GRAZING AND HAYING EFFECTS ON RUNOFF AND EROSION FROM A FORMER CONSERVATION RESERVE PROGRAM SITE

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ABSTRACT. *Grazing and haying effects on runoff and erosion from a former Conservation Reserve Program (CRP) site near Streeter, North Dakota, were determined. Treatments included undisturbed CRP, twice-over rotational grazing, season-long grazing, haying, and burning. Runoff and erosion were measured from simulated rainfall which was applied to 3.7 × 10.7 m (12.0 × 35.1 ft) plots. Following an initial stabilization period, no significant difference in runoff or erosion was found between the season-long grazing and burned treatments. Use of the CRP site for grazing or haying resulted in a significant increase in runoff compared to leaving the area in an undisturbed condition. Similar amounts of erosion were measured from the twice-over rotational grazing, season-long grazing, and hayed treatments. If adequate canopy and basal cover is maintained, use of this CRP site for grazing or haying would not be expected to result in excessive erosion.* **Keywords.** *Burning, Erosion, Grazing management, Haying, Hydrology, Runoff.*

The Conservation Reserve Program (CRP) was initiated to remove environmentally fragile areas from crop production. Approximately 14.8 million ha (36.5 million acres) of cropland, primarily west of the Mississippi River, were enrolled in this program (Taylor et al., 1994). To participate in the CRP, producers were required to convert cropland to vegetative cover for a 10-year period. The principal objectives of the CRP were to reduce erosion on highly erodible cropland, decrease sedimentation, improve water quality, foster wildlife habitat, curb the production of surplus commodities, and provide income support for farmers (Young and Osborn, 1990).

Soil structure has been found to improve when continuously cultivated land is put into grass (Lindstrom et al., 1994). The perennial grass cover established under the CRP at selected locations within the Great Plains has also resulted in significant increases in soil organic carbon (Gebhart et al., 1994). As CRP lands become eligible for release, many land managers will be concerned about adopting procedures that will help to maintain conservation benefits derived during the CRP.

Once CRP contracts expire, many of the CRP areas are expected to return to crop production. Because the CRP was established to help stabilize highly erodible soils, returning these areas to crop production could have detrimental effects on long-term soil productivity (Young and Osborn, 1990).

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The residual benefit of the CRP in reducing erosion was found to be eliminated approximately nine months following tillage on a site in Northern Mississippi where herbicides were used to prevent the regrowth of vegetation (Gilley and Doran, 1996). A no-till management system that helped to preserve existing surface cover and soil organic matter proved to be a suitable management practice for reducing the potential for erosion and degradation of soil quality at a former CRP area which were returned to crop production (Gilley et al., 1996).

Grazing and haying of CRP land is another management option that could be used to retain many of the conservation benefits derived during the CRP period. The effects of selected grazing management strategies on infiltration rates and interrill erosion for native rangelands have been topics of considerable research. This information could serve as a valuable resource for identifying optimum grazing management strategies.

The frequency and intensity of livestock grazing affects the amount and type of plant cover and soil characteristics (Thurow et al., 1986, 1988; Warren et al., 1986b; Pluhar et al., 1987). As vegetation cover is reduced, infiltration rates have been found to decrease and sediment production to increase (Hanson et al., 1973; Blackburn, 1975; Brock et al., 1982). Intensive rotation grazing associated with short-term, high stocking density has been used in an attempt to improve plant and animal production (Goodloe, 1969; Savoy and Parsons, 1980). Heavy stocking rates have been found to reduce infiltration rates and increase sediment production (Gamougoun et al., 1984; McCalla et al., 1984; Warren et al., 1986a). However, when compared with continuous grazing, rotational grazing systems have not produced significant hydrologic advantages (McGinty et al., 1979; Wood and Blackburn, 1981).

Much of the previous work related to range management has been conducted on native rangeland sites which have evolved over geologic time. In contrast, CRP areas had been intensively cropped before they were seeded under the current CRP program. The vegetation cover which became established had generally been left undisturbed. The hydrologic response of these potentially fragile CRP areas to range management practices has not been thoroughly evaluated. Therefore, this study was initiated to determine the influence of selected grazing and haying practices on runoff and erosion from a former CRP site in Central North Dakota.

Experimental Procedures

Study Area

The study was conducted at the North Dakota State University Central Grasslands Research Center approximately 3 km (2 miles) northwest of Streeter, North Dakota (47°N, 99°W). Annual precipitation averages 462 mm (18.2 in.) while the frequency for a 64 mm (2.5 in.) rainfall of one-hour duration is once every 50 years. Mean daily temperatures range from −13°C (8°F) in January to 22°C (72°F) in July. The average frost-free growing season is 117 days, extending from May to September.

Soils on the study plots belonged to the Barnes series (Fine-loamy, mixed Udic Haploborolls). The Barnes series consists of deep, well-drained soils with moderately slow permeability which formed from glacial till on side slopes. For soils from this series that are used for livestock production, the main concerns are maintaining an adequate cover of the important forage species and achieving a uniform distribution of grazing.

Prior to 1987, the research site had been farmed using a crop-fallow rotation. The area was enrolled in the CRP in 1986 and seeded in the spring of 1987. In 1992, vegetation consisted of approximately 40% intermediate wheat grass [*Agropyron intermedium* (Host) Beauv.], 50% smooth bromegrass (*Bromus inermis* Leyss.) and 10% alfalfa (*Medicago sativa* L.). The site was not grazed or hayed until 1992.

Five experimental treatments were included in this study. A 55 ha (135 acre) season-long pasture and a three-pasture, twice-over rotational grazing system consisting of 95 ha (235 acres) were established in 1992. In the twice-over rotational grazing system, cattle were allowed to graze in a given pasture twice during the season. Beginning in 1992, 32 and 55 cow-calf pairs were released each May onto the season-long and twice-over rotational grazing pastures, respectively. The average grazing season length was 125 days.

Since 1992, the vegetation was mowed and bailed from an additional 36 ha (89 acres). After the annual haying operation, stubble height was approximately 15 cm (36 in.). A burned treatment was imposed within the season-long pasture on an area immediately adjoining the season-long grazing plots. Burning is not a common practice in this area, although it is sometimes used in other regions of the country to promote plant growth. Tests were also conducted on an undisturbed CRP site.

Rainfall simulation tests were performed in July 1995. Tests on the season-long grazing area were initiated while the area was being grazed. The twice-over rotational grazing treatment was evaluated approximately 1 week after cattle were removed following the first grazing period on one of the three pastures. Rainfall simulation runs on the hayed treatment were begun one day following harvest. For the burned site which was part of the season-long grazing pasture, tests were begun one day after burning.

Vegetation Characteristics

Canopy cover was measured at the time of the rainfall simulation tests using the point quadrant method (Mannering and Meyer, 1963). Photographic colored slides were taken at three locations on each plot. The slides were later projected onto a screen containing a grid and the number of canopy elements intersecting the grid points were determined. The ratio of the number of intersection points over the total grid points is the fraction of the area covered by canopy. This ratio times 100 is the percent canopy cover.

Basal cover was determined using a frame with 10 evenly spaced pins (Kincaid and Williams, 1966). The frame was placed at 10 locations on each plot to obtain 100-point measurements per plot. Grass, litter, and forbes all contributed to the basal cover measurements.

A circular frame covering 0.589 m^2 (6.34 ft^2) was used to obtain samples for biomass measurements from two areas on each experimental treatment. Standing vegetation and residue lying on the soil surface within the frame were removed and composited at the time of the rainfall simulation tests and stored in paper bags. The plant and residue material was later oven dried, and the weight of biomass per unit area was calculated.

Soil Characteristics

A frame with 10 evenly spaced pins was also used to measure surface roughness (Kincaid and Williams, 1966). The frame was placed at 10 locations on each plot for a total of 100 point measurements per plot. Standard deviations of pin heights were used as an index of surface roughness.

Immediately before each simulated rainfall event, samples for determination of bulk density were collected by the core method (Black, 1965) from a depth of 0 to 10 cm (0 to 4 in.) at 6 locations on each rainfall simulation site. Two additional soil samples from the 0 to 10 cm (0 to 4 in.) soil layer were obtained by compositing two randomly sampled cores from each treatment location. These samples were later analyzed for organic matter by the Walkley-Black method (Walkley and Black, 1934).

Runoff and Erosion

Using sheet metal borders, two rainfall simulation plots, 3.7 m (12.0 ft) across the slope × 10.7 m (35.1 ft) long, were established on uniform slopes for each of the experimental treatments. Slope gradients for the plots are shown in table 1. A portable rainfall simulator based on a design by Swanson (1965) was used to apply rainfall at an intensity of approximately 69 mm/h (2.7 in./h). The first rainfall application (initial run) of 1 h duration occurred at existing soil-water conditions. A second 1 h rainfall simulation run (wet run) was conducted approximately 24 h later. A trough extending across the bottom of each plot gathered runoff. Discharge was measured using a flume with stage recorder. Runoff samples were collected at 5-min intervals during the simulation runs and later analyzed for sediment concentration.

Table 1. Vegetation and soil variables at the time of the rainfall simulation tests

Variable	Undis-turbed	Twice-over Rotational Grazing	Season-long Grazing	Hayed	Burned
Canopy cover (%)*	100a	100a	100a	98a	6b
Basal cover (%)	92a	89a	91a	83ab	79b
Total biomass (kg/ha)†	980a	610b	678b	286c	0d
Slope (%)	9.3a	7.5c	8.1b	8.4b	9.0a
Surface roughness (mm)†	15.7a	10.9b	8.3b	7.0b	8.3b
Bulk density (g/cm^3)†	1.08c	1.47a	1.41a	1.21b	1.41a
Soil organic matter (%)	3.4b	2.4c	3.2b	4.9a	3.2b

* Within each row, differences are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

† Metric to English unit conversion: 1.12 kg/ha = 1 lb/acre; 25.4 mm = 1 in.; 0.515 g/cm^3 = 1 slug/ft^3.

Results and Discussion

Vegetation Characteristics

It can be seen from table 1 that for the undisturbed, twice-over rotational grazing, and season-long grazing treatments, canopy completely covered the ground surface. Even after haying, 98% of the surface was covered with canopy. In contrast, almost the entire canopy was removed by burning. The 6% canopy cover which remained on the burned treatment was caused by scattered clumps of vegetation that were not completely destroyed by burning.

Using Duncan's multiple range test, no significant difference in basal cover was found between the undisturbed, twice-over rotational grazing, season-long grazing or hayed treatments. However, the burning operation caused a significant reduction in basal cover when compared to the undisturbed, twice-over rotational grazing and season-long grazing treatments. The grazing and haying operations did not appear to significantly affect either total canopy or basal cover when compared with the undisturbed site.

In contrast, when compared to the undisturbed treatment, total biomass present at the time of testing was reduced significantly as a result of grazing and haying. The two grazing treatments contained similar amounts of biomass. Biomass measured on the hayed treatment consisted primarily of stems near the soil surface which were not removed during the haying operation.

Soil Characteristics

Slope gradients in this study ranged from 7.5% on the twice-over rotational grazing treatment to 9.3% on the undisturbed plots (table 1). Relative variations in slope between experimental treatments were small, but significant differences were found between selected experimental treatments.

Surface roughness was significantly larger on the undisturbed plots than the other experimental treatments. The plants on the undisturbed treatment appeared to have become clumpy causing small hummocks to form. The twice-over rotational grazing, season-long grazing, hayed and burned treatments had similar surface roughness values.

The largest bulk density values were found on the grazing treatments. The cattle appeared to have caused compaction within the 0 to 10 cm (0 to 4 in.) depth. Bulk density measurements were significantly less on the hayed plots than the grazing treatments. The twice-over rotational grazing, season-long grazing, hayed and burned treatments each had bulk densities greater than the undisturbed site.

Significant differences in percent organic matter were found among selected experimental treatments. The largest organic matter values were found on the hayed treatment and the smallest on the twice-over rotational grazing site. The nonuniform incorporation of vegetative material into the soil medium during the grazing and haying operations may have contributed to differences in soil organic matter between experimental treatments.

Runoff and Erosion

Results of the simulation tests which are presented in table 2 show that no runoff occurred during the initial or wet simulation runs on the undisturbed treatment. Soil water content at the 0 to 15 cm (0 to 6 in.) depth was approximately 16% immediately before the initial run on the undisturbed, twice-over rotational grazing, season-long grazing and burned plots. The infiltration rate on the undisturbed treatment was greater than 69 mm/h (2.7 in./h) after the application of approximately 138 mm (5.4 in.) of rainfall.

A substantial amount of runoff occurred on the twice-over rotational grazing, season-long grazing, hayed, and burned plots during both simulation runs. Runoff quantities were greater during the wet run than the initial run for each of the experimental treatments. For both the initial and wet runs, no significant difference in runoff occurred between the various experimental treatments, with the exception of the undisturbed site.

Erosion for the initial run on the burned treatment was larger than on the other experimental treatments. Substantial reductions in erosion occurred on the burned treatment during the wet run. Debris dams formed at numerous locations on the burned plots. Water deposited behind the dams served to protect the soil surface from raindrop impact and provided areas for sediment deposition. Erosion during the wet run on the burned

Table 2. Runoff, sediment concentration, and soil loss for selected experimental treatments

Treatment	Run	Runoff† (mm)	Sediment Conc. (ppm × 10^3)	Soil Loss (kg/ha)
Undisturbed	Initial	0b‡	0.00c	0c‡
Twice-over rotational grazing	Initial	31a	1.57b	450b
Season-long grazing	Initial	31a	1.62b	450b
Hayed	Initial	29a	2.30a	570b
Burned	Initial	39a	2.28a	1130a
Undisturbed	Wet	0b	0.00d	0c
Twice-over rotational grazing	Wet	37a	1.19c	440b
Season-long grazing	Wet	45a	1.19c	530ab
Hayed	Wet	41a	1.60a	610ab
Burned	Wet	45a	1.45b	630a

* Plots were 3.7 × 10.7 m (12.0 × 35.1 ft). Values given are the average of two replications. Runs lasted for a 60-min duration. Average rainfall intensity was 69 mm/h (2.7 in/h).

† Within each type of run and for each column, differences are significant at the 5% level (Duncan's multiple range test) if the same letter does not appear.

‡ Metric to English unit conversion: 25.4 mm = 1 in.; 1.12 kg/ha = 1 lb/acre.

treatment was similar to values obtained for the season-long rotational grazing and hayed plots.

No significant difference in erosion was found between the twice-over rotation grazing, season-long grazing, and hayed treatments during either the initial or wet simulation runs. Removal of a substantial amount of biomass during the haying operation did not significantly affect erosion. Therefore, if adequate canopy and basal cover is maintained, use of this CRP site for grazing or haying would not appear to result in excessive erosion.

Summary and Conclusions

Canopy and basal cover on the grazing and hayed treatments were similar to the undisturbed CRP. When compared to the adjoining season-long grazing treatment, canopy and basal cover were reduced significantly as a result of burning. Total biomass at the time of testing was significantly less on the grazing and hayed treatments than the undisturbed treatment.

Surface roughness was significantly greater and bulk density significantly less on the undisturbed CRP site than the other experimental treatments. The relatively large bulk densities measured on the grazing treatments imply that considerable compaction took place near the soil surface.

No runoff occurred during the initial or wet simulation runs on the undisturbed treatment. The grazing and haying operations resulted in significantly reduced infiltration rates. For both rainfall events, the twice-over rotational grazing, season-long grazing, hayed, and burned treatments yielded similar amounts of runoff.

Erosion on the season-long rotational grazing and burned plots were similar, following an initial stabilization period. When compared to the undisturbed site, grazing and haying resulted in a significant increase in erosion. Similar amounts of sediment were produced on the twice-over rotational grazing, season-long grazing and hayed treatments. However, use of this CRP site for grazing and haying would not be expected to result in excessive erosion, if adequate canopy and soil surface cover is maintained.

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