United States
Environmental Protection
Agency

Environmental Research
Laboratory
Athens GA 30613

Research and Development

EPA-600/S3-82-032 Sept. 1982

EPA

Project Summary

Field-to-Stream Transport of Agricultural Chemicals and Sediment in an Iowa Watershed: Part I. Data Base for Model Testing (1976-1978)

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Data on the field-to-stream transport of sediment and chemicals from an agricultural watershed were collected in a three-year study to provide information for testing and evaluating mathematical models under development for predicting agricultural nonpoint source pollution. These models are prepared as tools to evaluate the effectiveness of different farm management practices in controlling losses of nutrients, pesticides, and sediment in field drainage to receiving waters. In the study, data were collected for small corn, soybean, and pasture fields; for two larger mixed-cover watersheds; and at three drainage-stream sites.

During the study (1976-1978), annual rainfall (753 mm) and streamflow (124 mm) averaged a little below normal. Sediment losses were also low because of a lack of intense rains, averaging 2.6 t/ha from row-crops and 0.9 t/ha from the watershed as a whole. Soluble chemical losses (NH_4-N, NO_3-N, PO_4-P, Cl and TDS) in surface runoff were less than that deposited with rainfall. Because NO_3-N, Cl and TDS were concentrated in subsurface drainage, losses from the watershed as a whole due to streamflow (surface plus subsurface drainage) were significantly larger than losses from surface runoff alone.

Average annual pesticide losses from the field were least for the shortest-lived herbicide (0.2% of that applied) and greatest for the most persistent (1.6%). No runoff event occurred within a week of application. On the basis of percentage applied, losses or export from the watershed as a whole were about 25% of the losses from the two individual fields studied. With the exception of the strongly adsorbed paraquat, at least 80% of the losses occurred in the water phase as opposed to that adsorbed on sediment.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Concern about potential pollution from agricultural land drainage and associated land erosion has increased due to some recent trends in agriculture. Increases in intensive row-crop farming, higher fertilizer application rates, and larger areas treated with pesticides tend to increase the nonpoint source pollution potential. Other trends, however, such as increasing use of conservation tillage and less persistent pesticides, should reduce the pollution potential from agricultural lands.

During the past decade, environmental scientists and engineers have accepted simulation modeling as a technique for predicting effects of weather and management changes on the quality of agricultural drainage water. Using relatively limited site-specific information, simulation models can provide required water quality management information, for the control of nonpoint pollution in a specific watershed. These models, however, must be calibrated and verified using data from carefully monitored watersheds. Although some water flow and quality data are often available from either small areas, e.g., plots, or large river systems, comprehensive data sets that define areal and temporal changes from the field to the stream are rare.

The primary objective of the study summarized here was to collect data on stream hydrology and on sediment, nutrient, and pesticide transport from field to stream for intensively cropped agricultural watersheds, ranging in size from a few hectares to about 50 km^2, and at the same time provide additional understanding of the physical and chemical processes occurring that influence chemical losses.

The study area was located in the upper portion of the Four Mile Creek watershed in northwest Tama County, Iowa (Figure 1). Data were collected for the crop years 1976 to 1978, for small (5 to 6 ha) pasture, corn and soybean fields, for two larger mixed-cover watersheds, and at three stream stations. Soil profile sampling on the three fields was performed to determine the amounts (concentrations) and location (depth of migration) of nutrients and pesticides as a function of time.

Results

Table 1 presents a summary of inventory data for the Four Mile Creek watershed for the three years of the study and includes data from a previous study (1970) for comparison. It is obvious that the watershed was being more intensively farmed during this later study, with 55% of the area in corn and 22% in soybeans, with nearly all the row-crops receiving herbicides. In addition, 73% and 97% of the corn was

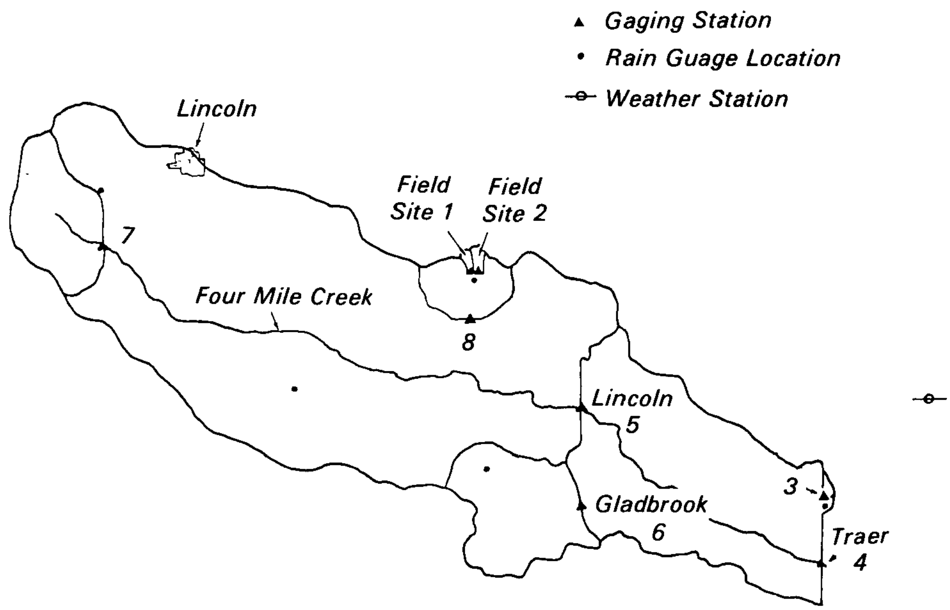

Figure 1. Four Mile Creek watershed instrumentation.

Table 1. Four Mile Creek Watershed Inventory

	1970	1976	1977	1978
Corn (% area)	40	55	54	55
fertilized (%)	87	98	97	97
N (kg/ha)	115	159	166	174
P_2O_5 (kg/ha)	59	55	62	57
herbicide (%)	71	99	98	98
insecticide (%)	54	58	80	80
Soybeans (% area)	17	20	24	22
fertilized (%)	10	12	24	14
P_2O_5 (kg/ha)	69	49	58	55.
herbicide (%)	75	94	95	97

the pasture, which averaged 9 mm/yr of treated with insecticides and fertilizer, respectively. Nine herbicides accounted for over 95% (by mass) of the herbicide used; five insecticides accounted for over 98% of the insecticides. About 1% of the watershed was terraced; a few farmers used conservation tillage, contouring and strip-cropping. Table 2 presents a summary of precipitation, flow, sediment and soluble chemical data. Precipitation during the study averaged 92% of normal; in one 12-month period, the study area received only 56% of the average annual precipitation. Average annual stream-flow from the whole watershed was 124 mm, 26 mm below the long term average of about 150 mm. Surface runoff from the two, small, row-cropped fields averaged 36 mm, of which over 50 was snowmelt The same was found for surface runoff. Annual sediment yield from the pasture, soybean and corn fields averaged 0.03, 1.3 and 4.5 t/ha, respectively. Sediment loss or export from the whole watershed of 50 km^2, averaged 0.9 t/ha. No really severe storms occurred during the study period.

In general, concentrations of NH_4-N and PO_4-P were higher in surface runoff water than in subsurface drainage; the reverse was found for NO_3-N, Cl and TDS. Average surface runoff losses from pasture, corn, and soybean fields of all dissolved chemicals were less than the amounts deposited by precipitation. The amounts of NO_3-N, Cl, and TDS lost annually with the streamflow which included shallow subsurface drainage and base flow as well as surface runoff, were equal to or greater than the amounts deposited in precipitation

Table 2. *Nutrients and Sediment in Precipitation, Surface Runoff, Tile, and Creek Flow*

	Year	Amount mm	NH_4-N ppm	NH_4-N kg/ha	NO_3-N ppm	NO_3-N kg/ha	PO_4-P ppm	PO_4-P kg/ha	Cl ppm	Cl kg/ha	TDS ppm	TDS kg/ha	Sediment ppm	Sediment kg/ha
Precip.	1976	554	.78	4.20	0.8	4.1	.054	.290	1.5	8.2	33	179	—	—
	1977	828	.87	7.20	1.0	8.3	.028	.230	1.5	12.5	51	420	—	—
	1978	878	.78	6.85	0.8	6.8	.063	550	2.0	17.6	50	439	—	—
Runoff														
Corn:														
Site 2	1976	51.3	.42	.22	5.3	2.7	.047	024	2.1	1.1	165	85	10210	5387
Site 1	1977	11.9*	2.66	.32	0.7	0 1	.819	097	7.6	0.9	134	16	43373	5558
Site 2	1978	47.3	.43	.20	3.0	1 4	.112	.053	1 7	0.8	58	27	5173	2488
Soybeans:														
Site 1	1976	58.6	.09	.05	3.5	2.1	.029	.017	7.3	4 3	134	78	4739	2779
Site 2	1977	0.9	.06	<.01	0.2	<0.1	046	<.001	0.9	<0 1	83	1	20457	180
Site 1	1978	46.4	.24	.11	1.7	0.8	.349	.162	8.0	3 7	80	37	1869	867
Pasture:														
Site 3	1976	13.1	.20	.03	0.8	0.1	1 154	.151	4.0	0.5	133	17	305	40
	1977	8.7†	.62	.05	0 4	<0.1	898	.078	1.7	0.1	56	5	312	27
	1978	6.1	.54	.03	0 5	<0.1	1.051	.064	3.2	0 2	89	5	79	5
Tile drainage	1976	—	.11	—	10.2	—	.069	—	14 4	—	330	—	—	—
	1977	—	.13	—	14.0	—	.116	—	20.2	—	352	—	—	—
	1978	—	.10	—	13.4	—	.102	—	17.9	—	312	—	—	—
Intra basin														
Site 7§	1976	6.7	—	—	—	—	—	—	—	—	—	—	—	—
284 ha	1977	2.6	.02	<.01	0.5	<0.1	.173	.004	3.6	0.1	108	3	992	26
	1978	32.1	1 00	.32	3.0	1.0	1.361	.437	9 0	2.9	148	47	585	188
Site 8§	1976	8 9	—	—	—	—	—	—	—	—	—	—	—	—
149 ha	1977	9.2	.22	.02	0.9	<0.1	.174	.016	2.3	0.2	68	6	7966	736
	1978	42.0	.71	.30	3.7	1.5	.570	.240	10.0	4.2	115	48	2029	852
Creek														
Site 6§	1976	13.1	.02	<.01	5.8	0.8	.029	.004	11.0	1.4	317	42	59	8
345 ha	1977	69.9	.14	.10	11.2	7.8	.201	.141	12.0	8 4	306	214	602	421
	1978	250.5	.15	.38	11.3	28.3	149	.374	13.2	33.0	280	703	793	1988
Site 5§	1976	13.5	.02	<.01	5.8	0.8	.027	004	17 9	2.4	349	47	52	7
3575 ha	1977	52.1	.40	.21	11.6	6.1	.299	.156	23.1	12.1	434	226	182	95
	1978	203.5	.38	.77	12.5	25 5	.161	.328	17.1	34.7	308	627	793	1614
Site 4	1976	122.7	24	.29	7.9	9.7	066	.081	12.1	14 8	271	333	1274	1564
5055 ha	1977	43.6	.23	.10	10.0	4.4	.114	050	17.3	7.6	330	144	171	74
	1978	197.4	.37	.74	11.0	21.6	.107	.212	15.3	30.1	278	549	509	1004

**40% of this runoff occurred within 24 h of fertilizer application and incorporation.*
†A very localized rain caused 98% of this runoff.
§Only one sample taken on sites 7 and 8; limited number on sites 5 and 6 since flow monitoring began 5/29/76 for these sites.

(particularly greater for NO_3-N). The amounts of NH_4-N and PO_4-P lost with the annual stream flow were still less than the amounts deposited with precipitation. Concentrations of N and P associated with sediment were somewhat dependent on the concentrations of sediment in runoff; the higher the sediment concentration, the lower the nutrient concentration in the sediment. On average, about 2 kg of N and 1 kg of P were lost per tonne of sediment

The herbicides alachlor, metribuzin, and paraquat were soil applied without incorporation at planting to the soybean field. Similarly, propachlor, cyanazine and paraquat were applied to the corn field. Spray, filter paper, and soil tests were run to determine the amounts actually applied. At no time during the three-year study did a runoff event occur within one week of application, and therefore, runoff losses were low As shown in Table 3, losses ranged from 0% to 3.2% of the herbicide applied The least losses occurred with the shortest-lived herbicide, propachlor; the greatest losses occurred with the longest-lived herbicide, paraquat Soil core samples taken during the growing season, in addition to providing information on persistence, showed that the pesticides essentially remained in the top 7.5 cm of the soil With the exception of the strongly adsorbed herbicide, paraquat, over 80% of the herbicide runoff losses

Table 3. *Percentage of Applied Herbicides Lost*

Year	Site	Alachlor	Metribuzin	Propachlor	Cyanazine	Atrazine	Paraquat
1976	field	0.5	0.7	0.2	1.0	-	3.2
	4 mi watershed	0.1	0.1	0 1	0.1	0.2	1.0
1977	field	0.0	0.0	0.0	0.005	0.0	0 2
	4 mi watershed	0.0	0.0	0.0	0.0	0.0	0 0
1978	field	0.3	0 4	0.3	0.8	-	1.4
	4 mi watershed	0.1	0.1	0.1	0 1	0.3	0.1

occurred in the solution phase. Losses of the herbicides with streamflow from the whole watershed, on a percentage of applied basis, were about 25% of the edge-of-field losses.

Stream cross sectional areas were measured at several points to determine what portion of the total sediment load could be attributed to bank erosion and/or channel degradation Comparison to areas measured in a previous study indicated that about 25% of the sediment transported from the watershed came from the channel.

Conclusions

- Snowmelt can be a significant portion of annual surface runoff (averaged about 50%).
- Recent tillage is an important factor affecting rainfall-runoff amounts.
- Good rainfall distribution data, areally and with time, are critical to runoff modeling.
- Rainfall-runoff and sediment losses from grassland are very low (sediment yield was less than 50 kg/ha yr^{-1}).
- For row-cropped watersheds, sediment sizes and concentrations in runoff increase with rainfall intensity.
- On a relative basis, sediment size was coarsest in runoff directly from the field and finest after passage through a good grassed waterway.
- Streambank erosion can account for a significant portion of sediment yield from the watershed (up to 25%).
- Soluble nutrient amounts deposited in precipitation are significant (and in this study are larger than) relative to losses in surface runoff.
- Significant portions of NH_4-N and PO_4-P losses can occur with snowmelt (in one year 75%).
- Annual NO_3-N losses, associated primarily with subsurface drainage, can be significant (up to 22 kg/ha).
- Concentrations of PO_4-P can exceed 1.0 ppm in runoff where animal wastes, decaying vegetation and P fertilizer are deposited on the soil surface
- Nutrient losses associated with sediment usually exceed those associated with water.
- Pesticide losses are usually less than 1% of that applied if a runoff event does not occur within one week of application.
- With the exception of very strongly adsorbed pesticides, the great bulk of pesticide loss takes place in solution
- The limited data indicate a significant attenuation of losses between field and stream.
- Work on methods of chemical application to improve efficiency of use and to decrease losses to surface waters is needed
- Means to implement improved agronomic management practices relative to chemical use (amount and timing) and their application methods need to be devised (similar to the means of implementation of soil conservation practices)

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The complete report, entitled "Field-to-Stream Transport of Agricultural Chemicals and Sediment in an Iowa Watershed. Part I: Data Base for Model Testing (1976-1978)," (Order No. PB 82-254 046; Cost: $40.50, subject to change) will be available only from:
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