Grazing Research and Water-Use-Efficiency on Reclaimed Pastures in North Dakota

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ABSTRACT - The purposes of this paper are to provide a review of grazing research on reclaimed, cool-season pastures in North Dakota and to compare water-use-efficiency (WUE) of forage grown on unmined and mined land. Data have documented that vegetation and animal production from reclaimed pastures is similar to that from unmined pastures. Soil loss measured on reclaimed pastures was similar to soil loss from native rangeland as long as the reclaimed pastures were not heavily grazed. Vegetation productivity and surface ground cover measurements provided an appropriate and adequate documentation of reclamation success for the postmine land use of tame pastureland.

Forage WUE was highest in years when maximum air temperatures and free water evaporation were lowest. Light and moderate grazed pastures, over all years studied, produced the most and ungrazed and heavy grazed the lowest forage for unit of water used. Forage WUE for the reclaimed pastures (9.2 to 13.8 kg/ha/mm) compared well with forage WUE for non-irrigated, unmined land (10.0 kg/ha/mm).

INTRODUCTION

The need to develop energy sources in the United States to become more energy independent has resulted in increased surface mining for low-sulfur lignite and subbituminous coal in the northern Great Plains during this past decade. Simultaneously with increased surface mining activity came the concern to reclaim mined lands to a productivity level equal to or better than before mining. Extensive research, new legislation, and increased reclamation experience by the mining industry followed and have advanced reclamation technology.

The purposes of this paper are to provide a review of grazing research on reclaimed, cool-season pastures in North Dakota and to compare water-use-efficiency (WUE) of forage grown on unmined and mined land.

REVIEW OF GRAZING RESEARCH ON RECLAIMED COOL-SEASON PASTURES

We began postmine grazing research in 1976 on the first reclaimed grassland area released from bond in North Dakota. This grassland was dominated by cool-season, introduced grasses and alfalfa and was grazed each year from late May through early July as cool-season pasture. In the first study, we determined the effects of grazing intensity (ungrazed, light, moderate, and heavy) on vegetation and animal performance on the reclaimed grassland (1). Vegetation and animal production on the reclaimed pastures was similar to that measured on unmined pastures.

In the second study, a rainfall simulator was used to evaluate soil protection from water erosion on native and the reclaimed cool-season pastures (2). Total ground cover or bare soil measured with the point frame method was highly correlated with soil loss measured on the native and reclaimed grassland. This point frame method is satisfactory for determining adequate cover to maintain soil protection on reclaimed land or native range. As long as the reclaimed pastures were not heavily grazed, soil loss measured by rainfall simulation from reclaimed pastures was similar to that from native range.

Several research projects have dealt with the reestablishment and use of grasslands on reclaimed soils (3). The current reclamation method, which replaces subsoil and topsoil over reshaped spoils, provides a good growth media for reestablishment of grasslands. There is some uncertainty of success in grassland establishment from year to year because of limited and irregular precipitation on both mined and unmined land. However, when established, reclaimed grasslands can produce vegetation and animal products and provide soil erosion protection equal to, and in some cases better than, unmined grasslands.

Since many reclaimed areas are approaching the end of the responsibility period required by the Surface Mining Control and Reclamation Act of 1977, decisions on what constitutes reclamation success soon must be made. Several characteristics of reclaimed pastures, gained from eight years of research on a reclaimed grassland in North Dakota, were quantified and evaluated as measures for determining reclamation success for reclaimed pasture and occasional hayland (4). Characteristics included productivity (vegetation and animal), ground cover and soil loss, species composition and numbers, and seasonality of use. Of these, vegetation productivity and surface ground cover were determined to provide an appropriate and adequate measure for documenting reclamation success for the postmine land use of pasture and occasional hay production.

WATER-USE-EFFICIENCY ON RECLAIMED COOL-SEASON PASTURES

Water is a primary factor affecting plant growth. In the western United States, the amount of water received annually as precipitation is usually much less than the potential evapotranspiration. Therefore, the amount of plant dry matter produced per unit of water used (water-use-efficiency) is important to crop and forage management. Various legumes, pasture grasses, and range grasses are known to vary in their water-use-efficiency (WUE) (5). Management practices, such as fertilization of native range communities have also been found to improve WUE (6) (7). Holmen et al. (8) found that irrigation of bromegrass (*Bromus inermis*) and a bromegrass-alfalfa (*Medicago sativa*) mixture to a medium soil water level improved WUE over non-irrigated, dryland plots. Their data further suggest that water use by irrigated grasses is even more efficient when fertilizers are applied to correct nutrient deficiencies.

Determination of the plant dry matter produced per unit of water used is an equally important measure on reclaimed mine land as it is on unmined land. Since in the mining and reclamation process, soil/spoil profiles are reconstructed, data are needed to evaluate the

WUE of plants growing on these reclaimed minesoils. The WUE's of wheat grain (4.4 to 5.3 kg/ha/mm), corn silage (7.2 to 11.7 kg/ha/mm), and grass-legume forage (4.6 to 7.2 kg/ha/mm) grown on fertilized leveled spoils in North Dakota have been reported (9). Topsoil thickness and fertility on reclaimed land have also been found to affect the WUE of corn silage and wheat (10).

Study Area

The reclaimed cool-season pastures were located in Oliver County, near Center, North Dakota. Climate of the area is semiarid with annual precipitation averaging 450 mm, about half of which is received during May, June and July. Potential evapotranspiration exceeds precipitation during the growing season. Temperature extremes range from -35°C in winter to 43°C in the summer.

Soils before mining were predominantly Sen (fine-silty, mixed *Typic Haploborolls*) with small outcrops of Cabba (loamy, mixed calcareous, frigid, shallow *Typic Ustorthents*). This area was surface-mined for lignite by the Baukol-Noonan, Inc. coal company in the late 1960's and reseeded in 1973 in conformance with the 1969 State of North Dakota Reclamation Law. The company salvaged some topsoil and spread it over reshaped spoils to provide an average thickness of 97 mm over the area. Spoil material at the site is good quality, having a silt loam texture and being low in sodium (SAR=2).

The area was fertilized in 1973 with 112 kg/ha of 11-11-0 fertilizer and seeded to a mixture of cool-season species including smooth bromegrass, crested wheatgrass (*Agropyron desertorum*), intermediate wheatgrass (*Agropyron intermedium*), alfalfa, and biennial yellow sweetclover (*Melilotus officinalis*). The area has not been fertilized since seeding.

Methods

The reclaimed grassland, with a good stand of 44% smooth bromegrass, 30% alfalfa, 25% crested and intermediate wheatgrass, and 1% other species, was divided into pastures 0.7, 1.4, and 2.1 ha in size, each replicated twice. Two exclosures per pasture, for a total of six per replicate, provided an ungrazed treatment. Pastures were grazed annually from late May through early July as cool-season pastures during 1976 to 1981. Three yearling steers on each pasture provided a stocking rate of 0.73, 0.49, and 0.24 ha/steer/season, designated as light, moderate, and heavy grazing, respectively. These stocking rates resulted in an average utilization of 48, 64, and 96%, respectively, for the light, moderate, and heavy grazing intensities.

Weather data were collected by the U.S. Weather Bureau Station at Center, ND, about 2 km west-northwest of the reclaimed grassland.

Soil water content was measured with a neutron moisture meter at six access tube sites located in each pasture, and at one located in each exclosure, to a depth of 1.83 m. Soil water measurements from the tube sites in each pasture near the caged area were assumed to be representative of water used by the vegetation under each cage. Measurements reported in this paper were taken in the spring (mid-April to early May) and at the end of the growing period (near the date of peak-biomass accumulation, late June or early July). The difference in soil water content readings between the spring and the end of the growing period provided a measure of water used or lost from the soil.

Yearly forage production was measured near the date of peak biomass accumulation each season by harvesting one 0.9 x 3.1 m plot per exclosure with a sickle bar mower and by hand-clipping one 0.6 x 0.6 m quadrat under six cages per pasture grazing treatment. Cages were moved and set at the beginning of each grazing season. All standing live and dead vegetation was harvested and oven dried. Litter on the ground surface was not collected. Hand-clipped samples were hand-separated into current and previous year's plant material and were used to estimate current year's forage production. Forage production measured in this manner estimated the forage available for grazing and yield of a one-harvest hay production system.

Total water used to produce the measured forage was considered to be the sum of precipitation received and the soil water used or lost during the growing period. Water-use-efficiency (kg/ha/mm) is the quotient resulting from division of forage production (kg/ha) by total water used (mm). Water-use-efficiency data for years 1977 through 1981 were analyzed as a randomized complete block, split plot in time, with years as whole plots and grazing intensities as subplots. Year and grazing intensity means with significant F tests were further separated using Duncan's multiple range test which controls the Type I comparisonwise error rate, not the experimentwise error rate. Significant interaction means were evaluated by graphical analysis.

Results

Growing period weather data for the study period of 1977 through 1981 are summarized in Table 1. The most precipitation was received during 1977. The coolest growing period occurred during 1981. Free water evaporation was lowest during the 1979 growing period.

Table 1. Weather data for each growing period.1/

Growing Period	Precip. (mm)	Mean Max. Temp. (°C)	Mean Min. Temp. (°C)	Mean Temp. (°C)	Free Water Evap. (mm)
4/15/77-7/12/77	218	25.3	8.9	17.1	675
4/21/78-7/17/78	170	23.3	8.7	16.0	512
5/2/79-7/10/79	114	22.5	8.2	15.3	300
4/4/80-6/30/80	145	24.0	5.6	14.8	562
4/8/81-6/29/81	127	20.9	5.7	13.3	423

1/ Data from U.S. Weather Bureau, Center, ND.

Forage WUE was greater during the 1978, 1979, and 1981 growing periods compared to 1977 and 1980 (Table 2).

Table 2. Forage WUE observed for each year during study, averaged across all grazing intensities.

Year[1]	Forage WUE
	(kg/ha/mm)
1981	13.3 a[2]
1978	12.8 a
1979	12.4 a
1980	9.5 b
1977	8.1 b

[1] F=30.35, P>F=.0030.
[2] Means in columns with same letter are not significantly different according to Duncan's multiple range test.

Light grazing resulted in the greatest forage WUE, moderate grazing an intermediate level, and ungrazed and heavily grazed intensities the lowest forage WUE (Table 3).

Table 3. Forage WUE observed for each grazing intensity during study, averaged across all years.

Grazing Intensity[1]	Forage WUE
	(kg/ha/mm)
Light	13.8 a[2]
Moderate	12.2 b
Ungrazed	9.7 c
Heavy	9.2 c

[1] F=28.15, P>F=.0001.
[2] Means in columns with same letter are not significantly different according to Duncan's multiple range test.

A significant interaction (Fig. 1) for year and grazing intensity was also observed (F=6.95, P>F=.0004). During the 1980 growing season, forage WUE for light, moderate, and heavy grazing intensities fell below the forage WUE for the ungrazed vegetation.

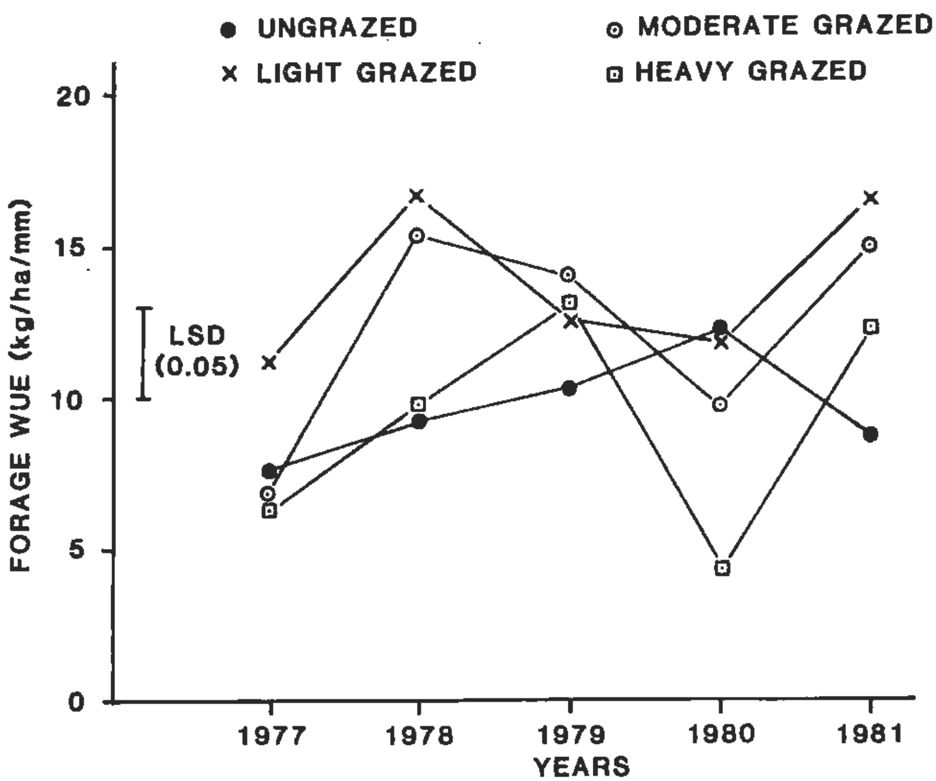

Fig. 1. Interaction of year x grazing intensity observed during study.

Discussion

The greatest mean forage WUE was measured on the cool-season pastures during the growing periods of 1978, 1979, and 1981, and the lowest during 1977 and 1980. Maximum air temperatures and free water evaporation were the lowest when WUE's were highest, indicating water was more efficiently used in producing forage under cooler climatic conditions.

Mean forage production per unit of water used was highest when the pastures were lightly grazed each season. Moderate grazing pressure resulted in an intermediate level of forage WUE and ungrazed or heavily grazed, the lowest. This is interesting since ungrazed vs. heavy grazed treatments represent direct opposites in use. This suggests that the vegetation on these reclaimed cool-season pastures was stimulated to produce more total vegetation per unit of water used when lightly or moderately grazed. However, these are not simple relationships. The effect varies with changes in climatic conditions from year to year. Past heavy grazing pressure caused the greatest reduction in forage WUE during the unfavorable 1980 growing period, a response also expected on unmined cool-season pasture.

Water-use-efficiencies of brome-alfalfa mixtures on unmined land have been reported by Holmen et al. (8). They found that the WUE of a brome-alfalfa mixture on non-irrigated, unmined land for the two year period of 1955-56 averaged 10.0 kg/ha/mm. The WUE measured for the reclaimed cool-season pastures, also primarily a brome-alfalfa mixture, compared well, ranging from 9.2 to 13.8 kg/ha/mm. The comparison of these data indicates that water can be as efficiently used by vegetation on reconstructed minesoils as similar species on unmined nondisturbed soils. It also suggests that the soil characteristics of this reclaimed grassland important to plant-water relations have not been adversely affected or altered by the mining disturbance.

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