soil erosion losses. The research also showed that conservation practices of grass and terraces effectively reduced such losses of nitrogen and phosphorus to lower levels. Nitrogen and phosphorus entering streamflow were reduced even when nitrogen and phosphorus were applied at about 2½ times the normal application of 150 pounds of nitrogen and 35 pounds of phosphorus per acre.

Conflicting statements about the effects of sediment plus the interaction of sediment and various agricultural chemicals on the water quality of rivers and lakes have appeared in newspapers and other publications for a number of years. These statements have placed the agricultural industry on the defensive regarding possible pollution from agricultural sources. Agricultural scientists maintain that chemical fertilizers and other products are necessary to grow needed crops at a reasonable cost (Aldrich, 1972; Borlaug, 1972; Ennis, 1971; Viets, 1971). The question arises, "How far can we go to safeguard the environment without crippling agriculture?" Some information was available on sediment yields from agricultural watersheds, but limited data are available on the loss of chemicals from such watersheds.

For these and similarly compelling reasons, the Agricultural Research Service initiated a project in 1969 to study the movement of agricultural chemicals from four watersheds near Treynor, Iowa. An excellent base for such a study existed because records on crops, management, weather history, surface runoff, and soil loss were begun in 1964. Complete control of farming operations on these watersheds is maintained.

State and Federal agencies have conducted studies to determine sediment yields from agricultural areas, and this research has provided much information. A number of empirical equations (Musgrave, 1947; Wischmeier, 1965) have been developed to predict soil losses from agricultural lands. At Treynor, Iowa, erosion from continuous corn on the contour averaged 24 tons per acre per year (Spomer *et al.*, 1973). This much sediment in streams and lakes

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is a major source of pollution. In the same report covering 8 years of research, good conservation practices on the Treynor watersheds were shown to reduce annual sediment yield to less than 1 ton per acre.

There has often been more speculation than fact on the contribution of agricultural chemicals to watercourses and lakes. This has led to some rather serious charges regarding agriculture's share in the deterioration of the environment. Two nutrients receiving major interest are nitrogen (N) and phosphorus (P); both are necessary to produce high crop yields.

Losses of N from agricultural and forested areas have been reported by several researchers (Bormann *et al.*, 1968; Jaworski and Hetling, 1970; Massey *et al.*, 1953). The loss of N varied from less than 1 pound per acre to 3.0 pounds per acre per year for forested areas (Cooper, 1969; Frink, 1967) to a high of 12.9 pounds per acre yearly from corn plots (Timmons *et al.*, 1968). Researchers report P losses of 0 to 14.3 pounds per acre per year in surface water in Illinois (Engelbrecht and Morgan, 1961), and Scarseth and Chandler (1938) reported that plots in Alabama receiving 307 pounds P per acre over a 26-year period lost 60 percent of the added P by soil erosion. Research in Georgia shows P losses of 0.03 to 0.04 pound per acre per year (Thomas *et al.*, 1968) and in Wisconsin 0.64 pound per acre (Massey, *et al.*, 1953). Most of these and other data are from small plots, and few data are available from field-size agricultural areas.

Research Watersheds. The four research watersheds used in this study are near Treynor, Iowa, and are within and typically represent the deep loess soils of the Missouri Valley in western Iowa and northwestern Missouri. This area is characterized by a deep loess cap over glacial till. Soil types on these watersheds are typic hapludolls, typic haplorthents, and cumulic hapludolls. All of these soils are fine, silty, mixed mesics and have moderate to moderately rapid permeability. Depth of the loess cap ranges from 80 feet on the ridges to 15 feet in the valleys. Most main and upland valleys have moderately to deeply incised channels. Each watershed is entirely tillable, but erosion is serious if conservation practices are not used.

Watershed size, land use, conservation practices, and fertilizer applications are shown in Table 1. Two watersheds were farmed on approximate contours, which is typical of farming practices in the area. A third watershed was 90 percent terraced, and all three watersheds have been continuously corn cropped since 1964. The fourth watershed was in bromegrass and pastured, with good management to prevent overgrazing.

These research watersheds were instrumented in 1964 to collect hydrologic and erosion data. Research objectives were to study gully erosion and the causes for gully development and to determine the effects of level terraces and other conservation and management practices on sheet-rill and gully erosion. Some results of this research are summarized in Table 2 for the years 1964 through 1971 (Spomer *et al.*, 1971, 1973).

A study to determine agriculture's contribution of N and P to the quality of water in streams was initiated in 1969. Conservation and land use practices were

Table 1. Watershed size, land use, conservation practice (1964-1971), and annual fertilizer application rates for 1969-1971.

Watershed No.	Size	Land Use	Conservation Practice	Fertilizer N	Fertilizer P
	acres			pounds/acre	
1	75	Corn	Contour	400	87*
2	83	Corn	Contour	150	35
3	107	Brome Grass	Rotation Grazing	150	35
4	150	Corn	Terraced	400	87

*Phosphorus was applied at the rate of 35 pounds per acre on all watersheds in 1971.

continued with fertilizer applied as shown in Table 1. N and P were applied at about 2½ times a normal application rate on watersheds 1 and 4 to measure the effect of differences between normal and excessive fertilization.

Hydrology and Erosion. Annual values and 8-year averages for precipitation, water yield, and components of surface runoff and base flow are given in Table 2. The table shows that annual rainfall for 1964 through 1971 was above average except for 1966. The long-term average annual rainfall of 28.45 inches is based on the 100-year record at Omaha, Nebraska, 15 miles from the research watersheds. The average precipitation for the 8-year study was 32.09 inches, or 3.64 inches more than the long-term average.

Land use and conservation treatment differences on these comparable watersheds significantly affected total water yield (surface runoff and base flow) passing the gaging site (usually expressed as inches of water depth over the contributing watershed area). The effect of crops, management, and conservation practices on water yield is more clearly shown in Figure 1. The average annual water yield from contoured-corn watersheds 1 and 2 and level-terraced corn watershed 4 was nearly equal (Fig. 1.). Surface runoff accounted for 65 percent of the water yield on contoured-corn watersheds 1 and 2 but only 10 percent of the total water yield from level-terraced corn watershed 4. Figure 1 also shows that total water yield from pastured-grass watershed 3 was two-thirds of that from contoured-corn watersheds 1 and 2, and surface runoff was one-third of the total water yield on watershed 3. Both level terraces and grass reduced surface runoff to levels that eliminated most of the erosion potential of the runoff water. The 8-year averages in Table 2 show that surface runoff from the level-terraced and grass watersheds was one-seventh and one-third, respectively, of that from the contoured-corn watersheds.

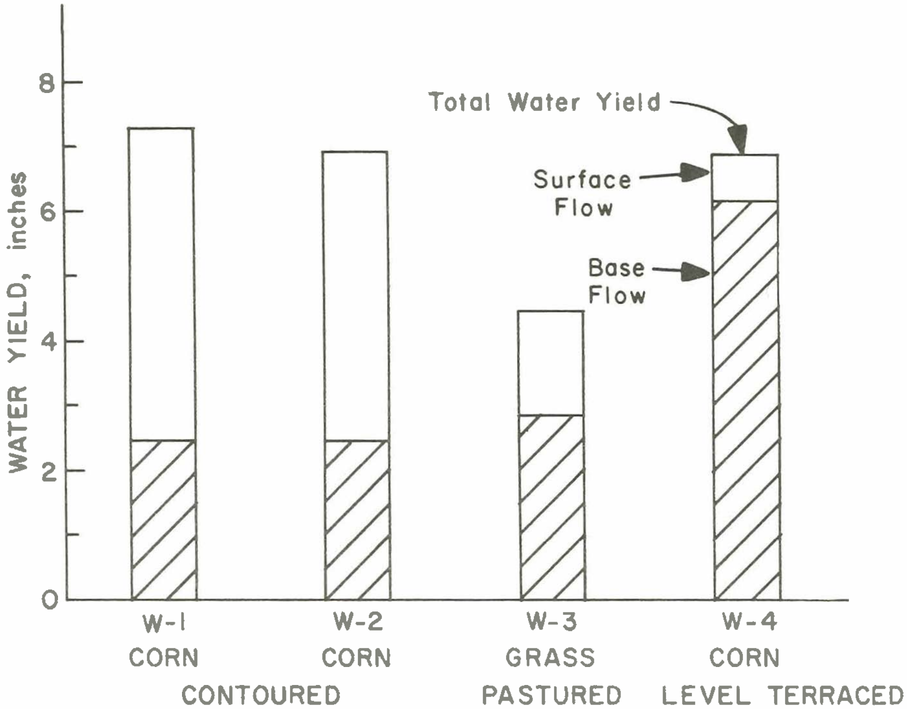

Figure 1. Land use and conservation treatment effects on the average annual water yield of the Treynor, Iowa watersheds, 1964-1971.

A prime factor in erosion is the peak runoff rate and, on the level-terraced and grass watersheds, all runoff peaks were 0.50 inch per hour or less, except for the storm of June 20, 1967, that produced a peak runoff of 2.01 inches per hour on the grass watershed. This can be compared with many peak runoff values that exceeded 1 inch per hour on the contoured watersheds with peak runoff values in 1967 of 5.87 and 4.87 inches per hour, respectively, on watersheds 1 and 2 (Spomer *et al.*, 1971, 1973).

During a 30-day storm period in May and June of 1967, precipitation of 18 to 22 inches was measured on the research watersheds. The probability of rainfall of this magnitude exceeds a 100-year frequency based on the 100-year record of the U.S. Weather Bureau at Omaha, Nebraska (Hershfield, 1961).

Surface runoff for this 1967 storm period was 11 inches, 10 inches, 2 inches, and less than 1 inch, respectively, for contoured-corn watersheds 1 and 2, grassed watershed 3, and level-terraced watershed 4. Runoff frequently exceeded 50 percent of the rainfall during this 30-day storm period on the contoured-corn watersheds. Runoff on grassed and level-terraced watersheds was less than 17 percent of the rainfall except for the June 20 storm when runoff from the grassed watershed was 34 percent of the rainfall.

Table 2. Precipitation, runoff, and sediment yield according to erosion source from Treynor, Iowa watersheds, 1964-1971.

Year	Watershed No.	Annual Precip. Inches	Runoff: Base	Runoff: Surface	Runoff: Total	Sediment Yield: Sheet-rill Tons/Acre	Sediment Yield: Gully Tons	Sediment Yield: Total Tons/Acre
			-------Inches--------					
1964	1	35.61	1.92	4.56	6.48	1/ 25.0	1/ 670	34.0
	2	35.16	2.15	4.02	6.17	1/ 25.0	1/ 331	29.0
	3	33.49	2.36	.42	2.78	.3	64	2/ .9
	4	34.80	5.66	.80	6.45	.7	10	2/ .8
1965	1	45.35	3.56	10.62	14.18	44.0	1,162	59.6
	2	44.34	2.97	10.68	13.65	36.4	660	44.4
	3	44.28	4.62	4.60	9.22	1/ .4	1/ 86	1.2
	4	44.87	10.56	2.51	13.07	1/ .9	1/ 16	1.0
1966	1	20.32	2.54	.65	3.19	6.7	93	7.9
	2	20.53	2.40	.88	3.28	8.6	177	10.7
	3	22.01	2.54	.38	2.92	1/ .1	1/ 10	.2
	4	21.88	5.91	.19	6.10	.6	14	.7
1967	1	38.25	2.27	11.57	13.84	99.1	1,455	118.5
	2	37.61	2.50	10.45	12.95	75.2	1,374	91.6
	3	34.23	3.30	2.65	5.95	.6	120	1.7
	4	34.55	7.28	.73	8.01	2.9	3/ -23	2.7
1968	1	32.30	1.67	1.15	2.82	3.7	102	5.1
	2	32.50	1.82	1.13	2.95	4.1	44	4.6
	3	31.10	1.59	1.02	2.61	.2	13	.3
	4	32.18	4.23	.12	4.35	.3	2	.3
1969	1	31.42	3.18	2.53	5.71	1.8	118	3.4
	2	31.54	2.97	2.35	5.32	1.0	55	1.7
	3	30.64	3.29	1.73	5.02	.1	19	.3
	4	30.70	6.11	.27	6.38	.1	-5	.1
1970	1	31.51	2.21	2.14	4.35	11.8	177	14.0
	2	30.82	2.35	1.79	4.14	7.4	171	9.5
	3	28.86	2.19	.37	2.56	< .1	5	.1
	4	28.79	3.99	.13	4.12	.1	< 1	.1
1971	1	28.93	2.06	4.94	7.00	20.0	399	25.4
	2	29.02	2.62	3.84	6.46	13.3	241	16.2
	3	29.70	2.84	1.52	4.36	1/ .4	1/ 30	.6
	4	29.96	5.49	.71	6.20	1/ 1.5	1/ 6	1.6
Averages (1964-1971)	1	32.96	2.43	4.77	7.20	26.5	522	33.5
	2	32.69	2.47	4.39	6.86	21.4	382	26.0
	3	31.79	2.84	1.59	4.43	.3	43	.7
	4	32.22	6.15	.68	6.84	.9	3	.9
Averages (1969-1971)	1	30.62	2.48	3.20	5.69	11.2	231	14.3
	2	30.46	2.65	2.66	5.31	7.2	156	9.1
	3	29.73	2.77	1.23	3.98	.2	18	.3
	4	29.82	4.86	.36	5.57	.6	< 1	.6

1/ Division between sheet-rill and gully erosion estimated.
2/ Total and component erosion values estimated.
3/ Negative value indicates channel fill.

Sheet erosion losses for this storm period were 99 and 75 tons per acre from contoured-corn watersheds 1 and 2, respectively. Sediment yields were 0.6 ton per acre from grassed watershed 3 and 2.6 tons per acre from level-terraced watershed 4. These data dramatize the effectiveness of conservation treatments to reduce sediment yield from sheet erosion. Furthermore, reduced erosion and sediment yields greatly improve the water quality downstream.

The average annual gully erosion on watersheds 1 and 2 was 522 and 382 tons per year, respectively. This compares with 43 and 3 tons per year, respectively, for the grassed and level-terraced watersheds. The effect of conservation practices on reducing erosion and pollution is again demonstrated. During 1967, more than 1,000 tons was eroded from each of the contoured watersheds, 1 and 2, as shown in table 2. Large volumes of materials were transported from the gullies during years with large surface runoff.

Nitrogen and Phosphorus Movement. A summary of 3 years of data on the movement of nitrogen in surface runoff from the four Treynor watersheds is shown in Table 3 (Schuman *et al.*, 1973a). The data show that annual losses of nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) in surface runoff have been small. The 3-year averages show that 0.16 to 1.51 pounds of NO_3-N per acre per year has been transported in the surface runoff water from the four watersheds. The 3-year averages of NH_4-N in the surface runoff varied from 0.22 to 1.21 pounds per acre per year. The largest amounts of NO_3-N and NH_4-N losses occurred on watershed 1 where N was applied at the rate of 400 pounds per acre per year. Watershed 4, however, also received N at 400 pounds per acre per year (Table 1), but the average annual loss of soluble N in surface runoff from this watershed was 0.16 pound per acre which is very low. The big difference in soluble N lost between these two watersheds can be attributed to the differences in surface runoff (Table 2). During 1969-1971, the average annual surface runoff from watershed 1 was about nine times the surface runoff from watershed 4. The 3-year averages (Table 3) show that the conservation watersheds (3 and 4) reduced the losses of NO_3-N and NH_4-N to one-third of those measured from the contoured-corn watersheds (1 and 2).

Nitrogen associated with the sediment transported out of the watersheds (Table 3) varied from 1.08 to 32.6 pounds per acre per year based on 3-year averages for the watersheds. Once again, the largest amount of N lost was measured on watershed 1 where sediment losses (Table 2) were greater. Fertility treatment effect was not evident for weighted per unit sediment N losses (pounds N per ton of sediment) when these losses were compared for watersheds 1 and 2 (Table 4).

Comparison of N losses from contoured-corn watersheds 1 and 2 with pastured-grass watershed 3 and level-terraced corn watershed 4 shows that good conservation practices reduce N losses. Average annual N losses with sediment shown in Table 3 are 1 and 2 pounds per acre, respectively, for conservation watersheds in grass and level-terraced corn. Sediment N losses from the contoured-corn watersheds are 10 to 30 times these values. This demonstrates the effectiveness of grass and terraces in reducing the movement of nutrients into streams and lakes by retaining the soil on the land.

The loss of P from the watersheds was quite small as shown in Table 3 (Schuman *et al.*, 1973b). Three-year averages for the watersheds show that inorganic P in runoff water varied from 0.04 to 0.19 pound per acre per year. Because P is readily adsorbed on soil particles, the highest P loss would be

Table 3. Annual losses of nitrogen and phosphorus in surface runoff -- Treynor, Iowa (1969-1971) (Schuman et al., 1973a, and Schuman et al., 1973b)

Watershed No.	Year	Solution Nutrients in Surface Runoff			Sediment Nutrients 1/	
		NO_3-N	NH_4-N	Inorganic P	TKN2/	Bicarb P3/
		pounds/acre				
1	1969	2.05	1.38	0.17	5.22	0.27
	1970	1.30	.37	.08	30.99	.85
	1971	1.17	1.88	.21	61.59	1.69
	1969	1.29	.85	.08	2.64	.15
	1970	.47	.31	.04	22.44	.42
	1971	.84	1.39	.17	36.84	.98
	1969	1.02	.59	.17	.46	.05
	1970	.15	.08	.06	.19	.02
	1971	.86	.38	.34	2.58	.11
	1969	.21	.11	.07	.28	.08
	1970	.13	.03	.01	.46	.01
	1971	.14	.52	.05	6.27	.20
		Three-Year Averages, 1969-1971				
1		1.51	1.21	0.15	32.60	0.92
2		.87	.82	.10	20.64	.52
3		.68	.35	.19	1.08	.06
4		.16	.22	.04	2.34	.10

1/ For chemical analyses, see references by Schuman et al., 1973a and 1973b.
2/ Total Kjeldahl nitrogen.
3/ Sodium bicarbonate extractable P.

Table 4. 1969-1971 average loss of nitrogen per unit of sediment yeild.

Watershed No.	Sediment Nitrogen lb/ton
1	2.90
2	2.78

expected to be associated with the sediment, and this was the case. These losses, however, were small. Data in Table 3 show that the average annual loss of sediment P has been 0.06 to 0.92 pounds per acre.

The application rate of P at 87 pounds per acre on contoured-corn watershed 1 and level-terraced corn watershed 4 was followed for 2 years—1969 and 1970. In 1971, P was applied at the rate of 35 pounds per acre on all watersheds. The data show that P in runoff and with the sediment was higher on contoured-corn watershed 1 than on the other two corn watersheds. Runoff and sheet-rill erosion were also greater. It is significant that the most inorganic P lost in runoff was from the pastured-grass watershed. This can be attributed to the leaching of P from the grass residue, fertilizer added to the soil surface without incorporation, and animal droppings. The highest P concentrations occurred during snowmelt on the grass watershed. This agrees with findings in Minnesota by Timmons *et al.* (1970) that showed that leaching of residues of forage crops resulted in considerable P loss with more than 70 percent in the form of inorganic P.

Average annual losses of inorganic P and sediment P from level-terraced watershed 4 were 0.04 and 0.10 pound per acre, respectively. This was one-fourth and one-ninth of the P in these forms transported from watershed 1. Terraced watershed 4 and watershed 1 received the same high fertility treatment of 87 pounds per acre of P for the years 1969 and 1970. Although the losses were small, once again the effect of conservation practices is pronounced. It is also noteworthy that P losses with sediment from pastured-grass watershed 3 were the smallest of any of the watersheds because sediment losses were low. The conclusion, then, is that conservation practices that reduce runoff and erosion also effectively reduce nutrient movement from agricultural lands.

Summary and Conclusions. Conservation and management practices dramatically reduce surface runoff and sediment yield from agricultural lands. The lower volume of runoff will reduce downstream peak flood stages and the associated damages. Furthermore, the corresponding reduction of soil erosion by about 24 tons per acre on the average is significant in improving the water quality of streams and lakes because sediment in itself is considered a major pollutant.

In addition, grass and terraced watersheds were effective in reducing the movement of N and P downstream. These conservation practices drastically reduced the amount of NO_3-N, NH_4-N, and sediment-associated N. Total N that moved with sediment from the conservation watersheds was one-tenth to one-twentieth of the N measured in the sediment from the contour-farmed watersheds. Similar relationships were shown for P movement in surface runoff.

It can be concluded that soil conservation and management practices that reduce runoff and soil erosion also are effective in reducing the movement of N and P from agricultural lands. This combined benefit of conservation is of great importance to society as a means to improve the environment while still permitting agriculture to maximize crop yields to meet the ever-increasing demand for food.

A complete terrace system which provides the conservation treatment described in this paper and improves surface runoff water quality is costly and reduces farmability of the land. Grass management was shown to be effective in improving surface runoff water quality, but the cash returns from grass are low. This land, however, has the potential for producing valuable cash row crops. The need therefore exists to combine some form of mulch tillage or no-tillage with a minimum of terraces to achieve an acceptable water quality in surface runoff from these agricultural lands. The search for new and acceptable methods to achieve both runoff and erosion control, as well as reduction of nutrient discharge, continues.

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