Snow Trapping by Contour Furrows in Southeastern Montana

EARL L. NEFF

Abstract

Contour furrows on fine-textured range sites in southeastern Montana caught an annual average of 22 mm more snow equivalent than nearby nonfurrowed areas. In addition, the furrows held snowmelt onsite in the spring and significantly reduced winter runoff in nearly half of the years of record. Except in years of much below normal winter precipitation, however, the winter runoff from furrowed areas was still more than adequate to fill well-designed stockponds.

Overwinter soil water recharge on eastern Montana rangelands is a major factor affecting herbage production the following growing season. Neff and Wight (1977) in a study on saline upland and panspot range site, and Wight and Black (1978), in a study on a sandy range site, demonstrated that each additional millimeter of available soil water in the spring increased range forage production the following growing season about 7 kg/ha. The rapid spring melt of shallow snow packs on frozen, fine-textured soils with naturally low infiltration rates is a serious limitation to soil water recharge. Various surface modification treatments, including contour furrowing, have been used to increase soil water recharge by creating additional surface storage, thus providing a longer time for infiltration (Branson et al. 1966; Wight and Siddoway 1972; Soiseth et al. 1974; Wight 1976).

The objective of this study was to assess the effects of contour furrows on snow trapping and winter runoff on fine-textured rangeland soil in southeastern Montana.

Site Description and Methods

This study was conducted about 29 km south of Ekalaka in southeastern Montana. The climate is arid to semiarid continental. Winters are cold and relatively dry, and summers are warm. The average annual precipitation is about 300 mm. About 13% of the precipitation is snow that accumulates from December 1 to the initial snow melt, usually between February 1 and 15. Based on data from nearby weather stations, the precipitation during the 1968-78 study period was about 120% of the 78-year average and about 115% of the average over the last 24 years.

In November 1967, sixteen 0.8-ha watersheds were established—twelve on a panspot range site, where the average slope is 1 to 5%, and four on a saline upland range site, where the average slope is 3%. The soils of the panspot range site are in the Bickerdyke and Bascovy series, which are, respectively, members of the very fine and fine, montmorillonitic, Borollic Vertic Camborthids. The soils of the saline upland range site are in the Dilts series, a member of the family of the clayey, montmorillontic, acid, frigid, shallow Ustic Torriorthents. Half of the watersheds at each range site were contour furrowed with an Arcadia Model B contour furrower. Two pairs of offset disks, 1.5 m apart, formed two furrows about 50 cm wide and 15 to 25 cm deep. Rippers ahead of the disks fractured the soil to a depth of 25 to 40 cm. Intrafurrow dams were constructed about every 5 m. The furrow and ridge portions represented about 40 and 60%, respectively, of the treated area.

Author is research hydraulic engineer, U.S. Dep. Agr., Science and Education Administration, Agr. Res., Northern Plains Soil and Water Research Center, P.O. Box 1109, Sidney, Montana 59270.

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Neff (1973) related the water storage capacity of contour furrow to furrow age and initial storage capacity. This relationship indicated that storage decays exponentially with time and that furrows lose about 50% of the initial capacity in the first 10 years after construction. Loss of storage for the furrows in the study reported here is expressed by the equation:

$$S = 43e^{-0.07t} \quad (1)$$

where S = water storage capacity in millimeters and
t = time after construction in years.

Water equivalent of the snow pack was measured with a Federal Snow Sampler at about 2-week intervals each year during the period between January 1 and the initial snow melt. Single samples were taken at four locations on each of the nonfurrowed watersheds and at two locations on each of the furrowed watersheds. At each location on the furrowed watersheds, samples were taken on a transect that included samples from at least two furrows and two ridges. Data from 1973 were estimated on the basis of sketchy field measurements because of an unexpected mid-January snow melt. No field data were collected in 1975.

Winter precipitation was recorded each year between December 1 and the date initial snow melt began, usually between February 1 and 15, and the maximum snow water accumulation and density was measured just before initial melt. The furrow water storage capacity was determined from equation (1). Winter runoff was the estimated volume resulting from the snow melt. Winter runoff was estimated because snow drifted into flumes and ice formed in and below the flumes and in the flume stilling wells, which prevented accurate measurement. In the estimates I assumed no evaporation from the snowpack in the 7- to 14-day period between the date of measurement of the maximum show accumulation and the date on which snow melt began. On the nonfurrowed watersheds, winter runoff was assumed to equal the maximum snow water accumulation for each year. This assumption was made because the soil was frozen during winter runoff each year, as evidenced by soil cores of concrete frost taken with the Federal Snow Sampler, and, in addition, the third-hour infiltration rate of these soils, even when unfrozen, is only about 2.5 mm/hr as measured by double-ring infiltrometers (Soiseth et al. 1974). Winter runoff from the contour-furrowed watersheds was assumed to equal the difference between maximum snow water accumulation and furrow water storage capacity each year.

Results and Discussion

Because there was no significant difference in snow water deposition between the saline upland and panspot range sites (annual average 56 mm and 62 mm, respectively), the range sites were combined and analyzed as one sample. Results were summarized in Table 1.

To compare the amount of snow trapped on the small furrowed experimental watersheds to that trapped on large areas treated by furrowing, snow samples were taken in

Table. 1. Winter precipitation, snow water accumulation, snow density, furrow water storage capacity, and runoff by years and treatment.

Year	Winter ppt.	Maximum snow water accumultion (mm)				Snow density (%)			Furrow water storage capacity (mm)	Winter Runoff (mm)	
		Non-furrowed	Furrowed			Non-furrowed	Ridge	Furrow		Non-furrowed	Furrowed
			Ridge	Furrow	Area						
1969	71	61	46**	108**	71	30	26*	34*	39	61	32**
1970	39	28	43**	107**	69**	44	33*	42	36	28	33
1971	51	44	31**	124**	68**	22	14**	36**	34	44	34**
1972	40	38	48	100**	69**	20	21	29**	31	38	38
1973[1]	17	12	15	40**	25**	NR[2]	NR[2]	NR[2]	29	12	0**
1974	18	12	14	36**	23**	16	15	20*	27	12	0**
1976	33	29	34	89**	56**	31	25	35	25	29	31
1977	38	28	34	86**	55**	30	20**	37*	24	28	31
1978	100	89	88	139**	108**	26	26	30**	22	89	86
Average[3]	45	38	39	92	60	27	22	33	30	38	32
Mean	42		43	99**	65**	27	22**	33**		42	36*

*Significantly different from nonfurrowed at the 5% level ($P = 0.05$).
**Significantly different from nonfurrowed at the 1% level ($P = 0.01$).
[1]Snow accumulation data were estimated in 1973.
[2]NR means no record.
[3]Average includes estimated values for 1973.
Mean of all field samples.

1971, 1972, and 1974 in an area of several hundred hectares that was furrowed in 1960. This comparison was made to determine if snow trapped upwind on large furrowed areas affected downwind deposition. The small experimental watersheds trapped slightly more snow than the large area. The watershed vs. large area measurements in 1971 were 68 and 64 mm; in 1972 were 69 and 58 mm; and in 1974 were 23 and 18 mm, respectively. Not enough samples were taken on the large area to test these differences statistically, but the differences of 4 mm, 11 mm, and 5 mm are of relatively minor practical significance. The samples showed, therefore, that furrowed areas of up to several hundred hectares do not require an upwind contributing area for optimum snow deposition.

Table 1 shows that the average winter precipitation was 45 mm and the average maximum snow-water accumulation was 60 mm. The logical question arises: "Where did all the snow that was trapped in the furrows come from?" The answer lies in the method used to measure winter precipitation. Several investigators including Warnick (1951, 1953), Weiss (1961), and others, have demonstrated that precipitation gages are notoriously poor devices for measuring snow precipitation. The 45 mm recorded in this study could easily be in error by 50% due to wind effects, which means that the actual winter precipitation was probably closer to 60-70 mm than to 45 mm. If this is true, then furrows trapped most of the snow that fell, which explains why large furrowed areas do no need an upwind contributing area.

In 4 of 8 years of record, snow density on the ridges between furrows was significantly less than that on the nonfurrowed watersheds. Snow density in the furrows was significantly greater in 6 of 8 years. Vegetation on the ridges provided some mechanical support and bridging strength in the snow pack, which prevented the snow from compacting as much as it did in the furrows or in the nonfurrowed watersheds.

Most of the increased snow catch was deposited in the furrows. The ridges between furrows averaged about as much as the nonfurrowed areas. For snow management, this is important for two reasons.

a) Snow concentrated in drifts is not subject to evaporation losses caused by wind movement of individual snow particles. This may be offset, however, by higher evaporation losses during the melt period, because snow in drifts takes longer to melt and is thus subjected to evaporation processes for a longer time.

b) The deeper snow in the furrows provides insulation, which prevents or reduces soil freezing. This in turn increases infiltration during snowmelt.

Except during the years when snowfall was much below normal, contour furrows had only a minor effect on snowmelt runoff, because the amount of snow water trapped in the furrows exceeded the furrow water-holding capacity. This is an important consideration because ranch operators in the northern Great Plains depend on snowmelt runoff as the main water supply for stock ponds and reservoirs (Wight et al. 1975). In years with slightly below- to above-normal winter precipitation, contour furrowed areas yielded about 35-mm snowmelt runoff. This is enough to fill most stock ponds based on the rule-of-thumb design (personal communication from Soil Conservation Service personnel) of 100 ha of contributing area for each hectare-meter storage capacity of the reservoir (30 acres per acre-foot storage capacity). There was no snowmelt runoff from contour furrowed areas in 1973 and 1974—years when winter precipitation was much below normal. In low snowfall years, contour furrows could significantly reduce the water supply to downstream ponds.

Conclusions

Contour furrows efficiently trapped and held snow during the winter accumulation period, stored snowmelt, and increased the length of time for infiltration. Except for years when winter precipitation was much below normal, furrows had little effect on winter runoff because the amount of snow water trapped was greater than the water storage capacity of the furrows.

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