Runoff and Sediment Yields from Runoff Plots on Chained Pinyon-Juniper Sites in Utah

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Highlight: *Runoff and sediment production from a chained pinyon-juniper site in both southeastern and southwestern Utah was measured from about June 6 to October 1 over a 5-year period (1968–1972) using .04-hectare (0.11 acre) runoff plots. Treatments evaluated included chained-with-debris-windrowed, chained-with-debris-in-place, and natural woodland. All treatments were fenced to exclude livestock. Runoff events occurred at both sites during only 2 years (1968, 1970) of the study. Results indicate that chained-with-windrowing plots yield from 1.2 to 5 times more water during a runoff event than respective woodland plots. Runoff from debris-in-place plots was equal to or less than that measured from the natural woodland for all storms. Runoff data and sediment indexes indicate that when runoff exceeds about 0.1 cm from the woodland, from 1.6 to 6 times more sediment can be expected from windrowed sites than from adjacent woodland. Sediment yields from debris-in-place sites were similar to those from adjacent unchained woodland for all storms during this study.*

Hydrology of the pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) type has received increased interest over the last several years. One of the interesting aspects has been the influence of vegetation modifications on surface runoff and sediment yields. The most common method for modifying pinyon-juniper plant communities is by pulling a large anchor chain between two tractors to uproot the trees. Then, depending on debris disposal techniques, the site is drill or broadcast seeded to other more desirable species. As far as hydrologic performance of the plant community is concerned, the resulting change from woodland to grass-shrubs may significantly alter runoff quantities and resultant sediment discharge.

Studies outlined by Myrick (1971) indicate that chaining and burning of slash, followed by seeding, will cause an increase in runoff for the first couple of years following treatment, then runoff decreases as the new plants establish themselves. He indicates that size of storm may be an important factor in such evaluations. Baker et al. (1971) report the results of a 25-year storm (September, 1970) on alligator juniper (*Juniperus deppeana*) and Utah juniper (*Juniperus osteosperma*) watersheds on the Coconino National Forest in north central Arizona. In the Utah juniper type, the cabled (treated 1963, slash burned) and chemically treated (100 percent herbicide treated in 1968, no removal or burning) watersheds had 2.0 and 1.3 times, respectively, greater peak discharges than their woodland controls. The response of total runoff on the cabled and chemically treated watersheds was 2.1 and 1.3 times their respective woodland controls. There was no effect from a 5-year old treatment where the trees were felled and left in place. The sediment yield on the cabled juniper watershed was 2465 kg/ha (1.1

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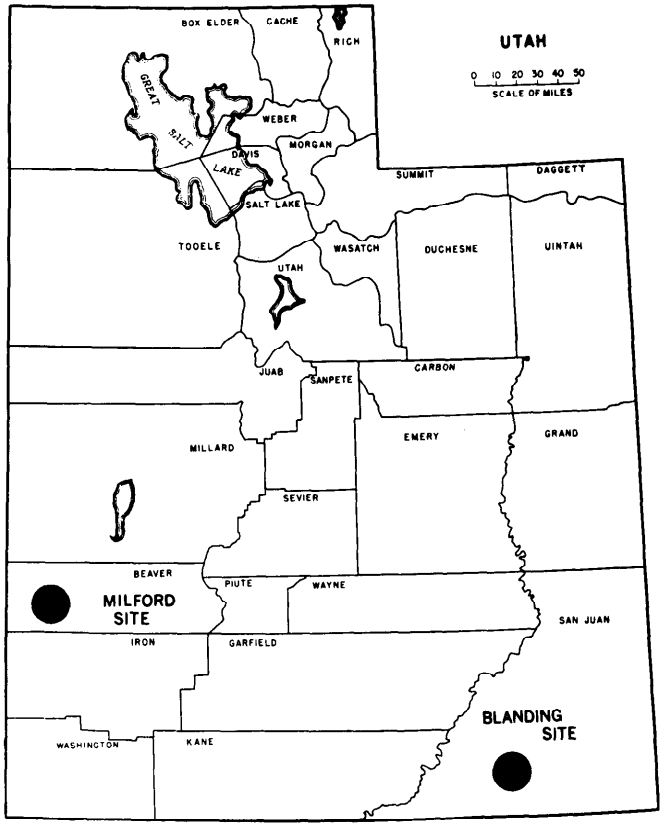

Fig. 1. *Map showing general location of the two study sites in southeastern and southwestern Utah.*

tons/acre) while sediment yield from the chemically treated watershed was 112 kg/ha (.05 ton/acre). Again, size of storm is important. Brown (1971) indicates that, for the various treatments on the same experimental area, there had been no significant changes in water or sediment yields as of November, 1969. Where only select portions of watershed have been treated, increased runoff may not be as noticeable (Collings and Myrick, 1966).

The objective of this study was to evaluate runoff and sediment production from about June 6 to October 1 for a 5-year period from pinyon-juniper sites chained-with-debris-windrowed, chained-with-debris-in-place, and natural woodland, using .04-hectare (.11 acre) runoff plots. It should be emphasized that 5 years is the minimum amount of time required for a study of this type in a semiarid situation. Results and conclusions must therefore be interpreted with this in mind, realizing that no information is available to define whether or not storm characteristics during this 5-year period were typical, below average, or above average for the two study sites.

Site Descriptions and Methods

The study was undertaken at two locations in southern Utah (Fig. 1). One site is located about 72 kilometers west of Milford and the other site about 70 kilometers west of Blanding.

Chaining treatments were applied at both sites in the fall of 1967, and included chaining with windrowing of debris and double chaining with debris-in-place. The windrowed treatments were drill seeded to crested wheatgrass (*Agropyron cristatum*) at 9.1 kilograms/ha (8 lb/acre) and the debris-in-place treatments were broadcast seeded (same rate) to crested wheatgrass. Treatments were applied to from 12 to 16 ha at each site. The two sites were then fenced to exclude livestock.

The Milford site is within the Basin and Range Province at an elevation of approximately 2,000 m. Parent material of the soil is basaltic rock. Soil profile depth is 1.3 meters. Soil texture varies from sandy loam to loam; average rock content (by weight) of the soil is 35%; pH averages about 8.0; and organic matter content generally ranges from 1.0 to 2.0%. The mature woodland has a canopy cover which averages 15% juniper (*Juniperus osteosperma*—350 trees/ha) and 10% pinyon (*Pinus edulis*—125 trees/ha). Brush cover averages 7% and is composed of big sagebrush (*Artemisia tridentata*), black sagebrush (*Artemisia nova*), and broom snakeweed (*Gutierrezia sarothrae*). Small amounts of phlox (*Phlox* spp.), *Lupine* spp., *Eriogonum* spp., *Penstemon* spp., and Indian ricegrass (*Oryzopsis hymenoides*) also occur as part of the understory.

The chaining-with-debris-in-place treatment at Milford currently has a 5 to 10% cover of big sagebrush and about the same amount of broom snakeweed. Ground cover consists primarily of weakly developed erosion pavement (30-60%), litter (20-45%), crested wheatgrass (*Agropyron cristatum*) (10-15%) and the balance bare ground. The chain-with-windrowing treatment currently has from 15 to 50% erosion pavement, 30 to 60% bare soil, 15 to 35% crested wheatgrass, and the balance litter (Table 1).

The Blanding site is within the Colorado Plateau at an elevation of about 2,150 m. The parent material of the soil is primarily sandstone, and the soil profile depth is 1.5 meters. Soil texture is mostly sandy loam with few, if any, rocks present; pH averages about 8.0; and organic matter content

Table 1. Average cover characteristics (%)[1] on .04-hectare runoff plots during 1968–71 at the Milford and Blanding study sites.

	Milford			Blanding		
Runoff plot	Tree[2]	Shrub	Ground[3]	Tree	Shrub	Ground
Windrow						
Treated						
1	0	1	83	0	1	43
2	0	0	36	0	0	33
3	0	0	48	0	0	49
4	0	0	64	0	0	36
5	0	0	26	0	0	40
Woodland control						
1	21	0	77	48	2	60
2	24	2	87	16	0	22
3	36	0	51	18	1	49
4	29	4	90	24	4	48
5	30	2	93	24	0	49
Debris-in-place						
Treated						
1	0	7	94	5	0	71
2	0	8	91	2	0	70
3	1	4	92	2	0	70
4	2	5	93	0	0	72
5	3	11	93	1	0	63
Woodland control						
1	26	14	84	41	0	45
2	21	14	95	39	0	55
3	18	12	88	34	0	43
4	26	6	90	45	0	61
5	24	4	92	46	0	60

[1] Percent cover in 1968 and 1969 determined from line transect data across each plot at 5.7, 9.9, and 22.2 m from top end of each runoff plot. During 1970 and 1971 an additional transect at 16.5 m from top end of each runoff plot was added. Measurements were made in September of each year.

[2] Includes both pinyon and juniper.

[3] Includes grasses, forbs, litter, rock, and erosion pavement.

averages slightly less than 2.0%. The mature juniper (500 trees/ha) and pinyon (200 trees/ha) canopy coverage averages 24 and 8%, respectively. Shrub cover is less than 1% and consists of big sagebrush. Bare ground and litter make up the balance. The bare ground category actually includes some cryptogam species present in the top 3 cm of soil.

The chaining-with-debris-in-place treatment at Blanding currently has a ground cover which consists primarily of 25 to 45% bare ground, 30 to 60% litter, and 12 to 20% crested wheatgrass. The chain-with-windrowing treatment currently has from 40 to 65% bare ground, 15 to 30% litter, and 17 to 25% crested wheatgrass cover (Table 1).

Paired runoff plots .04 hectare (0.11 acre) in size were used during the period of approximately June 6 to October 1 for each of 5 years to study runoff under natural summertime convectional rainfall (Fig. 2). The runoff plots were all located prior to the chaining in the fall of 1967 and were installed following the chaining treatments. There were separate controls for each treatment and five paired runoff plots per treatment, for a total of 20 plots per study site. Plot borders were defined by redwood boards carefully buried in the ground. The collection trench at the bottom of each plot was lined either with 6 ml polyethylene sheeting, 0.3-cm asphalt coated plywood, or 30-cm half-round corrugated 16-gauge steel, depending on the year. The area immediately below each collection trench was sloped and drained to prohibit flow back into the trench. Redwood boards 5 cm x 10 cm were used as a lip at the front of the trench when plywood or polyethylene sheeting was used. Each collection trench conveyed runoff water to a 30-centimeter Type HS flume with a Stevens Type F water level recorder. The runoff water then dropped into one end of a 2.1 x 0.6 x 0.3-m aluminum sediment tank with 2.5-cm baffles spaced at about 30-cm intervals on the bottom. When the tank filled, water ran out the opposite end. The tank simply provided a sediment index for each plot, since there was no attempt to collect all the runoff water. Sediment records are probably biased, therefore, toward the fraction of materials which would settle to the bottom of the tank before being carried out. Because of high rabbit populations at Milford, runoff plots were fenced during the spring of 1970 to exclude rabbits. No fencing was necessary at Blanding.

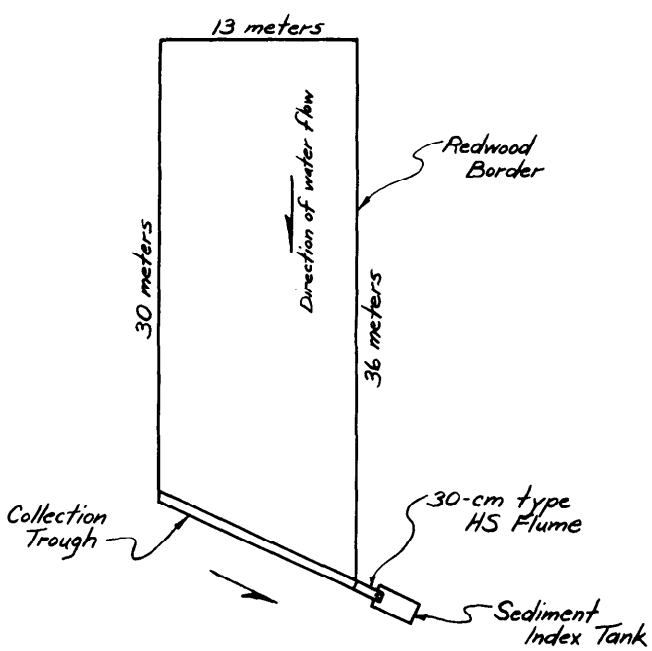

Fig. 2. *General layout of .04 hectare (0.11-acre) runoff plots.*

Two recording 20.3-cm (8-inch) raingages and several additional nonrecording 20.3-cm raingages are maintained at each site.

Table 2. Average runoff values (area centimeters) from paired runoff plots at Milford and Blanding. Each value is an average of five runoff plots.

Place and date	Total rainfall (cm)	Chain-with windrow		Chain-with debris-in-place	
		Woodland control	Treated	Woodland control	Treated
Milford					
7-30-68	4.19	1.96	3.23[2]	No record	No record
7-31-68	1.52	.30	.48[3]	No record	No record
8-08-68	1.78	.05	.18[3]	No record	No record
9-05-70	3.73	.18	.30[3]	.18	.05
Blanding					
7-28-68	1.14	.05	.18[3]	.05	0
7-30-68	1.14	.08	.23[1]	.08	.02
8-05-68	3.68	1.07	1.32[2]	.81	.36[3]
8-03-70	3.23	.13	.63[1]	.05	0
8-04-70	2.06	0.30	0.94[2]	.10	.05
8-16-70[4]	2.54	0.38	0.69[1]	.10	0[2]
8-19-70	1.90	0.41	0.81[2]	.08	.05

[1] Significantly different from woodland at .05 level of probability.
[2] Significantly different from woodland at .10 level of probability.
[3] Significantly different from woodland at .20 level of probability.
[4] Total precipitation on the windrowed site and adjacent woodland was 2.54 cm, while on the debris-in-place site and adjacent woodland total precipitation was 1.93 cm.

Results and Discussion

Runoff events occurred at both sites during only 2 years (1968, 1970) of the study. During 1968, plot construction was still underway, so some data on both runoff and sediment was lost. This was particularly true for sediment records.

Table 2 is a tabulation of runoff events recorded at the Milford site. During 1968 there were three storms of sufficient size and intensity to produce runoff. In all cases the chain-with-windrow plots yielded more water than plots in the woodland. The large amount of runoff recorded on July 30,1968, was a result of moist soils resulting from several consecutive days of small storms, plus high intensity rainfall. The only other runoff event at Milford was recorded on September 5, 1970, when 3.73 cm (1.47 inches) of rainfall fell, only a small part of which fell at intensities great enough to cause overland flow. Grass cover on the chain-with-windrowing area had increased significantly by 1970, but there is no evidence to indicate that the increased vegetal cover influenced runoff. From 1.6 to 1.7 times more water was yielded from chained-with-windrowing plots than was yielded from woodland plots for the three larger runoff events at Milford. As for debris-in-place plots, there were no records for 1968, and runoff from the September 5, 1970, storm was not significantly different from the natural woodland.

Table 2 also shows runoff events at the Blanding study site. The trend, regardless of year, is the same as at Milford. The only major runoff event recorded from debris-in-place plots during the entire 5-year study was during the storm of August 5, 1968. Even though ground cover (grass, forbs, litter) had increased from 11% or less on windrowed plots in 1968 to from 44 to 74% in 1970, more water was still being yielded from windrowed plots than from adjacent woodland plots. From 1.2 to 3.5 times more water was yielded from chained-with-windrowing plots than from woodland plots in

Table 3. Sediment index records (kilograms) from paired runoff plots at Milford and Blanding. Each value is an average of five runoff plots.[1]

Place and date	Total rainfall (cm)	Chain-with windrow		Chain-with debris-in-place	
		Woodland control	Treated	Woodland control	Treated
Milford					
8-08-68	1.78	0	0	No record	No record
9-05-70	3.73	0.5	3.0[4]	0.2	0.4
Blanding					
7-28-68	1.14	0	0	0	0
7-30-68	1.14	0	0	0	0
8-05-68	3.68	26.6	41.9	6.2	4.0
8-03-70[2]	3.23	0.8	3.2	0.3	0
8-04-70	2.06				
8-16-70[2]	2.54[3]	8.4	19.1[5]	1.7	1.5
8-19-70	1.90				

[1] Sediment records not available for storms of 7-30-68 and 7-31-68 at Milford.
[2] Sediment index records are combined for storms on these two dates.
[3] Total precipitation for two storms on the windrowed site and adjacent woodland was 4.44 cm, while on the debris-in-place site and adjacent woodland the total precipitation was 3.68 cm.
[4] Significantly different from woodland at .10 level of probability.
[5] Significantly different from woodland at .20 level of probability.

1968, and from 1.8 to 5 times more water was yielded from windrowed plots in 1970.

Sediment index records are given in Table 3. The runoff data and sediment indexes indicate that when runoff exceeds about 0.1 cm from the woodland, from 1.6 to 6 times more sediment can be expected from windrowed sites than from adjacent woodland. Sediment yields from debris-in-place sites were similar to those from adjacent unchained woodlands for all storms during this study.

Relationship of Runoff to Infiltrometer Studies

Infiltrometer studies at both the Milford and Blanding study sites have shown that mechanical disturbance on the chain-with-windrowing treatment results in a significant decrease in infiltration rates during select periods of a simulated storm (Gifford, et al., 1970; Gifford, unpublished data; Busby, unpublished data). Part of the reduction in infiltration rates on the windrowed treatments at the Blanding site can be attributed to destruction of cryptogamic soil crusts as a result of mechanical disturbance associated with chaining activities (Loope and Gifford, 1972). Infiltration rates on the chain-with-debris-in-place treatment have not been as greatly affected due to much less mechanical disturbance of surface soils.

Increased runoff from windrowed treatments (as compared to runoff from the woodland) seems logical, based on infiltrometer studies. However, why has there been no increase in runoff from the debris-in-place treatment? It appears that infiltration rates at given points on the debris-in-place treatment have been only slightly affected by the chaining activities. Apparently, in these instances, the debris left scattered on the soil surface acts as both retention and detention storage, the magnitude of which is large enough to minimize or nearly eliminate all runoff. The soil under the debris-in-place treatment is not able to absorb water any faster than is the soil under the woodland–it's just held on the landscape until the soil has the time to absorb it. Skau (1961) has estimated that the volume of pits alone (left after uprooting juniper trees) on a Beaver Creek watershed southwest of Flagstaff, Ariz., was enough to reduce surface flow .2 to .7 cm annually. That did not include influence of debris which was left scattered around. The debris-windrowed treatment does not have this added protection, and the potential for plant cover (even under protection from all grazing), under conditions of this study, was not great enough to reduce overland flow below that measured from the woodland. This is combined with the fact that nearly the entire windrowed treatment yields water during a runoff event while in a woodland most of the water is yielded from the interspaces between the trees, the result being a smaller contributing area within the woodland and, therefore, less water yield.

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