Vegetation Response to Contour Furrowing

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Highlight: Over an 8-year period, contour furrowing on a panspot range site increased average annual herbage production 165% (527 kg/ha), increased plant available soil water 107%, and reduced total basal cover 73% (from 15.72 to 4.22%). On a saline-upland site, contour furrowing increased available water but had no measurable effect on total herbage production and basal cover. Thickspike and western wheatgrass accounted for most of the increased yields on the contour-furrowed panspot site. High yields on the furrowed plots were due primarily to increased soil water resulting from increased overwinter recharge and reduced summer runoff.

Range forage production in arid and semiarid regions is closely associated with soil water availability, which is limited by precipitation amounts and runoff. Contour furrowing was one of the first land surface modification treatments applied to rangeland to reduce runoff. Since this treatment was introduced in the 1930's, it has been applied in a wide variety of furrow sizes and spacings. While optimum spacing is related to furrow size, spacings wider than 1.5 to 1.8 m have generally been ineffective (Bennett 1939; Barnes 1950). In the past 20 years, most contour furrowing has been done with the Arcadia Model B contour furrower developed by the U.S. Forest Service. Herbage yield responses to contour furrowing have ranged from none to increases of 100% or more and have been closely associated with the type of furrowing treatment and site characteristics (Wight 1976). In addition to increasing forage production, contour furrowing has been used extensively, primarily by the Bureau of Land Management, to reduce runoff and erosion on fine-textured, erodible rangelands.

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At present, contour furrowing is generally not used as a range improvement practice because unfavorable economics have discouraged its use by private landowners, and changes in management philosophies have restricted its use by the Bureau of Land Management and other land management agencies. However, on rangelands with high runoff and resultant low productivity, contour furrowing can significantly reduce runoff and increase forage production. More information is needed regarding long-term vegetation responses and site-treatment interactions. The purpose of this paper is to examine the vegetation responses of panspot and saline-upland range sites to contour furrowing. Vegetation responses were examined in terms of herbage production, species composition, and associated environmental factors. The results and data presented here are part of a cooperative study between the Agricultural Research Service, U.S. Department of Agriculture, and the Bureau of Land Management, U.S. Department of the Interior, to evaluate contour furrowing effects on the vegetation and hydrology of fine-textured rangelands in southeastern Montana.

Site Description and Methods

This study was conducted about 29 km south of Ekalaka in the southeast corner of Montana. The climate is arid to semiarid continental with cold, relatively dry winters and warm summers. The long-time average annual precipitation is about 300 mm, with 80% of the precipitation received during April through September. Based on data from nearby weather stations, the precipitation during 1968–76 study was about 120% of the 76-year average and about 115% of the last 22-year average. The average frost-free season is 127 days.

The contour furrowing treatments were applied to panspot and saline-upland range sites, which are characterized by impervious saline-sodic soils with low forage productivity. The panspot soils are in the Bickerdyne and Bascovy series, fine or very fine, montmorillonitic, Borollic Vertic Camborthids. The saline-upland soils are in the Dilts series, clayey, montmorillonitic, acid, frigid, shallow Ustic Torriorthents. A dominant feature of these soils is low infiltration and high runoff. Neff and Wight (1977) estimated that approximately 40% of the late fall, winter, and early spring precipitation was lost by runoff.

Vegetation of the panspot site included thickspike wheatgrass (*Agropyron dasystachyum*), western wheatgrass (*A. smithii*), Sandberg bluegrass (*Poa secunda*), prairie Junegrass (*Koeleria cristata*), big sagebrush (*Artemisia tridentata*), and pricklypear cactus (*Opuntia* sp.). Small residual pedestals of coarse-textured materials had abundant blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), and clubmoss (*Selaginella densa*). The saline-upland site was dominated by alkali sacaton (*Sporobolus airoides*) and Nuttall alkaligrass (*Puccinellia airoides*). Other species present were Nuttall saltbush (*Atriplex nuttallii*), broom snakeweed (*Gutierrezia sarothrae*), racemed poison-vetch (*Astragalus racemosus*), and *Eriogonum multiceps*.

Sixteen 0.8-hectare watersheds, twelve on the panspot range site with average slopes of 1 to 5% and four on the saline-upland range site with an average slope of 3%, were established in November 1967. Half of the watersheds at each site were contour furrowed with the Arcadia Model B contour furrower. Two pairs of offset disks 1.5 m apart formed two furrows approximately 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 the ridge portions represented about 40 to 60%, respectively, of the treated area. The treatments were applied in a randomized complete block design with treatments replicated six times on the panspot site and two times on the saline-upland site.

Annual herbage production was determined by clipping vegetation at ground level in eight randomly located 0.25- × 2-m quadrats or four 0.5- × 2-m quadrats in each watershed. Plots were clipped when vegetation reached peak standing crop, usually in late July or early August. No yield measurements were made in 1973 because of early grazing. Yields were determined separately for the dominant species and major species groups (i.e., grasses, forbs, and shrubs). Because of the difficulty in separating thickspike and western wheatgrass, the thickspike-western wheatgrass complex was harvested as a single category. No estimates were made of annual big sagebrush growth. Furrows and ridges were harvested separately in 1968, 1969, 1970, 1972, and 1976; in the other years, sampling quadrats were located to include a proportional amount of ridge and furrow. There was no measurable productivity in the furrows until 1971. Grazing was not a treatment but plots were grazed in 1969, 1971, and 1973 to remove accumulated residue.

Soil water was measured by the neutron scatter method to a depth of 120 cm periodically (biweekly to monthly) during the growing seasons at two locations in each watershed and included both ridges and furrows of the treated plots. Cm-days of available water was determined by plotting soil water content for the April 1 to July 31 growing season and measuring the area between the plot and a base line representing the water content below which water was unavailable to plants. This integrated area is an index reflecting both the amount and duration of available soil water. The base line or lower limit of soil water availability was determined as the lowest water content that occurred naturally in the field during the 9-year study. Because most of the root activity on these two sites is limited to the top 60 cm of soil profile, available soil water was determined for this zone only.

Nitrogen (N) and phosphorus (P) contents were determined annually on the mature thickspike-western wheatgrass plants.

Basal cover was determined for the years 1968–71 and again in 1974 with the point quadrat method. Species composition based on basal cover was determined in 1974. Point data were taken along six permanently located line transects at 5-cm intervals with a 20-point frame for a total of 1,200 points per plot. Only the basal hits are discussed in this paper. The percentage basal cover data were normalized by the transformation

$$X = \sqrt{X + 0.5},$$

Table 1. Average annual herbage yields (kg/ha) and composition on check and furrowed plots for 1969–1976.

	Site					
	Saline-upland			Panspot		
Species	Check	Furrowed	Furrowed/ check	Check	Furrowed	Furrowed/ check**
Nuttall alkaligrass	23	80	3.47	—	—	—
Alkali sacaton	59	73	1.26	—	—	—
Thickspike-western wheatgrass	23	29	1.22	119	558*	4.64
Total grass	139	218	1.55	271	704*	2.60
Forbs	78	114	1.49	31	129*	4.00
Total	241	350	1.45	320	847*	2.65
Percent grass	58	62	—	85	83	—

* Means significantly different from the check (P=0.1).
**Furrowed/check data not analyzed statistically.

and analyzed statistically. All data were analyzed with a split-plot analysis of variance with furrowing treatments as the main plots and years as the subplots.

Results and Discussion

Herbage Production

The effect of contour furrowing on herbage production is shown in Table 1 and Figure 1. Except for the treatment year, contour furrowing generally increased herbage production on all plots. On the saline-upland site, yield increases due to contour furrowing were not significant (P = 0.1). However, with only two replications and two treatments, an analysis of variance was not very discerning. On the panspot site, furrowing increased average herbage production 527 kg/ha (165%).

Increases in the dominant forage species accounted for most of the yield increases on the contour-furrowed plots. Nuttall alkaligrass and alkali sacaton increased 247 and 26%, respectively, on the saline-upland site; and thickspike-western wheatgrass increased 364% on the panspot sites (Table 1). Blue grama and buffalograss, which represented about 25% of the basal cover on the nonfurrowed panspot site, accounted for only 17.8 and 1.7% of the total production on the check and furrowed plot, respectively. Forbs, which accounted for only 10 and 32% of the total production on the untreated panspot and saline-upland sites, respectively, responded to contour furrowing in about the same proportion as did the dominant grasses. The major forb response to contour furrowing on the panspot site in 1976 was a heavy infestation of yellow sweetclover (*Melilotus officinalis*).

N and P Uptake

Herbage quality as determined by N and P contents of thickspike-western wheatgrass was significantly affected by contour furrowing (Fig. 2). In 1968, both the N and P contents were higher on furrowed than on nonfurrowed plots, indicating a nutrient enrichment as disturbed soil and sod weathered and decomposed. However, during the next few years, N and P contents were generally lower in the furrowed than in the nonfurrowed plots, indicating a

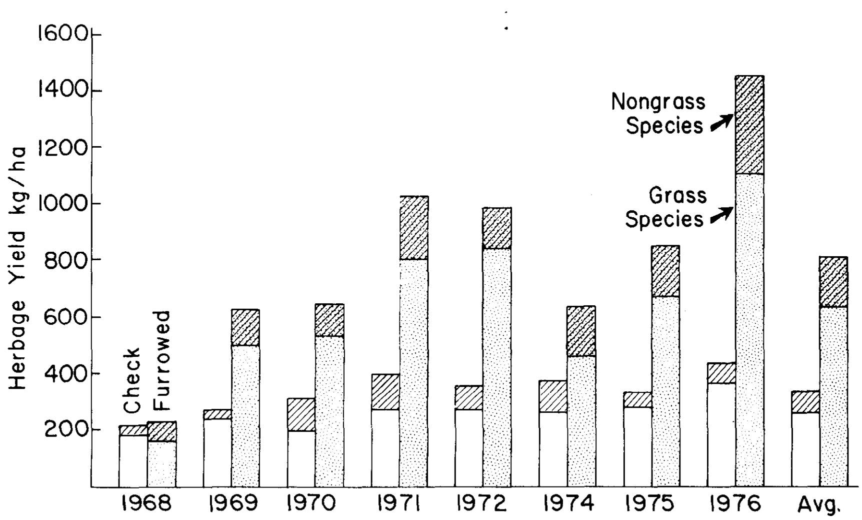

Fig. 1. *Herbage production under contour furrowing on panspot range site.*

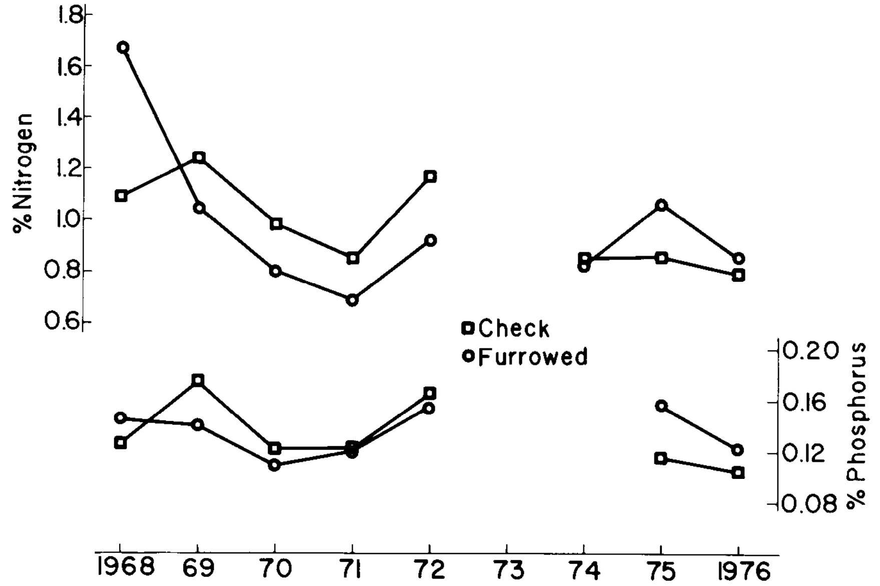

Fig. 2. *N and P content of thickspike-western wheatgrass under contour furrowing.*

dilution effect as the furrowed plots produced 2 to 3 times more vegetation than did the nonfurrowed plots. Also, decreases in N and P contents are associated with decreases in leaf:stem ratios as plants grow more vigorously. Although N and P contents were lower on the furrowed than on the nonfurrowed plots, total uptake of N and P was higher on the furrowed plots because of the increased production. As indicated in Figure 2, this situation again reversed itself in about 7 years, with the furrowed plots producing forage higher in N and P contents than did the nonfurrowed plots. After 7 years of increased soil water and productivity on the furrowed plots, the soil nutrients were probably cycling in greater quantities on the furrowed than on the nonfurrowed plots.

Species Composition

Except for the rapid establishment of tumblegrass (*Schedonnardus paniculatus*) in the furrows on the panspot site, the furrows revegetated slowly and for the first 3 years nearly all of the herbage was produced on the ridges (Table 2). However, within about 4 years the major forage species reestablished in the furrows and the furrow production was equal to or greater than that of the check plots but only about half that of the ridges. By 1976, furrow production was about 70% of ridge production on the panspot and saline-upland sites. The furrow production was two and a half times that of the check plots on the panspot site, but was not significantly different from that of the check plots on the saline-upland site. Thickspike-western wheatgrass accounted for most of the herbage production in the panspot furrows. On the saline-upland site, Nuttall alkaligrass was more productive in the furrows than on the ridges or check plots while alkali sacaton favored the ridges and the check plots more than the furrows.

Changes in percent composition 7 years after treatment are shown in Table 3. Most changes were beneficial, with the biggest changes occurring in the major forage species—Nuttall alkaligrass, alkali sacaton, and the thickspike-western wheatgrass. Tumblegrass and foxtail barley (*Hordeum jubatum*), which are of little forage value, also increased in the furrows of the panspot site. Foxtail barley was restricted almost entirely to those furrowed areas where water remained ponded for a considerable time. However, in 1976 tumblegrass and foxtail barley comprised only 2.0 and 1.2%, respectively, of the total grass yield.

Basal Cover

On the saline-upland site, only the basal cover of alkali sacaton and the shrubs was initially reduced by contour furrowing (Table 3). However, by 1974, there were no measurable differences in the check and contour-furrowed plots. On the panspot site, contour furrowing reduced the basal cover of nearly all species except thickspike-western wheatgrass and tumblegrass; these were increased. Contour furrowing reduced total basal cover from 15.72 to 4.28%, mostly due to a reduction in clubmoss from 9.38 to 0.36%. Disregarding clubmoss, the basal cover 7 years after treatment on the furrowed plots was still only about half that on the nonfurrowed plots (3.86 vs 6.35%). Blue grama and buffalograss were also significantly reduced by contour furrowing and accounted for much of the loss in total cover on the furrowed plots. Except for the first year after treatment on the saline-upland site, there were no measurable changes in shrub cover as a result of contour furrowing.

Soil Water

Increased soil water was the major beneficial effect of the contour furrowing treatments and was closely associated with changes in herbage production. In a previous paper, Neff and Wight (1977) reported that contour furrowing increased overwinter recharge 157 and 162%, respectively, on the saline-upland and panspot sites and

Table 2. A comparison of herbage production rates (kg/ha) in the furrows (F), ridges (R), and checks (C).

	1969			1972			1976			
Species	F	R	C	F	R	C	F	R	C	LSD
Saline-upland										
Nuttall alkaligrass	0	76	6	56	97	9	110	82	46	180
Alkali sacaton	0	2	66	0	87	40	79	211	100	121
Forbs	0	193	49	87	186	49	86	131	233	205
Total grass	0	155	102	182	355	123	188	292	178	97
Total yield	0	350	159	287	541	206	302	432	467	236
Panspot										
Thickspike-western wheatgrass	0	619	121	406	880	95	423	900	115	205
Foxtail	0	12	0	—	—	—	137	22	0	—
Forbs	0	188	22	97	55	27	388	312	31	185
Shrubs	0	28	10	3	10	17	0	9	40	32
Total grass	0	835	242	614	984	273	722	1364	365	207
Total yield	0	1051	274	714	1049	317	1111	1685	436	244

LSD (P=0.1) valid for within-year comparisons only.

Table 3. Basal cover and composition of species and species groups on check and furrowed plots.

	Basal cover %										Composition %	
	1968		1969		1970		1971		1974		1974	
Species	C[1]	F[2]	C	F	C	F	C	F	C	F	C	F
Saline-upland												
Thickspike-western wheatgrass	0.21	0.04	0.29	0.21	0.13	0.21	0.17	0.29	0.13	0.29	6.5	18.6
Nutall alkaligrass	0.17	0.21	0.25	0.25	0.04	0.17	0.08	0.29	0.08	0.21	4.4	13.8
Alkali sacaton	1.50	0.33*	0.71	0.17	0.83	0.21*	1.00	0.42*	0.71	0.50	52.0	32.4
Total grass	1.88	0.58*	1.29	0.75*	1.08	0.67*	1.29	1.08	1.08	1.17	74.9	77.1
Total forb	1.04	0.21	0.38	0.42	0.46	0.21	0.33	0.25	0.29	0.29	18.6	19.5
Total shrub	0.54	0.25*	0.21	0.04	0.04	0.00	0.00	0.00	0.13	0.04	6.5	3.3
Total cover	3.46	1.04*	1.88	1.21	1.58	0.88	1.63	1.33	1.50	1.50		
Panspot												
Thickspike-western wheatgrass	0.67	0.43	0.85	1.10	0.75	1.69*	0.63	2.40*	0.71	1.39*	5.4	35.5*
Blue grama	1.92	0.29*	1.64	0.32	2.46	0.60	1.58	0.35	1.82	0.61	15.8	14.6
Buffalograss	0.83	0.25*	0.97	0.26*	1.47	0.32*	0.88	0.42	1.29	0.17*	9.3	4.8
Sandberg bluegrass	0.58	0.18	0.53	0.47	0.81	0.26*	1.06	0.47*	1.08	0.57*	7.7	10.7
Tumblegrass	0.06	0.13	0.00	0.17*	0.00	0.13*	0.03	0.17*	0.04	0.26	0.2	6.2
Foxtail barley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.42	0.0	1.2
Cactus	0.83	0.06*	0.65	0.07*	0.42	0.07*	0.57	0.07*	0.24	0.08	1.8	1.8
Clubmoss	9.03	0.19*	10.13	0.31*	8.38	0.11*	8.75	0.26*	9.38	0.36*	47.9	7.0*
Big sage	0.81	0.42*	0.74	0.60	0.53	0.47	0.57	0.36	0.32	0.21	2.2	4.6
Total grass	5.33	1.38*	4.67	2.54*	5.92	3.10*	4.53	4.13*	5.63	3.24*	46.2	77.1*
Total forb	10.92	0.50*	11.15	0.85*	9.10	0.54	9.50	0.69	9.74	0.71	51.0	16.4
Total shrub	0.85	0.65	0.82	0.78	0.64	0.57	0.61	0.46	0.36	0.28	2.7	6.5
Total cover	17.10	2.53*	16.64	4.17*	15.65	4.21*	14.64	5.28*	15.72	4.22*		
Total minus clubmoss	8.07	2.33*	6.51	3.86*	7.28	4.10*	5.89	5.01*	6.35	3.86*		

[1] C = check.
[2] F = furrowed.
* Means significantly different from the check (P=0.1).

that this increase accounted for about 60% of the herbage production increase on the contour furrowed plots. In this study, contour furrowing increased available soil water, measured as cm-days, 107 and 36%, respectively, on the panspot and saline-upland sites. A regression analysis of the available soil water and yield data indicated that during 1969–75, 67% of the yield variation was explained by soil water differences. However, in 1976, only 40% of the yield variation could be accounted for by available soil water differences. This was due in part to infestations of yellow sweetclover on some of the contour-furrowed sites which, in some instances, more than doubled herbage production. We suspect that the ability of sweetclover to fix atmospheric nitrogen was the main reason for the high sweetclover production, which reemphasizes the role of N in limiting the productivity of these range sites.

Conclusions and Application

The results of this study show that contour furrowing is an effective tool for increasing soil water and herbage production on panspot and saline-upland range sites. Species composition changes were beneficial for increased production of grazeable herbage.

Where the inherent productivity is very low, as on the saline-upland site in this study, increases in productivity up to 200% may not be economically feasible. On the panspot site, productivity levels were approaching the range of economic consideration, and treatment application decisions would have to be based on current cost-benefit ratios which are determined primarily by treatment costs, treatment longevity, and livestock values. With a furrowing machine and furrow construction such as discussed by Neff (1973) and Wight (1973), furrowing treatments should cost less than \$50/ha (\$20/acre).

In a previous study on a similar range site, Neff (1973) estimated that furrows lost over half of their water detention capacity within 10 years and had an effective life (at least 1.3 mm water detention capacity) of about 25 years. The furrows in this experiment were carefully constructed with an original water detention capacity of about 40 mm. After 10 years, the furrows were well stabilized and still had about 20 mm water detention capacity. Their effective life should extend well beyond 25 years. Also, as indicated by the data of Soiseth et al. (1974), the beneficial effects of contour furrowing should be autocyclic—i.e., as more water enters the soil, salinity decreases and herbage production increases, resulting in increased infiltration and nutrient availability which, in turn, favors increased herbage production. Thus, the beneficial effects of contour furrowing may last well beyond the actual effective life expectancy of the furrows.

The furrowed panspot site plots averaged 527 kg/ha more herbage than did the check plots. Assuming only 50% utilization of the additional forage and 370 kg dry matter/AUM for summer grazing (Cook 1970), contour furrowing would increase the carrying capacity by 0.71 AUM/ha per year. For AUM values of \$3.00–\$6.00, contour furrowing would be worth from \$2.13–\$4.26/ha (0.86–\$1.72/acre) per year. The presence of a N-fixing legume, yellow sweetclover, in 1976, greatly enhanced the value of contour furrowing on the N-deficient soils. With a yield difference of 1,020 kg/ha between check and furrowed plots; contour furrowing would have been worth from \$4.14–\$8.28/ha per year (\$1.67–\$3.34/acre per year) in 1976. Also of value, but difficult to give monetary values, are the beneficial effects of contour furrowing for watershed protection and wildlife needs.

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