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RUNOFF AND SOIL LOSS UNDER A CENTER PIVOT IRRIGATION SYSTEM ON CRETE AND WYMORE SOILS IN NEBRASKA*

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The introduction of the center pivot as a means of water application in areas formerly thought too steep for irrigation has opened many new areas to irrigated agriculture. With this expansion, many people have been concerned about increased runoff. This study was designed to determine if application of water through a center pivot produced runoff and increased the amount of soil loss on sloping clayey soils of the Crete and Wymore series. Small runoff plots were constructed near the perimeter of the irrigated circle for collection of runoff and sediment.

The study concludes that center pivot application of water on slopes of 2, 4, and 8 percent results in no direct runoff if the crop production system is well managed. It did, however, indicate that runoff from a rain may increase when the soil is moist from irrigation.

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INTRODUCTION

During recent years, use of the center-pivot irrigation system has opened up many areas previously unsuited to irrigation because of the percent, shortness, and variable aspect of slopes. The location of suitable aquifers along with the availability of the new technology of the center pivot has allowed expansion of irrigation into areas such as southeastern Nebraska where the soils are clayey and many slopes exceed 6 percent. The low intake rate of clayey soils in combination with steepness of slope would be expected to result in increased runoff and greater soil loss through erosion when irrigation water is applied.

Although water can be applied quite uniformly with a center-pivot system, the amount of water entering the soil may not be proportional to the application if runoff is severe. Runoff is mainly dependent on soil characteristics, surface conditions, and intake rate and slope (Kincaid, et al., 1969; Wischmeier, 1966).

The purpose of this study was to determine if application of water through a center-pivot system produced runoff and increased the amount of soil loss from sloping soils with physical properties usually associated with a slow rate of water intake. Chosen for the study was a quarter section of land in Gage County, Nebraska. Three mapping units that differed in slope and/or soil types were selected from within the irrigated area. The mapping units were:

Site 1 – Crete silty clay loam (Pachic Argiustoll, fine montmorillonitic mesic), 2 percent slope, well drained.

Site 2 – Wymore silty clay loam (Aquic Argiudoll, fine montmorillonitic mesic), 4 percent slope, well drained.

Site 3 – Wymore silty clay loam (Aquic Argiudoll, fine montmorillonitic mesic), 8 percent slope, well drained.

Sites were located 8.1 m from wheel track 7, one-fifth the way between towers 7 and 8 of an 8-tower quarter-section center-pivot system.

The area was chisel-plowed in November, 1976, after the corn was harvested; corn stalks were left on the soil surface.

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At this time, 160 kg of nitrogen per hectare was applied. In early April, 1977, the soils were described and sampled using standard procedures (Soil Survey Staff, 1962 and 1972) just before the single disking and corn planting on the contour on April 18. The field was cultivated on June 7, 1977, to loosen the soil.

Precipitation and irrigation water reaching the test site was measured by a universal recording rain gauge and by 1-gallon containers with funnels of 10.2 cm diameter. The 1-gallon containers were placed in triplicate above the corn plants at a height of 250 cm.

Runoff plots that were 2 meters wide and 5 meters long and had a 1-square-meter collection area (total of 11 square meters) were constructed perpendicular to the contour at each site. Metal edging was driven to a depth of 15 cm along the sites of the plot and a sill plate was driven to a depth of 40 cm at the lower end of the plot. The slight ridging of the contour rows did not restrict the flow of surface water or channel runoff to single break-over points. Runoff water and eroded soil sediment from the plots were collected in a 90 x 60 x 60 cm sump installed close to the down-gradient side of the sill. The sump was lined with a sheet of polyethylene. Runoff was measured volumetrically and was mixed thoroughly to suspend all of the sediment. Samples consisting of 400 ml of runoff and suspended sediment were oven dried, and then the dry sediment was weighed to calculate soil losses.

Minimum tillage consisted of chiseling, disking, and a single cultivation. On June 8, 1978, the amount of plant residue left on the soil surface after these operations was 900 lbs. per acre. Residue evaluation was made by William E. Riensch, Conservation Agronomist, Soil Conservation Service, USDA, Lincoln, Nebraska.

RESULTS AND DISCUSSION

Particle-size distribution for each soil shows similar relationships (Table I). The Crete soil has a higher clay content in the B21t horizon than the Wymore soils; however, the soil at each site is high in clay and silt and low in sand content. Low infiltration rates and slow percolation are usually associated with soil of this texture.

Rainfall and irrigation water applications were measured from June 16 to September 8, 1977 (Table II). One irrigation was made on June 10 and six others in the period June 19 to July 21. Irrigation was not needed for the rest of the growing season because rainfall was sufficient. Total amount of water supplied to the soil by rainfall and irrigation was 61.2 cm. No runoff or soil losses resulted from any of the seven irrigations, during which an averate rate of 2 cm of water was applied per hour. Amounts of runoff resulting from 9 of 24 rainfall events at each site are given in Table III.

The following conditions probably account for the lacl of runoff with irrigation: a large number of cracks at the soi surface increased the initial intake rates and helped to preven crust formation; the soil surface was protected by plant resi due; the soil surface generally was dry at the time of irrigation The effect of moisture at the soil surface was illustrated durin the study. Irrigation on June 19 was followed two days late by 2.88 cm of rain which resulted in appreciable amounts o runoff and soil loss on all slopes. About a month later, whe the soil surface was dry, a greater amount of rain (3.28 cm o July 28) did not cause any runoff. This relation of runoff t antecedent soil moisture condition probably holds for al types of irrigation systems.

TABLE I

Particle-Size Distribution for the Soil Profiles at Three Sites in a Field Irrigated by a Center Pivot

soil horizon	depth cm	% sand 2000-50um	% silt 50-2um	% clay 2 um
		Site 1		
AP	0-13	5.2	64.3	30.5
B1	13-20	5.4	66.4	28.2
B21t	20-51	2.5	46.3	51.2
B22t	51-69	2.8	49.9	37.3
B3	69-91	4.2	60.2	35.6
C1	91-152	3.8	64.9	30.3
		Site 2		
AP	0-18	4.3	58.8	36.9
B1	18-23	3.2	58.6	38.2
B21t	23-38	2.6	54.5	42.9
B22t	38-66	2.4	58.9	38.7
B3	66-81	2.3	67.0	30.7
C1	81-117	2.3	69.7	28.0
C2	117-152	1.8	72.3	25.9
		Site 3		
AP	0-13	2.8	57.5	39.7
B1	13-20	2.6	55.2	42.2
B21t	20-38	2.3	57.2	40.5
B22t	38-51	1.7	62.0	36.3
B23t	51-69	2.2	65.4	32.4
B3	69-89	3.2	67.1	29.7
C	89-152	3.3	72.2	24.5

TABLE II

Amount of Rainfall and Center Pivot Irrigation
In Southeast Nebraska, 1977

Date	Rainfall cm	Irrigation cm
June 10		*2.01
June 16	2.81	
June 19		2.03
June 21	2.88**	
June 24	1.20**	
July 2		1.87
July 6		2.25
July 7	0.41	
July 11	2.08	
July 13		1.70
July 17		2.21
July 21	0.25	2.01
July 24	1.80	
July 28	3.28	
August 1	0.67	
August 4	1.05	
August 5	0.99	
August 8	4.04**	
August 11	2.24**	
August 14	2.48**	
August 15	8.64**	
August 19	0.21	
August 22	0.10	
August 25	0.81	
August 26	0.61	
August 28	1.86**	
August 31	0.46	
September 1	0.33	
September 3	8.03**	
September 4	1.90**	
Total	49.13 cm	Total 12.07 cm

Total rainfall + total irrigation = 61.2 cm

* This irrigation was applied before taking the measurements and is not included in the calculations.

** Rainfall resulting in runoff on one or more slopes.

Amounts of rain-caused runoff at a given site during the several storms depended on soil and plant conditions and rainfall characteristics. For all rainfall events, however, amounts of runoff from the three sites were related to differences in slope. As shown geographically by Figure 1, the

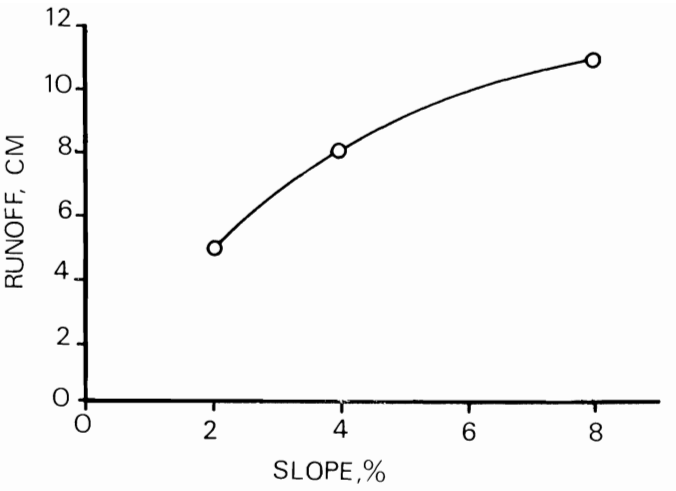

Figure 1. Total amounts of runoff from three different slopes, 1977.

difference between the amounts of total runoff from slopes of 2 and 4 percent was greater than the difference between the amounts of total runoff from slopes of 4 and 8 percent. Total amounts of runoff from June 18 to September 8, 1977, were 4.8, 8.0, and 10.8 cm for slopes of 2, 4, and 8 percent, respectively. These amounts represent 10, 16, and 22 percent of the total rainfall on the three slopes.

Sediment or soil loss during six of the nine rainfall events is given in Table III. Rain storms with low amounts and low intensities (all rainfall events except those on August 15 and September 3) resulted in average soil losses that increased 69 percent and 75 percent as the slope went from 2 to 4 percent and from 4 to 8 percent, respectively. During rain storms of high amounts and high intensity (rainfall events on August 15 and September 3), the amount of average soil loss became smaller as slope went from 2 to 4 percent, then became larger as slope went from 4 to 8 percent. This can possibly be explained as follows: When rain falls on a dry soil, the soil is slaked and thrown into suspension and this suspended material is carried off by rain with just enough quantity and intensity to cause runoff; whereas, with rains of high intensity and amounts, the suspended material is soon washed away and the remaining wet soil packs down.

Total amounts of soil loss for six events were 1.4, 1.4, and 2.3 metric tons per hectare for the 2, 4, and 8 percent slopes. The lack of difference in total soil losses from the 2 or 4 percent slope may be due to the presence of cracks in these soils resulting in deposition of soil sediment. This phenomenon may be more active with low velocity runoff water on flatter slopes. On the 8 percent slope, velocity of runoff water is high and there was no time for soil sediments to settle into the cracks and most sediments remained with runoff water, thus resulting in a 60 percent greater soil loss.

TABLE III

Amounts of Runoff and Soil Loss Resulting from Precipitation on Three Test Sites, 1977

		Dates of Runoff Events										
		6/21	6/24	8/8	8/11	8/14	8/15	8/28	9/3	9/4	Irrigation	Total
Amount of rain (cm)		2.88	1.20	1.35 2.69	2.24	2.48	8.64	.89 .97	8.03	1.90	2.04**	33.2
Intensity (cm/hr)		.72	1.60	4.05 .77	.75	1.47	6.97	.45 .19	3.74	.28	2.04**	
						Runoff (cm)						
Site	Slope											
1	2%	.99	.18	.11	.00	.38	.63	.00	1.21	1.34	0	4.8
2	4%	.56	.40	.86	1.10	1.22	.97	.18	1.37	1.38	0	8.0
3	8%	1.00	.48	1.17	1.59	1.61	1.51	.20	1.66	1.58	0	10.8
						Soil Loss (ton/hectare)						
1	2%	—*	—*	.07	.0	.15	.52	—*	.42	.27	0	1.4
2	4%	—	—	.14	.14	.19	.29	—	.36	.32	0	1.4
3	8%	—	—	.35	.29	.49	.44	—	.45	.27	0	2.2

* Missing Data
** Irrigation

CONCLUSIONS

1. Center-pivot irrigation system applying 2 cm of water at a rate of 2 cm per hour caused no direct runoff or soil loss from clayey soils having 2, 4, and 8 percent slopes. However, runoff resulting from medium to heavy rain on recently irrigated soil is likely to be greater than that resulting from an equivalent rain on dry soil.

2. The greater the slope, the larger the amount of runoff produced by medium to heavy rain. However, the difference in runoff amounts from the 2 and 4 percent slopes was greater than the difference in runoff amounts from the 4 and 8 percent slopes. Total runoff was 10, 16, and 22 percent of total rainfall on slopes of 2, 4, and 8 percent respectively.

3. Amounts of soil loss from the 2, 4, and 8 percent slopes were relatively high. Soil losses from the 2 and 4 percent slopes were virtually the same but from the 8 percent slope was 60 percent greater.

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