Some Responses of Riparian Soils to Grazing Management in Northeastern Oregon

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Abstract

Infiltration, sediment production, penetrometer penetrability and bulk density were measured on control/treatment paired plots of several grazing schemes in a riparian zone of northeastern Oregon. Treatments were in effect over a period of 5 years. Rest-rotation favored the hydrologic parameters measured, while deferred rotation and season-long did little to enhance, and sometimes hindered, hydrologic expression. Late-season grazing in September demonstrated a positive hydrologic response, whereas late-season grazing in October was negative—probably due to the onset of fall rains and a change in soil moisture conditions.

Although land managers generally acknowledge that the rate at which an upland soil accepts water largely determines erosion rates, surface ponding, soil moisture, and ground water recharge, little attention has focused on infiltration in riparian areas. Infiltration into the soil may influence stream systems because erosion delivers sediment and nutrients to the stream, and discharge and dissolved salt concentrations respond differently to runoff and groundwater flows (Morisawa 1968). Infiltration, therefore, may be of particular interest in a riparian zone, which is the last terrestrial area water crosses before entering the stream. Furthermore, compaction and low infiltration rates may interfere with the riparian zone's function as a stream source area. These areas contribute to streamflow according to rainfall characteristics and the water storage and transmission properties of the soil (Branson et al. 1981).

Several studies have linked cattle grazing with changes in upland soil properties (Gifford and Hawkins 1978, Moore et al. 1979, Branson et al. 1981, Gifford 1981). Livestock on upland systems can increase soil compaction and depress infiltration by grazing protective plant cover, reducing soil organic matter, and trampling the soil surface. The physical disturbance and removal of protective vegetation by grazing animals may dislodge soil particles, thereby increasing the potential for sediment production. Although there is little documentation of the effects of cattle grazing on soil properties in a riparian zone, the close linkage between grazing, soil-water relations, and plant communities on the uplands suggests that a similar pattern in the stream bottoms may exist. In fact, the moist riparian soils may be particularly subject to compaction and its attendant impacts on water transmission and root growth and aeration. Moist soils are generally more vulnerable to compaction and riparian areas tend to be moist more often and for longer periods than upland soils because (1) water is directed downslope to the riparian zone, (2) water does not run off flat floodplains and meadows as readily as off slopes, and (3) the water table is high in riparian areas. Increased sediment production from animal disturbance is also a concern in the riparian zone, where there is little or no opportunity for dislodged soil particles to settle before reaching the stream. In many areas, however, livestock production currently depends on access to streams for drinking water, and the reduction or exclusion of livestock is economically undesirable . Consequently manipulation of soil condition through the use of a particular grazing system may be an attractive option.

In 1975, the U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station initiated a multidisciplinary case study at Meadow Creek on the Starkey Experimental Forest and Range in northeastern Oregon. The study was conducted through the Range and Wildlife Habitat Laboratory in La Grande, Ore., and spanned 7 years. One objective was to compare infiltration rates, sediment production, and compaction associated with different systems of grazing cattle in a historically deteriorated riparian zone.

Site Description

The Starkey Experimental Forest and Range is located in the Blue Mountains about 48 km southwest of La Grande, Ore. The study area includes approximately 8 km of stream coursing in open ponderosa pine-Douglas fir forest. The floodplain rises about 1 meter above mean water level at low flow and averages 23 meters wide. Soil data is sketchy, but preliminary soil maps on file at the Range and Wildlife Habitat Laboratory in La Grande generally describe interspersed patches of well-drained Veezie gravelly loam (coarse-loamy over sandy or sandy-skeletal, mixed mesic cumulic haploxerolls) and Voats sandy loam (sandy-skeletal, mixed mesic fluventic haploxerolls). Areas of unvegetated riverwash also exist, as well as an occasional boggy patch. Average annual precipitation is 50 cm, occurring primarily as winter snowfall, with some contribution from spring and fall rain.

In the first part of this century, the study area was subjected to logging operations, which included roads and a splash dam, and to heavy livestock grazing. The Forest Service dedicated the Starkey Forest for research purposes in 1940 and began to regulate the land use activities and reduce grazing pressure (Skovlin et al. 1976). Although vegetation in the pastures gradually improved, the stream bottoms continued to be heavily used as cattle concentrated there for water and succulent forage (Strickler per. comm. 1980). Rocky Mountain elk *(Cervus elaphus nelsoni)* use the Forest primarily for spring and fall range, and mule deer *(Odocoileus hemionus hemionus)* are present year-round.

Methods

Stocking Systems

The area immediately adjacent to Meadow Creek was fenced into several small, contiguous pastures (Fig. 1) and stocked June through October with yearling heifers at the moderate rate used on the Starkey Forest as a whole (3.2 ha/AUM). These pastures held 2 to 20 heifers, depending on the pasture size and grazing system (Table 1). Because of the small pasture size, the number of animals using the riparian area was less than occurred on large pastures stocked at similar rates.

The following management options were applied to the Meadow Creek pastures: four-pasture rest-rotation, deferred rotation, season-long grazing, and no grazing. Rest-rotation pastures followed a pattern of rest, grazing late June–mid-August, grazing season-long, grazing mid-August-mid-October. Deferred rotation pastures were grazed alternate years, late June–mid-August and

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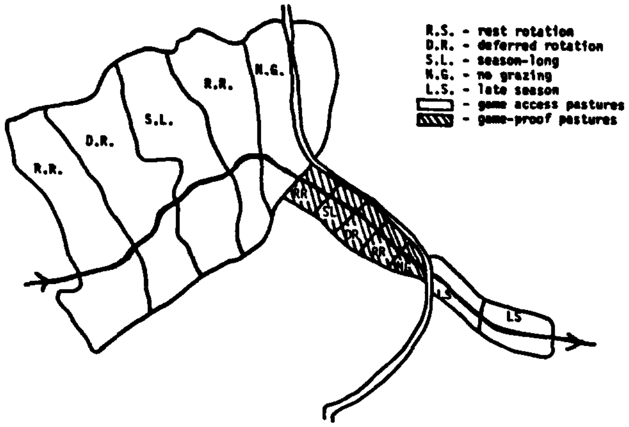

Fig. 1. *Diagram of Pastures on Meadow Creek.*

mid-August–mid-October. Season-long grazing lasted from late June–mid-October. Big game were allowed access to all treatments in one area and excluded from the same treatments in another area. In addition, short-duration, high-intensity, deferred-rotation grazing was tested in September and October. All pastures contained a small control exclosure.

Sampling Infiltration

Infiltration rates were estimated with a Rocky Mountain infiltrometer (Dortignac 1951) and a ring infiltrometer (Haise et al. 1956, Bertrand 1965) on paired treatment-exclosure plots in each grazing system. All plots were moistened and allowed to drain prior to testing to alleviate differences due to antecedent moisture. Ocular estimates of vegetative cover were recorded for interpretive use. The Rocky Mountain infiltrometer plots received 28-minute applications of simulated rainfall at a rate of approximately 7 cm/hour. This was the lowest application rate of the machine, simulating severe storm conditions for the area. Three 76.2 × 30.5 cm subplots were sampled at every plot early in the grazing season each year. The average infiltration rate from 5-minute intervals for times 3-28 minutes and the final rate on all treatments were calculated and used in separate analysis of variance (ANOVA) and least significant difference (LSD) tests. Tests were made in 1975, 1976, 1980, and 1981. In calibration years (1975 and 1981) the pastures were not stocked with cattle. Potential sediment production was measured from runoff produced on the Rocky Mountain infiltrometer plots.

Fifteen-centimeter diameter cylinders were used as single ring infiltrometers in early summer 1980, late summer 1980, and early summer 1981. Some pastures were too stony to properly set the rings and were dismissed as unsuitable. Pastures where soils were suitable were tested in exclosure-treatment pairs. Mean and final infiltration rates were calculated from the time needed to drain 10 cm of water and used in separate ANOVA and LSD tests. Rate measurements were attempted at 9 subplots for each plot in each season, but the actual sample size varied somewhat due to problems with rocks and animal burrows. The numerical estimates from both types of infiltrometers were useful for establishing trends, but should not be considered absolute values.

Sampling Soil Density and Bulk Density

Soil bulk density and penetrability were also estimated concurrently at the ring infiltrometer plots (Blake 1965, A.S.A.E. 1975). Eighteen measurements, to a depth of about 3 cm, were collected from each plot with a proving ring penetrometer in early summer 1980, late summer 1980, and early summer 1981. Three gravimetric soil cores per plot were collected through the duff layer into the upper 3.8 cm of soil in early summer 1981 and analyzed for bulk density. Differences between treatments and their paired exclosures were tested by one-way ANOVA and LSD.

Statistical Analysis

The Meadow Creek Study was designed as a case study and, as such, was not replicated. Statistical analysis was performed on multiple samples within a treatment as a guide in interpreting trends and processes specific to the conditions on Meadow Creek. The infiltration analysis examined patterns between treatment-exclosure pairs rather than comparing absolute values. Data of this nature are usually analyzed one of two ways—either for changes over time at a particular site or for differences between a treated area and a control. Neither of these approaches was entirely appropriate for these data because analysis for changes over time did not account for environmental influences other than the treatment, and treatment-control comparisons were only valid when both plots had equal value for the parameters at the first measurement. This is a difficult restriction in riparian areas where soil types and conditions often occur in extremely small, irregular patches due to channel changes and other hydrologic occurrences. Large sample sizes may be required and paired plots may not always have the same absolute values on test parameters. Therefore, an analysis was devised which employed part of each technique to examine trends rather than absolute values. First, each plot was analyzed

Table 1. Meadow creek stocking schedule.

Grazing treatment	Approx. pasture size (ha)	No. of animals	Stocking[1] rate	Approx. stream frontage	Meters of stream/animal/season
Big Game Access					
rest rotation	73.8	20 or 0	3.2 ha/AUM	544	27
deferred rota.	82.0	20	3.2 ha/AUM	444	22
season-long (5)	56.6	10	3.2 ha/AUM	409	41
rest rotation	61.2	0 or 20	3.2 ha/AUM	538	27
no grazing	49.0	0	—	352	—
Big Game-Proof					
rest rotation	5.7	4 or 0	3.2 ha/AUM	238	60
season-long (5)	4.7	2	3.2 ha/AUM	206	103
deferred rota.	4.7	4	3.2 ha/AUM	174	44
rest rotation	4.1	0 or 4	3.2 ha/AUM	257	64
no grazing	4.0	0	—	248	—
Late Season					
September	6.2	12	.85 ha/AUM	648	54
October	5.7	12	.77 ha/AUM	397	33

[1]Stocking rate to achieve 70% utilization.

for statistically significant change over time. Then, significant changes for each treatment plot were graphically compared with the response on its paired exclosure plot to, in effect, remove any environmental influences which would have affected both plots equally. Treatment response was indicated when significant changes on the treatment differed from those found on the paired exclosure. Several treatment-exclosure combinations were possible and each combination was coded as "plus", "minus" or "zero" based on the treatment's response to its paired exclosure (Table 2).

Table 2. Treatment response code for trends index in soil infiltration.

Exclosure plot	Treatment plot	Trend index
↑	↑	+
↑	no change	—
↑	↓	—
no change	no change	0
no change	↑	+
no change	↓	—
↓	↓	0
↓	no change	+
↓	↑	+

↑ = infiltration rate increase over time (1975 vs. 1981)
↓ = infiltration rate decrease over time (1975 vs. 1981)
+ = positive trend (increased infiltration rate) attributable to treatment
– = negative trend (decreased infiltration rate) attributable to treatment
0 = no change in trend attributable to treatment

When long-term data were not available (ring infiltration, bulk density, and penetrability), treatment-exclosure pairs were assumed to be comparable and tested directly with the *t*-test, ANOVA and LSD statistical tests. These results were also coded (Table 3).

Results

Long-term effects on infiltration were estimated from comparison of the Rocky Mountain infiltrometer infiltration rates at 28 minutes in 1975 and 1981. Infiltration increased in several control exclosures, suggesting a process of recovery from the previous heavy grazing. Rest-rotation grazing and no grazing appeared to follow the same patterns found in their paired control exclosures, while deferred rotation and season-long grazing responded negatively relative to their paired control exclosures, regardless of big game accessability. Rocky Mountain infiltrometer data indicated that the September late-season grazing treatment responded similarly to its paired control; however, the October late-season grazing treatment had lower infiltration rates than did its control (Table 4).

Table 3. Treatment response code for ring infiltration, soil penetrability and bulk density trend indices.

Soil attribute	Net response	Coded trend index
Ring infiltration	increase	+
	decrease	–
	no difference	0
Penetrability	increase	+
	decrease	–
	no difference	0
Bulk density	increase	–
	decrease	+
	no difference	0

Sediment production, as estimated from "Sprinkler" runoff, followed the same pattern as infiltration; the response of rest-rotation and no grazing treatments corresponded to their paired exclosures, while season-long grazing on the game-proof pasture had a negative response relative to its paired exclosure (Table 4).

If conditions are assumed to have been similar within each treatment exclosure pair in 1975, then changes over time can be estimated by comparing 1975 to 1981 treatment-exclosure ring infiltrometer results. Although these comparisons are not as well defined as the "sprinkler" results, they suggested that rest-rotation plots in the game-proof exclosures demonstrated a positive response relative to their paired controls; whereas the rest-rotation plots in the game-access plots were neutral. Season-long grazing plots were negative compared to their controls, in either case. Deferred rotation was negative in the big game access plots, but neutral in the game-proof pastures. Late-season grazing in October produced a negative ring infiltration response although September grazing had no effect.

Because soil compaction tests were not initiated until 1980, long-term changes were estimated by comparing conditions on treatment-exclosure pairs in 1981. This approach assumed that conditions in each half of a pair were equivalent at the onset in 1975. Compaction, as indexed by a proving ring penetrometer, increased significantly on all tested treatments with big game access. Where big game were excluded, the rest-rotation, deferred rotation, season-long and no grazing treatments did not compact

Table 4. Effects of grazing management on soil properties, a summary of the trend indices, 1975 to 1981 (0.05 significance)[1]

Grazing treatment	Rocky Mt.[2] infiltrometer	Sediment[2] production	Ring[3] infiltrometer	Penetrability[3] penetrometer	Bulk density[3] (soil cores)
Game access					
rest rotation	+	no data	0	—	—
deferred rotation	—	no data	—	—	0
season-long (5 yrs)	—	no data	—	—	0
rest rotation	0	0	no data	no data	no data
no grazing	+	+	0	—	0
Game-proof					
rest rotation	+	no data	+	0	0
season-long (5 yrs)	—	—	—	—[4]	—
deferred rotation	—	no data	0	0	0
rest rotation	0	no data	no data	no data	no data
no grazing	+	no data	no data	0	no data
Late season					
September	+	no data	0	0	0
October	—	no data	—	—	0

[1]See Tables 2 and 3 for further explanation of response symbols.
[2]Treatment response trend, relative to exclosure.
[3]Compares treatment to exclosure statistically.
[4]Plot located on trail.

significantly (Table 4). However, comparisons between big game pastures and game-proof pastures may not be valid in this study since the big game pastures extended onto the uplands and were larger than those which excluded game, and therefore required approximately 5 times more livestock than the smaller pastures to maintain the prescribed stocking rate. Stream frontage remained approximately constant for all pastures so animal impact per unit of streamside area may have been greater on big game pastures. The data may, therefore, reflect greater livestock use of the riparian area rather than big game use. Late-season grazing in October has a negative trend, but late-season grazing in September was neutral.

Bulk density increased significantly only on 1 of the 2 rest-rotation pastures which allowed big game access and on the season-long grazing which excluded big game. No other grazing systems affected bulk density.

Summary

Infiltration rates improved in several of the exclosures between 1975 and 1981, implying that a process of recovery from historical abuses was occurring. Few examples of pristine riparian areas like the one studied here exist for comparison, so "recovery" here may be defined for management purposes as an increase in infiltration rate and decrease in compaction and sediment production. The process of recovery has been recognized in other studies and is usually linked with a period of rest (Gifford and Hawkins 1978, Moore et al. 1979, Branson et al. 1981, Gifford 1981).

Rest-rotation appeared to favor recovery, while deferred rotation and season-long grazing did little to enhance it and sometimes actually seemed to hinder it. The positive infiltration response to the short-duration, high-intensity deferred rotation grazing scheme in September and the negative response to the same application in October probably reflected altered soil conditions in October due to the onset of fall rains.

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