Influence of Prescribed Burning on Infiltration and Sediment Production in the Pinyon-Juniper Woodland, Nevada

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Highlight: On arid and semiarid rangelands, areas between woody plants are named dune interspaces. Soil and litter accumulate under plants to form mounds which are called coppice dunes. The loss of soil-protecting litter after burning pinyon-juniper communities in eastern Nevada decreased rates of water infiltration on coppice dune soil at field capacity and increased sediment production from coppice dunes with the soil dry and at field capacity. Differences in infiltration rates and sediment production of dune interspace soil were related to preburn soil morphological differences, not to burning. Vesicular soil crusts and surface-soil bulk density of coppice dunes were not increased by burning. Coppice soil organic matter was not significantly lower on burned areas, although mean values were slightly lower than those on unburned areas. Soil-water repellency was decreased by burning. Burning is not expected to increase runoff or soil loss substantially on similar areas with coarse-textured soils, because post-burn infiltration rates on coppices in these tests exceeded rainfall rates expected from natural storms.

Prescribed burning of rangelands invaded by pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) is a relatively inexpensive and effective vegetation-conversion technique (Aro 1971). Evaluation of the environmental consequences of prescribed burning and other range improvement practices should include information on the rate of infiltration of water and on the sediment production of associated soils. Infiltration rate is related to sediment production and peak floods from the intense summer thundershowers characteristic of the Great Basin (Blackburn 1975).

Chaining pinyon-juniper in Utah adversely affected infiltration and erosion rates only in a few instances, when windrowing treatments resulted in severe mechanical disturbance of surface soils (Gifford 1975). On arid and semiarid rangelands, areas between woody plants, named dune interspaces, produce more runoff and sediment than do areas under plants, named coppice dunes, where soil and litter accumulate (Blackburn 1975). However, fire may decrease infiltration rates and increase erosion on coppice dunes in the following ways: by destroying soil-protecting vegetation and litter (Hendricks and Johnson 1944); by decreasing porosity as a result of organic matter loss and the associated breakdown in soil structure (Wahlenburg et al. 1939); by clogging soil pores with suspended material (Beaton 1959); or by intensifying water repellency in various soil layers (Adams et al. 1970; DeBano and Krammes 1966; and Buckhouse and Gifford 1976). This study compared unburned and prescribed-burned communities of pinyon (*Pinus monophylla*) and juniper (*Juniperus osteosperma*) to determine the effect of burning on infiltration rate and sediment production and associated cover and soil factors.

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Study Sites and Methods

Prescribed burns and adjacent unburned areas on the same soil family were studied at two sites near the White River, in eastern Nevada. Both sites were alluvial fans with a 5% slope at the lower site and an 8% slope at the upper site. Both sites supported a scattered pinyon-juniper community (Blackburn and Tueller 1970) with a dominant understory of big sagebrush (*Artemisia tridentata*) and desert bitterbrush (*Purshia glandulosa*). Soils were derived from volcanic parent material and were interpreted as coarse-loamy, mixed, mesic; and loamy-skeletal, mixed, mesic soil families of Aridic Argixerolls at the lower and upper study sites, respectively. Prescribed burning was done in April and May, 1975, and was evaluated 1 to 2 months and 1 year after burning.

Simulated rainfall was applied at the rate of 8.38 cm/hour for 1 hour with a mobile infiltrometer and methods described by Blackburn (1975). Fixed plots of 0.9144 by 0.9144 m or variable-sized runoff plots were used. Infiltration was measured with the soil surface initially air dry and at field capacity 24 hours later. Plots were positioned to contain 100% coppice-dune or dune-interspace soil. Six replications were included for each unburned and burned area of dune interspace and for each type of coppice dune (pinyon, juniper, big sagebrush, and bitterbrush). Infiltration was defined for any point in

Table 1. Mean infiltration rate (cm/hr) on unburned and burned coppice-dune and dune-interspace soils of scattered pinyon-juniper communities near the White River, Nevada.[1]

	Infiltration rate (cm/hr)							
	Tree coppice		Shrub coppice		All coppice		Interspace	
Site and treatment	Dry	F.C.	Dry	F.C.	Dry	F.C.	Dry	F.C.
Lower site								
Unburned	8.32a	8.26a	7.82a-c	7.25c	8.07a	7.76a	5.76ab	3.75c
Recent burn	8.13ab	7.47bc	7.77a-c	6.29d	7.95a	6.75b	5.94a	3.27cd
Year-old burn	8.20ab	7.80a-c	7.23c	5.72d	7.71a	6.76b	4.53bc	2.25d
Upper site								
Unburned	8.28a	8.22a	8.02a	7.42ab	8.15a	7.82a	4.12b	1.95c
Recent burn	7.84a	6.55cd	7.97a	6.81bc	7.91a	6.68b	3.86b	2.51c
Year-old burn	8.13a	7.58ab	7.55ab	5.83d	7.84a	6.71b	5.97a	3.85b

[1] Means followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple range test. Comparisons are made within sites, between moisture conditions (F.C. = Field Capacity), among and within rows and columns for tree and shrub coppice, and within columns for all coppice and for interspace.

time as the difference between total water applied and total runoff. Runoff from plots was funneled into buckets and pumped out and weighed in 5-minute intervals. Sediment was collected from a 900-ml runoff sample and sediment trapped in the collection apparatus. Samples were oven-dried and weighed before conversion to sediment loss (kg/ha).

Percentage of the ground covered by litter, rock, vegetation (grass, forbs, and tree and shrub seedlings only), and bareground were estimated visually for each plot. Large trees and shrubs were trimmed to near-ground level. Average litter depth and percentage of litter cover were converted to litter volume.

Soil temperatures were recorded at 0-, 1-, and 2-cm depths with Type K thermocouples before, during, and after burning.

Percent of plot area with a vesicular surface crust was estimated and was multiplied by a one-to-five rating to reflect vesicular horizon thickness and development. One represented well-aggregated soil with no vesicular crust, and five represented a vesicular crust thicker than 5 cm. This number was then divided by five to give index values of percent of vesicular-horizon development on each plot.

After each field capacity test, the percentage of dry, water-repellent area was noted. Bulk density at 5- and 10-cm depths and antecedent soil moisture content were determined on coppice and interspace areas adjacent to runoff plots with a Troxler surface-moisture density gauge. Particle-size distribution of coppice and interspace surface horizons was measured by the hydrometer technique (Bouyoucos 1962). Organic matter content of coppice and interspace surface horizons was determined by the Walkely-Black method (Black 1965).

Analysis of variance was used to compare terminal infiltration rate and sediment production at the end of 60 minutes with measured soil and vegetation variables. A multiple regression and correlation and a ridge regression (Hoerl and Kennard 1970) were used to determine those factors most influential in causing variation in infiltration and sediment production.

Results and Discussion

Infiltration Rates

At both sites infiltration rates on burned coppices were significantly lower than those on unburned coppices with the soil at field capacity, but they were similar with the soil initially dry (Table 1). Infiltration rates were generally similar for pinyon and juniper coppices and for sagebrush and bitterbrush coppices. Shrub coppices generally had lower infiltration rates than tree coppices on unburned and burned areas. Also, infiltration on shrub coppices tended to be lower 1 year after burning than immediately after burning.

Interspaces on the 1-year-old burn at the lower site had lower infiltration rates than interspaces on the unburned and recently burned areas. In contrast, interspaces on the 1-year-old burn at the upper site had higher infiltration rates than interspaces on the unburned and recently burned areas. Interspaces always had lower infiltration rates than did coppices.

Sediment Production

At both sites sediment production from burned coppices was generally significantly higher than that from unburned coppices, both with the soil dry and at field capacity (Table 2). Generally, sediment production between the two tree species and between the two shrub species had greater similarity than did production among tree and shrub species. Tree coppices produced more sediment on all burned treatments than on all unburned treatments, except that at the lower site the 1-year-old burn produced the same amount of sediment as did unburned with the soil dry. Shrub coppices generally produced more sediment than tree coppices, and sedimentation tended to increase with the age of the burn.

Table 2. Mean sediment production (kg/ha) on unburned and burned coppice-dune and dune-interspace soils of scattered pinyon-juniper communities near the White River, Nevada.[1]

	Sediment (kg/ha)							
	Tree coppice		Shrub coppice		All coppice		Interspace	
Site and treatment	Dry	F.C.	Dry	F.C.	Dry	F.C.	Dry	F.C.
Lower site								
Unburned	49e	50e	397cd	572b-d	140c	157bc	932a	850a
Recent burn	181d	194d	630bc	1,046a-c	338ab	456a	666a	870a
Year-old burn	55e	190d	1,229ab	1,861a	262a-c	602a	1,697a	2,753a
Upper site								
Unburned	105d	98d	537bc	813a-c	240c	282c	1,445a	1,820a
Recent burn	389c	603bc	794a-c	1,096ab	550ab	813ab	1,047a	2,188a
Year-old burn	457bc	741a-c	1,148ab	1,585a	724ab	1,072a	997a	1,145a

[1] Means followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple range test. Comparisons are made within sites, between moisture conditions (F.C. = Field Capacity), among and within columns for tree and shrub coppice, and within columns for all coppice and for interspace.

Table 3. Soil and cover factors influencing infiltration rates and sediment production, ranked in order of relative importance as indicated by the accompanying standard partial regression coefficients (in parenthesis); soil at field capacity.[1]

Infiltration rate		Sediment production	
Lower site	Upper site	Lower site	Upper site
$R^2 = 0.70$	$R^2 = 0.75$	$R^2 = 0.54$	$R^2 = 0.46$
Vesicular horizon development (−0.44)	Vesicular horizon development (−0.49)	Bare ground (0.47)	Litter volume (−0.43)
Bare ground (−0.38)	Litter cover (0.25)	Litter volume (−0.37)	Bare ground (0.28)
0−5 cm bulk density (−0.16)	Organic matter (0.25)		Vesicular horizon development (0.11)
	0−10 cm bulk density (−0.16)		
	Litter volume (0.11)		

[1] Read in columns by study site, most important variable listed first. All R^2 values are significant at the 0.01 level.

Interspaces generally produced more sediment than coppices overall, but sediment production for interspaces and shrub coppices was similar on burned areas. Sediment production tended to be lower with higher interspace infiltration rates.

Associated Factors

Important variables in the regression equations for infiltration and sediment production reflected soil morphological or cover differences that resulted either from burning or from inherent, preburn differences among coppice types, among interspace areas, or between coppice and interspace areas. The most important factors influencing infiltration rates were vesicular horizon development, bareground, litter cover, surface-soil bulk density, volume of litter, and surface-soil organic matter (Table 3). Important factors correlated with sediment production included vesicular horizon development, volume of litter, and bare ground (Table 3).

Soil temperatures recorded before, during, and after burning suggested that spring burning probably affected soil litter cover but was too cool (less than 50°C deeper than 1 cm) to cause soil morphological changes.

Analysis of variance and comparison of mean values of independent variables in regression equations indicated that, on coppices, vesicular horizon development and bulk density were not increased nor was soil organic matter significantly decreased by burning (Table 4). However, coppices had less vesicular horizon development, lower bulk density, and higher organic matter content than did interspaces in both unburned and burned areas. Data on these three variables, then, mainly reflected the inherent differences between coppice and interspace areas and not burning effects. Because dune interspaces have less vegetative cover and less litter accumulation, they receive less organic matter than do coppice dunes. Low soil organic matter is associated with high bulk density and the formation of a platy to massive vesicular surface horizon (Wood 1976), which readily slakes when wetted and has the low infiltration rate associated with high sediment production (Blackburn 1975).

Differences in cover and volume of litter best explain differences in infiltration rates and sediment production among unburned and burned coppices and among tree and shrub coppices. Litter protects the soil surface structure and porosity from destruction by reducing raindrop impact, allowing high infiltration rates, and controlling sediment production over a period of wetting. Because tree coppices generally had more litter cover and volume and less bare ground than did shrub coppices on all treatments (Table 4), infiltration rates were generally higher (Table 1) and sediment production lower (Table 2) on tree coppices than on shrub coppices.

Burned tree and shrub coppices had less cover and volume of litter and more bare ground than did unburned tree and shrub coppices (Table 4). Burning converted much of the coppice litter to light ash or charred fragments, some of which settled on the soil, with the rest blown away by post-fire winds. Coppices on the 1-year-old burns at the upper site generally had less litter cover and volume and more bare ground than coppices on recent burns. The tree coppices on the 1-year old burn at the lower site were on the edge of the burn and much of their litter was left in

Table 4. Mean values of soil and cover factors influencing infiltration rates and sediment production for unburned and burned pinyon-juniper sites near the White River, Nevada.[1]

Factor	Lower site			Upper site		
	Unburned	Recent burn	Year-old burn	Unburned	Recent burn	Year-old burn
Coppice vesicular horizon development (%)	3 ab	6 a	1 b	4 a	3 ab	1 b
Interspace vesicular horizon development (%)	61 a	59 a	82 a	84 a	52 ab	54 a
Coppice 0–10 cm bulk density (g/cm^3)	1.54	1.54	1.61	1.60	1.61	1.57
Interspace 0–10 cm bulk density (g/cm^3)	1.59	1.59	1.64	1.57	1.76	1.67
Coppice soil organic matter (%)	6.2 a	–[2]	5.9 a	7.7 a	–	6.6 a
Interspace soil organic matter (%)	2.3 a	–	3.1 a	0.6 a	–	3.6 a
Tree coppice bare ground (%)	1 d	25 b	6 c	1 f	19 de	27 cd
Shrub coppice bare ground (%)	17 b	80 a	78 a	10 e	45 bc	91 a
Tree coppice litter volume (dm^3)	43.0 a	8.3 c	21.0 b	32.0 a	12.0 b	8.6 bc
Shrub coppice litter volume (dm^3)	5.5 c	0.2 d	0.4 d	4.5 c	0.6dd	0.03 d
Tree coppice litter cover (%)	95 a	46 a	80 a	90 a	53 a-c	48 bc
Shrub coppice litter cover (%)	64 ab	13 c	12 c	78 ab	23 d	6 e

[1] Means followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple range test. Statistical comparisons are made among values within sites and within rows for coppice and interspace factors and within sites and within rows and columns for tree and shrub coppice factors.
[2] Organic matter comparison done after 1 year only.

place, while most of the shrub-coppice litter was destroyed by the fire. This explains the relatively high infiltration rates and low sediment production of the tree coppice for that 1-year-old burn treatment.

Litter volume explained the variation in sediment production better than the variation in infiltration rates. Unburned tree coppices with deep litter accumulation maintained high infiltration rates with a minimum of sediment production, even with the soil at field capacity. The loss of litter cover from burning, then, was the major cause of lower infiltration rates and higher sediment production on burned coppice dunes.

A 1- to 2-cm-thick water-repellent soil layer existed under the heavily decayed litter of some pinyon and most juniper trees. This nonwettable layer had little effect on infiltration rates and sediment production, because simulated rainfall infiltrated small wettable spots around the water-repellent areas and wet the soil below the repellent areas. Where fire destroyed most of the litter layer, most water repellency at the soil surface evidently was also destroyed; water-repellent areas were much less extensive on burned than on unburned coppices.

Infiltration rates differed among dune interspaces because of soil morphological differences. The vesicular pores were largest and the vesicular horizon was thickest in the middle of the dune interspaces. The vesicular pores decreased in size and the horizon became thinner near the coppice dune areas of litter additions. The vesicular horizon generally gave way abruptly to well-aggregated, weak, fine, subangular, blocky soil near the periphery of the coppice dunes. The soil aggregate stability and, consequently, the infiltration rate and sediment production of a particular dune interspace were, therefore, related to its proximity to surrounding vegetation, which added soil organic matter by litter fall and decomposition.

At the lower site infiltration rates of interspaces were lower on the 1-year-old burn than on unburned plots due to their greater vesicular horizon development (Table 4). Additional soil-surface examinations indicated that this difference probably resulted from the positions of interspace plots relative to coppice dunes and not from burning. Interspaces on the year-old burn at the upper site had higher surface-soil organic matter content than did unburned interspaces, resulting in less vesicular horizon development and, thus, higher infiltration rates (Table 4). The high organic content resulted from a higher preburn density of trees and shrubs on that particular burned area than on the unburned area. Indications are that variations in infiltration rates and sediment production on interspaces were not due to burning.

Conclusions

Sediment production from raindrop splash should be higher on burned than on unburned coppice dunes due to the absence of soil-protecting vegetation and litter cover, even if coppice infiltration rates are not exceeded. A thunderstorm of sufficient duration and intensity to exceed infiltration rates of coppice dunes on burned areas would produce much more sediment than would be produced on unburned areas. The associated increase in overland fow through dune interspace areas would also increase erosion of coppice dunes. However, the soils studied in these tests were coarse-textured and had relatively high infiltration rates. Even after burning and with the soil at field capacity, coppice infiltration rates were well above the 1-hour, 100-year return-storm intensity of 3.4 cm/hour for the area (Miller et al. 1973). Because most natural storms are less intense and shorter than the simulated thunderstorm used in the study, they will probably not exceed infiltration rates on burned coppice dunes. Prescribed burning of similar areas will probably not increase runoff and soil loss. Burning during cool and wet times of the year will reduce the loss of coppice litter and thus help maintain high infiltration rates and low sediment production.

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