Effects of Conservation on the Hydrology of Loessal Watersheds

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EFFECTS of conservation measures on water yield and flood peaks and volumes have been observed on five small watersheds in the deep loess soils area in west-central Iowa. Included in this research are the effects of contours, level terraces, and grass on hydrology and erosion. Only the hydrologic aspects will be considered in this preliminary report based on 3 years of results, 1964 to 1966. These and later results will provide valuable design criteria for conservation programs, particularly on watersheds with loessal soils.

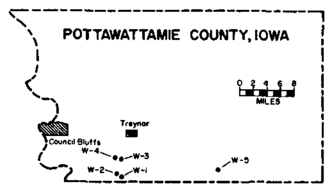
Watershed Descriptions

The five instrumented watersheds are located in Pottawattamie County of Iowa as shown in Fig. 1. They are within, and typically represent, SCS Land Resource Area M-107, Iowa and Missouri Valley deep loess hills. This area is characterized by a deep loess cap over glacial till. Loess depths on the watersheds range from about 80 ft on the ridges to less than 15 ft in the valleys. Most main and upland valleys have deep, incised chanels, which usually terminate upslope in an active gully head. A saturated zone above the till-loess interface causes seepage from the channel banks.

Soils on the research watersheds are of the Marshall-Monona-Ida-Napier series. All are deep, loessal, silt loam soils with moderate to moderately rapid permeability.

Slopes of the watersheds range from 2 to 4 percent on the ridges and bottoms to 12 to 18 percent on the sides. Each watershed is entirely tillable, but erosion is a severe problem on the steep slopes and at the gully heads.

In Fig. 1 are given the size, crop, and conservation practice of each of the five experimental watersheds. Watersheds 1 through 4 are cropped singly, and their total farming operation is controlled for this research project.



WATERSHED DESCRIPTION

WATERSHED	SIZE	CROPPING	LAND TREATMENT
	ACRES		
1	74.5	Continuous Corn	Field-Contoured
2	82.8	Continuous Corn	Field-Contoured
3	107	Grass	None
4	150	Continuous Corn	Level-Terraced
5	369	Mixed	Level-Terraced

FIG. 1 Location and description of research watersheds.

Watershed 5 is controlled and operated by eight farmers. All level terraces recommended by the Soil Conservation Service have been constructed on watersheds 4 and 5. These terraces have a capacity to store 2 or more inches of surface runoff from their contributing areas. Watersheds 4 and 5 have 92 and 85 percent, respectively, of their area above level terraces. Watersheds 1 through 4 provide the opportunity for observation of three land uses – contoured corn, grass, and level-terraced corn. Level-terraced watershed 5 is about two-thirds in row crops of corn and beans and one-third in grass.

All five watersheds are instrumented to measure precipitation and stream flow. Sixteen recording rain gages are used, and stream flow is measured by calibrated, broad-crested, V-notch weirs. Throughout the growing season, weekly observations of soil moisture are made to a depth of 20 ft and ground-water levels are observed in seven wells.

Observed Precipitation

The amount and distribution of precipitation during the years 1964 to 1966 are shown in Fig. 2. Precipitation for 1964 and 1965 was 6 and 16 in. above the 97-year normal of 28.7 in., whereas the 1966 amount was 8 in. below normal. Three periods were particularly wet: June 1964, June 1965, and September 1965. The soil remained quite wet during most of 1964 and 1965.

Several significant storms occurred during this 3-year period. Comparison with information from the U.S. Weather Bureau Technical Publication No. 40 shows that rainfall of two storms exceeded the 10-year frequency; three others exceeded the 5-year frequency, and six others exceeded the 2-year frequency. About 65 separate runoff events occurred on each of the contoured, corn watersheds during these 3 years.

Although these watersheds are closely grouped, some differences in storm precipitation occurred. Of the 65 storms on adjacent watersheds 1 and 2, 24 storms had precipitation differences greater than 0.10 in. Differences between adjacent watersheds 3 and 4 were smaller. On watersheds 1 and 4, which are 3 miles apart, only 16 of the 61 storms had comparable precipitation within the 0.10-in. limitation; however, annual precipitation amounts were quite similar.

Water Yield

Stream flow from the five watersheds was computed for each year, and the volumes were expressed as inches of depth over the respective watershed areas. Daily flow volumes were plotted to give annual hydrographs from which daily base-flow amounts were estimated for days having surface flow.

The observed annual precipitation and runoff amounts and 3-year totals for each watershed are given in Table 1. The runoff components, base and surface flow, are also expressed as a percentage of the total flow, and the runoff from all watersheds is expressed as a percentage of that observed on watershed 1, a contour, corn watershed. The annual runoff totals and their components, base and surface flow, are shown graphically in Fig. 3.

The annual precipitation amounts varied considerably from year to year but were similar for the five watersheds for each year (Table 1). The accumulated 3-year precipitation amounts varied less than 3 percent among the watersheds. However, water-yield values varied considerably. The accumulated 3-year amounts ranged from 15 to 26 in.

Base flow rates at the end of 1966 were approximately the same as at the beginning of 1964. This is an indication that the amount of ground water in storage was similar at the beginning and end of the 3-year period. This was not the case at the end of either 1964 or 1965, years when large amounts

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TABLE 1. ANNUAL WATER YIELD SUMMARY

Water-shed	Precipi-tation, inches	Runoff							
		Inches			Percent of total		Percent of W-1		
		Base*	Surface	Total	Base	Surface	Base	Surface	Total
					1964				
W-1	36.10	2.58	4.06	6.64	39	61	100	100	100
W-2	34.17	2.88	3.41	6.29	46	54	112	84	95
W-3	34.63	2.30	0.55	2.85	81	19	89	13	43
W-4	34.63	5.85	1.01	6.86	85	15	227	25	103
W-5	36.04	2.84	1.00	3.84	74	26	110	25	58
					1965				
W-1	45.35	3.56	10.62	14.18	25	75	100	100	100
W-2	44.35	2.96	10.69	13.65	22	78	83	101	96
W-3	44.28	4.61	4.61	9.22	50	50	129	43	65
W-4	44.87	10.55	2.52	13.07	81	19	296	24	92
W-5	44.18	7.40	3.99	11.39	65	35	208	38	80
					1966				
W-1	20.32	2.55	0.64	3.19	80	20	100	100	100
W-2	20.53	2.43	0.85	3.28	74	26	95	133	103
W-3	22.01	2.54	0.38	2.92	87	13	100	59	92
W-4	21.88	5.91	0.19	6.10	97	3	232	30	191
W-5	19.27	3.84	0.25	4.09	94	6	150	69	128
					1964-1966 Totals				
W-1	101.77	8.69	15.32	24.01	36	64	100	100	100
W-2	99.05	8.27	14.95	23.22	36	64	95	98	97
W-3	100.92	9.45	5.54	14.99	63	37	109	36	62
W-4	101.38	22.31	3.72	26.03	86	14	257	24	108
W-5	99.49	14.08	5.24	19.32	73	27	162	34	80

* Small amounts of tile flow included for W-4 and W-5.

of infiltration and percolation occurred and base flow rates were substantially above those of early 1964.

Fig. 3 shows that the paired, contoured, corn watersheds 1 and 2, which had similar treatment and precipitation, had similar water yields. The 3-year base, surface, and total water-yield amounts of watershed 2 were 95, 98, and 97 percent respectively of the watershed 1 totals.

The total water yield from level-terraced, corn watershed 4 has been quite similar to that of the two contoured, corn watersheds 1 and 2. The 3-year total water yield was 8 percent more than that of watershed 1. However, the water-yield components, base and surface flow, of watershed 4 were quite different from those of the contoured watersheds. The base flow from the terraced watershed was 86 percent of its total flow, compared with 36 percent from the contoured watersheds. Among the watersheds in 1966, terraced watersheds 4 and 5 had the largest stream flow amounts. Ground-water levels indicate that this was the result of increased retention on the terraced watersheds in late 1965.

The large base-flow amount from the terraced area is surely related to the increased infiltration and percolation. Deep soil-moisture measurements show that the loess below the root zone remains near field capacity. This would allow infiltrated water to percolate slowly to the ground water. The high base flows and similar water yields of the terraced watersheds, compared to the contoured watersheds, can be rationalized by assuming that (a) surface runoff between the terraces is similar to that from the unterraced areas, (b) losses of water are small from the time this runoff is trapped and infiltrated in a terrace channel until it reappears as base flow, (c) the ground-water divide is approximately the same as the surface divide, and (d) most of the ground-water accretion becomes measured base flow rather than bypassing the measuring station. Some preliminary observations indicate that these are good assumptions; however, much work remains to obtain verification.

Grassed watershed 3 has had 38 percent less water yield than the contoured, corn watersheds for the 3-year period. This lesser amount is probably caused by the longer growing season of grass and resultant greater evapotranspiration as compared with that of corn. Only 37 percent of the flow from watershed 3 was surface flow. However, this is considerably higher than the 14 percent observed from level-terraced watershed 4.

Watershed 5 is larger than any of the other four, is level terraced, and has mixed cropping of about one-third grass and two-thirds row crops of corn and soybeans. Data from this watershed provide an opportunity to verify predictions based on the results from the other four watersheds. Data from level-terraced, corn watershed 4 indicate that low amounts of surface flow and substantial amounts of base flow would be expected. Due to the reduction of water yield caused by grass, compared to corn, the predicted water yield from watershed 5 would be equal to a weighted average of the water yields from watersheds 3 (grass) and 4 (corn). Fig. 3 and data given in Table 1 show that watershed 5 has performed approximately as predicted. Total water yield was less than from level-terraced, corn watershed 4, but more than from grass watershed 3. Base flow was 73 percent of the total.

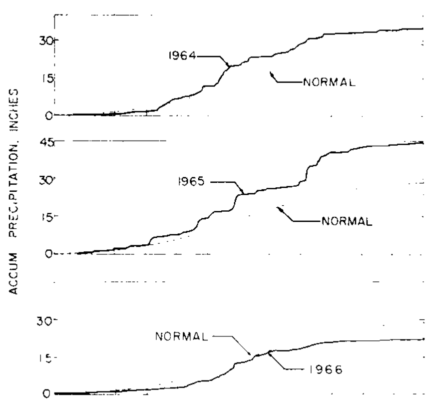

FIG. 2 Precipitation on watersheds used in the research study.

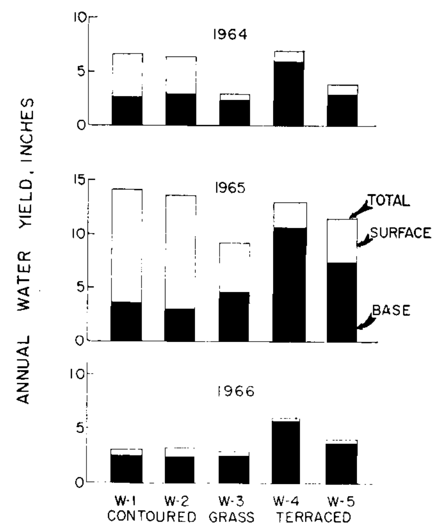

FIG. 3 Conservation effects on annual water yield.

Runoff Rates and Volumes

The two wet years, 1964 and 1965, provided many rainfall-runoff events —

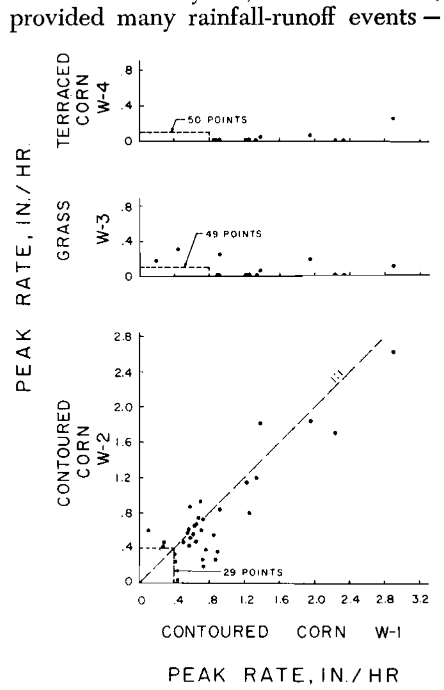

FIG. 4 Conservation effects on peak runoff rates.

more than 60 separate hydrographs. Intense rainfall bursts within a storm on these steep watersheds often produce separate hydrographs. The runoff durations are short; a hydrograph is usually completed in 20 to 30 min.

Peak runoff rates from watersheds 2, 3, and 4 are plotted versus those from watershed 1 in Fig. 4. Nearly all observed peaks are included. Only two or three events were omitted from each comparison because of unusually large precipitation differences.

Comparison of watershed 1 with watershed 2 shows that peak rates from these paired watersheds were similar. Much of the variation is related to precipitation differences. Comparisons of watersheds 3 and 4 with watershed 1 show the peak rates from level terraces and grass to be much less than those from contoured corn.

The peak rates, on the average, have been reduced more than 90 percent by both grass and level terraces. In general, level terraces lowered peak rates slightly more than did grass. Peak rates from level-terraced, mix-cropped watershed 5 have been quite similar to those from watershed 4. Comparisons of storm runoff volumes for individual events closely parallel the peak rate comparisons of Fig. 4.

Summary

Three years of data from five experimental watersheds show that conservation measures have considerable effect on the water yield and runoff rates from watersheds in the deep loessal soil regions. The hydrologic effect of contoured corn, level-terraced corn, and grass was observed on four single-crop watersheds and on one mixed-crop, level-terraced watershed. The level-terraced, corn watershed had 8 percent more water yield than the contoured, corn watershed. Only 14 percent of the water yield from the terraced watershed was surface flow, compared with 64 percent from the contoured watersheds. The grass watershed had a total water yield 38 percent less than that of the contoured, corn watersheds. Water yield from the mixed-crop, level-terraced watershed corresponded closely with predictions based upon results of the four single-crop watersheds.

These preliminary results indicate that level terraces on loessal soils reduce surface flows and sustain base flows but do not reduce total water yield. Grass cover reduces total water yield when compared with corn cover. Peak runoff rates are reduced more than 90 percent by both level terraces and grass compared with those from contoured, corn watersheds.

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Initial and Circulate:

Heinemann ______

Keppel ______ JK

Kramer ______

Piest ______ DR

Rausch ______

Saxton ______ DW

Whitaker ______

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