COMPLEMENTARY GRAZING OF RECLAIMED MINED LAND AND NATIVE RANGELAND PASTURES IN MONTANA[1]

by

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Abstract. A three year grazing study was conducted on Montana coal-mined lands revegetated with introduced, cool-season grasses and legumes. Objectives were to determine responses of mined land vegetation and soils to livestock (cattle) grazing, and to evaluate the capability of mined land vegetation to support livestock under two rotational grazing systems: exclusive grazing of mined land pastures season-long, and complementary mined land-native rangeland grazing. Spring and late summer grazing improved productivity of mined land vegetation, induced certain changes in plant species composition and diversity, and positively influenced certain soil attributes. Forage quality and animal gain data demonstrated highest utility of the introduced plant species for spring grazing, and lower value during the summer when animal performance on native range pastures was superior to that on mined land pastures. Total spring through summer cattle gains were higher with the complementary mined land-native rangeland grazing system than with the exclusive mined land system, although exclusive grazing of mined land vegetation produced acceptable season-long cattle gains.

Additional Key Words: Revegetation, Plant response, Forage Value

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Introduction

Much of the land impacted by coal surface mining in the Northern Great Plains of the United States will be reclaimed to rangeland capable of supporting multiple uses. Since livestock grazing comprises the major agricultural use of rangelands throughout the region, successful reclamation must include establishment of vegetation which both can meet livestock forage requirements and persist under grazing pressure (DePuit

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1988). In a recent review of mined land grazing, Laycock (1989) noted basic forage requirements to include adequate quantity and quality of vegetation for planned use, no unacceptable forage elemental toxicity, and vegetation self-sustenance under grazing.

Progress in revegetation technology has largely laid to rest the question of re-establishing adequate forage quantity on northern plains mined lands (Ries and DePuit 1983, DePuit 1988), and documentation is beginning to accumulate that mined land vegetation can withstand grazing pressure if successfully established and grazed properly (e.g., Kleinman et al. 1984, Hofmann and Ries 1988, Laycock and McGinnies 1985, Schuman et al. 1986). Evidence also exists that grazing can be used on mined lands to change plant species composition or increase vegetation diversity (Kleinman et al. 1984, Young and Rennick 1983, Williamson 1981). Schuman et al. (1980) reviewed existing information on forage nutritional quality and trace element content on northern plains mined lands, and found little evidence for widespread elemental toxicity, although occasional nutritional imbalances and deficiencies were noted.

Another important aspect of mined land grazing involves its influence on minesoils and surface hydrology. Mined land research in North Dakota has noted increased runoff, reduced infiltration and increased compaction under overly heavy grazing intensities (Hofmann and Ries 1988, Hofmann et al. 1983). Conspicuously little information has been published, however, on grazing's effects on other physiochemical attributes of minesoils.

A key element in successful revegetation for grazing involves selection and establishment of plant species appropriate for the type of grazing operation planned for the site. Berg (1975) recognized at least three types of grazing land-use alternatives for mined lands: 1) special use areas for wildlife, emphasizing suitable browse species, 2) pastures for more general livestock [and wildlife] use, primarily composed of native species, and 3) special use pastures for livestock, composed of a limited number of highly productive, probably introduced plant species under more intensive management. In a later paper, Currie (1981) strongly supported the third of the above alternatives, citing the potential benefits of introduced (i.e., non-native) species on mined lands for increasing area-wide animal production when grazed complementarily with native pastures. Such "complementary" grazing systems basically involve rotational grazing on pastures with different species composition through a growing season, and have sometimes been noted to increase livestock production/carrying capacity and/or improve vegetation condition in the northern plains (e.g., Lodge 1970, Houston and Urick 1972, Smoliak 1968, Hart et al. 1983).

Objectives

A three year grazing study was implemented on coal-mined lands in southeastern Montana revegetated to a mixture of introduced plant species. This research was directed to meet two broad goals:

First, to determine the capability of the reclaimed site to withstand a specific regime of repeated spring and late summer grazing within a complementary grazing system. Specific objectives were to evaluate effects of the grazing regime on:

1) Productivity and composition of mined land vegetation,

and 2) Selected minesoil properties.

Second, to evaluate the utility of the given mixture of mined land plant species for support of cattle under complementary versus season-long rotational grazing. Specific objectives involved:

1) Characterization of forage nutritional quality of mined land vegetation during three portions of the grazing season,

and 2) Determination of animal performance under two rotational grazing systems.

Methods and Procedures

Study Area

The study was conducted at the Western Energy Company Rosebud Mine near Colstrip, southeastern Montana. Elevation of the site is 980m, and climate is semiarid and continental. Average annual precipitation is 40.1 cm, about one-half of which occurs as rain from April through July. Precipitation during the years of this study was near average in 1976 and 1977 (41 and 39 cm, respectively) and above average in 1978 (58 cm).

The area lies within the eastern Montana ponderosa pine savannah vegetation type (Munshower et al. 1978). Mixed prairie vegetation predominates, and cool-season perennial grasses are usually dominant on good condition range sites with forbs, warm-season grasses and shrubs in subdominant concentrations. Livestock (cattle) grazing constitutes the prime agricultural land use of much of the vicinity, and carrying capacities vary from 1.0 to 2.4 ha/AUM.

Spoil grading was completed at the mined land study site in 1971, leaving a rolling terrain with slopes of 3:1 or less gradient. The site was not topsoiled following grading. Spoils were fine sandy loams with low organic matter and macronutrient concentrations (DePuit and Coenenberg 1980). In May of 1972, a mixture of native and introduced grasses, shrubs and legumes (DePuit and Coenenberg 1980) was broadcast seeded, and nitrogen and phosphorus fertilizer was applied in 1972 and 1974. Although nearly half of the seeding mix was composed of native species, vegetation was dominated by a productive mixture of introduced grasses and legumes by 1975. Major plant species were crested wheatgrass (*Agropyron cristatum*), smooth bromegrass (*Bromus inermis*), tall wheatgrass (*Agropyron elongatum*), Ladak alfalfa (*Medicago sativa*) and yellow sweetclover (*Melilotus officinalis*).

In 1976, a 33 ha portion of the revegetated minesite was fenced to construct 8 pastures. A 9th pasture was located on nearby native rangeland that had been deferred from grazing for 7-8 years. Mined land pastures averaged 8.2 ha in size, while the rangeland pasture covered 14.0 ha.

Soils in the rangeland pasture were classified as Borollic Camborthids, fine silty, mixed (Lonna loam soil type), and possessed low organic matter and moderate macronutrient concentrations. The site was rated in good range condition, with annual productivity averaging 1165 kg/ha and livestock carrying capacity of 1.0 ha/AUM (Munshower et al. 1978). Dominant plant species were needle-and-thread (*Stipa comata*) and western wheatgrass (*Agropyron smithii*), with green needlegrass (*Stipa viridula*) and prairie junegrass (*Koeleria cristata*) as subdominant species.

Study Design

Two grazing systems were implemented in similar fashion each year from 1976 to 1978 (three years). System 1 involved rotational grazing exclusively on mined land vegetation during spring, summer and late summer periods. System 2 was complementary grazing of mined land pastures in the spring, the native rangeland pasture during the summer, and mined land pastures again in late summer. The average durations of grazing periods were 47 days (April 30 - June 15) for spring, 76 days (June 16 - August 31) for summer, and 23 days (August 31 - September 23) for late summer.

Yearling steers were used as experimental animals. Stocking rates were adjusted each year based upon estimated forage availability and a desired moderate level of forage utilization (55-60 %) during each grazing period in each pasture. Stocking rates on mined land pastures averaged 2.5, 1.5 and 1.2 AUM/ha during spring, summer and late summer grazing periods, respectively, which were 1.5 to 6 times higher than rates typical on native rangeland of the area and similar to rates reported for introduced species pastures elsewhere in the region (e.g., Houston and Urick 1972).

Each of the 8 mined land pastures and the native rangeland pasture received the same grazing treatment three years in succession from 1976 to 1978. Experimental animals were introduced into mined land Pastures 1, 2 and 3 in spring. The herd was divided during the summer period to move cattle either into mined land Pastures 7 and 8 (System 1) or into the native range Pasture 9 (System 2). During late summer, the cattle were moved back into Pastures 1, 2 and 3, with the same individual animals assigned to the specific pastures they occupied the preceding spring.

Mined land Pastures 1 through 6 represented three replications of two treatments: spring/late-summer grazing (Pastures 1, 2 and 3), and no grazing (control)(Pastures 4, 5 and 6). Vegetation and soils data were compared between these two treatments before grazing and during each of the three grazing seasons to address our first goal of evaluating minesite capability to withstand spring/late-summer grazing. Plant responses were determined by measurements of forage utilization and peak aboveground biomass of dominant and subdominant species/growth forms; biomass data were also relativized to derive the Shannon-Wiener index of vegetation diversity (Chambers 1983). Soil attributes sampled included major nutrients, organic matter content and bulk density. Plant and soil sampling methods were described in detail by DePuit and Coenenberg (1980).

Our second goal of evaluating utility of mined land vegetation for grazing was addressed in two ways. First, seasonal differences in minesite forage quality were determined by nutritional analyses of plant tissue collected in the spring, summer and late summer grazing periods. Forage samples of all dominant plant species were analyzed for protein, total digestible nutrient and mineral content using procedures described by DePuit and Coenenberg (1980). A second approach, for evaluating the two grazing systems, involved comparing animal weight gains/losses between the complementary and season-long grazing schemes. Experimental animals were individually weighed before and after each seasonal grazing period in each year to provide an indication of animal performance over the grazing period.

Vegetation, animal and soils data were subjected to analyses of variance. Duncan's Multiple Range test was used to determine significant treatment differences, and $P < 0.10$ was used for all mean separations.

Results and Discussion

Site Responses to Spring/Late-Summer Grazing

Vegetation. DePuit and Coenenberg (1980) presented forage utilization data for the spring and late summer grazing periods. Total forage consumption was moderate, averaging 60% during the spring and 48% during the late summer.

During the spring, cattle utilized crested wheatgrass, smooth bromegrass and legumes at similarly high percentages (53-64%), while utilization of tall wheatgrass and other perennial grasses was far lower (25-33%). Grazing preference changed somewhat during the late summer, with heaviest utilization of smooth bromegrass (66%) and alfalfa (51%), and much lower consumption (27-38%) of all other species.

Plant productivity responses to grazing pressure are provided in Table 1. Total vegetation biomass was statistically similar between grazed and ungrazed pastures in 1975 and increased from 1975 to 1978 within both sets of pastures; by 1978, however, total productivity became significantly greater in grazed than in ungrazed pastures. These total productivity relationships can be largely tied to legume responses, since combined legume species biomass exhibited response patterns identical to those of total biomass.

Table 1 indicates higher total perennial grass biomass in grazed than ungrazed pastures both before grazing in 1975 and after grazing in 1978, and no significant change over time within either set of pastures. Individual grass species, however, did not always respond similarly. Productivity of crested wheatgrass and combined subdominant (i.e., "other") perennial grasses was relatively little-influenced by grazing, since biomass was higher in grazed than ungrazed pastures in both 1975 and 1978. Tall wheatgrass and smooth bromegrass biomass means were similar between grazed and ungrazed treatments in 1975. By 1978, tall wheatgrass productivity had declined significantly in ungrazed pastures while remaining constant under grazing, suggesting that three years of grazing had benefited this species. In contrast, smooth bromegrass biomass was significantly lower in grazed than in ungrazed pastures in 1978, despite an increase from 1975 to 1978 under both treatments. Successive spring/late-summer grazing thus retarded the expansion of smooth bromegrass.

Table 1. Comparison of estimated aboveground biomass production (kg/ha) in spring/late summer grazed and ungrazed mined land pastures prior to grazing initiation (1975) and after three years of grazing (1978).[1]

	Year/Grazing Treatment			
	1975 (Pre-Grazing)		1978 (Post-Grazing)	
Plant Species/Class	Grazed[2]	Ungrazed[3]	Grazed[2]	Ungrazed[3]
	kg/ha			
PERENNIAL GRASSES:				
Agropyron cristatum	1270 a	970 b	902 b	684 c
Agropyron elongatum	272 a	192 a	220 a	26 b
Bromus inermis	325 c	272 c	576 b	674 a
Other perennial grasses	102 a	46 b	82 a	48 b
Total perennial grasses	1969 a	1480 b	1780 a	1432 b
LEGUMES:				
Medicago sativa	475[4]	477[4]	1623 a	1424 a
Melilotus officinalis			2 a	1 a
Other legumes	25 b	15 b	106 a	40 b
Total legumes	500 c	492 c	1731 a	1465 b
OTHER SPECIES:				
Annual grasses	20 b	29 b	57 a	1 c
Annual & perennial forbs	0 a	0 a	4 a	6 a
Shrubs & half-shrubs	1 a	7 a	1 a	7 a
TOTAL LIVE VEGETATION:	2490 cd	2008 d	3573 a	2911 bc

[1] Within a plant species/class row, year-grazing treatment means followed by same letter are not significantly different at $P < 0.10$
[2] Means of Pastures 1, 2 and 3
[3] Means of Pastures 4, 5 and 6
[4] *M. sativa* and *M. officinalis* not differentiated in 1975

Biomass composition data for individual dominant species and groups of subdominant species were used to construct Shannon-Wiener indices (H') of vegetation diversity. Differences in H' values can be attributed entirely to differences in the evenness component of the index, since the richness component was identical for all treatment/year combinations. H' values were quite similar between grazed (0.58) and ungrazed (0.59) pastures prior to grazing in 1975. However, H' increased from 1975 to 1978 in grazed pastures while declining in ungrazed pastures. This resulted in a considerably higher diversity index value in grazed (0.63) than in ungrazed (0.51) pastures after completion of the three year grazing term.

The H' relationships suggest that grazing enhanced diversity of mined land vegetation through higher equity of composition among dominant species and groups of subdominant species.

However, from a floristic richness standpoint grazed pastures possessed only slightly higher numbers of plant species than ungrazed pastures in 1978 (DePuit and Coenenberg 1980); grazing thus did not appear to influence species richness of pastures as much as equity of species distribution.

Plant frequency data for individual species (DePuit and Coenenberg 1980) further elucidated effects of grazing on pasture floristics. Few differences in species frequency existed between grazed and ungrazed pastures prior to grazing in 1975. After three years of grazing, no species exhibited statistically higher frequency in ungrazed than in grazed pastures, while several dominant and subdominant species occurred with significantly greater frequency in grazed pastures. Summed frequency of rare (< 5% individual species frequencies) perennial grasses, legumes, forbs and shrubs in grazed pastures (19%) was over twice that in ungrazed pastures (9%) in 1978. These relationships indicate that three years of spring/late summer grazing never reduced and often increased distribution of specific dominant, subdominant and rare plant species.

Prior to grazing initiation in 1975, both spring/late summer grazed and ungrazed mined land pastures were characterized by massive accumulations of undecomposed standing and ground plant litter -- a consequence of high plant productivity under fertilization in preceding years. Table 2 presents plant litter accumulation responses under grazed and ungrazed treatments through the three year grazing term. With no grazing, standing dead litter accumulation was still relatively high in 1976, declined in 1977, and remained constant in 1978; ground litter in these pastures remained similarly high from 1976 to 1977, and declined in 1978. Despite these staggered but nonetheless eventual standing dead and ground litter

Table 2. Effects of spring/late summer grazing and non-grazing on accumulations of standing dead and ground plant litter in mined land pastures after the first (1976), second (1977) and third (1978) years of grazing.[1]

Plant Litter Class/Year	Grazing Treatment: Grazed[2]	Grazing Treatment: Ungrazed[3]
	-------- kg/ha ------	
STANDING DEAD LITTER:		
1976 (after 1 year grazing)	115 c	1185 a
1977 (after 2 years grazing)	117 c	584 b
1978 (after 3 years grazing)	47 d	421 b
GROUND LITTER:		
1976 (after 1 year grazing)	1379 c	2964 a
1977 (after 2 years grazing)	754 d	2774 a
1978 (after 3 years grazing)	550 e	1960 b

[1] Within litter classes, year-grazing treatment means followed by same letter are not significantly different at $P < 0.10$
[2] Means of Pastures 1, 2 and 3
[3] Means of Pastures 4, 5 and 6

declines, litter accumulations in ungrazed pastures were still substantial in 1978, and in all years were significantly higher than those in grazed pastures. Standing dead litter became greatly reduced in grazed pastures after only one year of grazing in 1976, and eventually declined further in 1978. Ground litter was also significantly reduced after the first year of grazing, and became progressively lower after the second and third years of grazing.

Soils. Soil testing after the first, second and third years of grazing yielded only small differences in soil phosphorus and potassium content between non-grazed and grazed mined land pastures (DePuit and Coenenberg 1980), indicating little influence of grazing on these soil nutrients. Grazing did affect soil nitrogen and carbon regimes, however. Table 3 indicates no statistically significant differences in organic carbon content in the upper 15 cm of minesoils between non-grazed and grazed pastures after three years of grazing, despite slightly higher carbon content in grazed pastures. However, total nitrogen (N) content was significantly higher in grazed than in non-grazed pasture soils in 1978, causing a significantly lower soil carbon: nitrogen (C:N) ratio in grazed than in non-grazed pastures by the end of the third, final grazing season. It is also noteworthy that the C:N ratio in grazed pastures in 1978 was substantially lower than the ratio prior to grazing initiation early in 1976.

Grazing thus promoted a reduction of the elevated C:N ratios that are often characteristic of surface minesoils in years following initial establishment of highly productive vegetation, primarily due to increased total soil N. This may have been caused by increased soil incorporation of green, lower C:N ratio live plant biomass through livestock trampling. Such increased plant biomass incorporation may also have contributed to the slightly but significantly higher soil cation exchange capacities in grazed pastures in 1978 (Table 3). However, most of the added N was apparently bound in non-plant available organic form, since concentrations of available inorganic (NO_3 + NH_4) N were still low in 1978 and not different between grazed and non-grazed pastures.

Soil bulk density data were collected to determine whether repeated spring/late summer livestock use would induce higher soil compaction in mined land pastures. Table 3 indicates no difference in bulk density between non-grazed pastures and general use areas within grazed pastures either before (1975) or after two years of grazing (late 1977), and bulk density did not change significantly from 1975 to 1977 within either grazing treatment. However, bulk density did increase significantly from 1975 to 1977 within heavy livestock use areas of grazed pastures (e.g., along fencelines and near water sources), to become significantly higher at 1.58 g/cm^3 than that in non-grazed pastures in 1977. These findings suggest that the moderate intensity of livestock use in grazed pastures had no major influence on pasture-wide soil bulk density, in agreement with results of mined land research in North Dakota (Ries and Hofmann 1984, Hofmann and Ries 1988) which found negative effects of grazing on surface hydrologic attributes of minesoils only under heavier grazing intensities. In our study, only localized areas of livestock concentration experienced elevated bulk densities -- presumably caused by increased soil compaction from animal trampling.

Table 3. Responses of selected attributes of the upper 15 cm of soils in non-grazed and spring/late summer grazed mined land pastures prior to grazing and after 2 to 3 years of grazing.[1]

Soil Attribute/Sampling Date	Mined Land Pastures Ungrazed[2]	Grazed[3]
TOTAL NITROGEN (%):		
1976 (Pre-grazing)[4]	0.086	
Late 1978 (after 3 years grazing)	0.040 b	0.062 a
CARBON (%):		
1976 (Pre-grazing)[4]	1.76	
Late 1978 (after 3 years grazing)	0.70 a	0.90 a
CARBON/NITROGEN RATIO:		
1976 (Pre-grazing)[4]	20.5	
Late 1978 (after 3 years grazing)	17.5 a	14.5 b
AVAILABLE (NH_4 + NO_3) NITROGEN (ppm):		
1976 (Pre-grazing)	5	
Late 1978 (after 3 years grazing)	3 a	4 a
CATION EXCHANGE CAPACITY (meq/100g):		
1976 (Pre-grazing)	nd[5]	
Late 1978 (after 3 years grazing)	4.1 b	6.0 a
BULK DENSITY (g/cm^3):		
1975 (Pre-grazing)	1.30 a	1.27 a
Late 1977 (after 2 years grazing)	1.35 a	1.45 a[6]

[1] Within attributes and sampling dates, pasture means with same letter are not significantly different at $P < 0.10$
[2] Means among Pastures 4, 5 and 6
[3] Means among Pastures 1, 2 and 3
[4] From a similar, immediately adjacent minesite
[5] nd = not determined
[6] Within areas of general, non-concentrated livestock use

Grazing Utility of Vegetation

Forage Quality. Nutritional quality data collected during the first and second years of study provided one indication of the relative suitability of mined land vegetation for grazing during the spring, summer and late summer periods utilized in the rotational grazing program. Table 4 indicates maximum overall forage quality for most species in the spring, due to usually highest concentrations of protein, total digestible nutrients (TDN), phosphorus (P), copper (Cu), sulfur (S) and zinc (Zn). With few exceptions, these forage quality attributes were similarly reduced in the summer and late summer. However, concentrations of certain other mineral nutrients were highest in some plant species during the late summer, including calcium in most grasses and all legumes, iron in both grasses and legumes, and manganese in grasses.

Concentrations of the potentially harmful trace elements fluorine, cadmium, lead, nickel and selenium were low (DePuit and Coenenberg 1980), and did not differ significantly among seasons for either grasses or legumes. However, seasonal differences in molybdenum (Mo) content were apparent for certain species (Table 4). Mo content of smooth bromegrass tended to increase from spring to summer to late summer. Although Mo content of alfalfa declined from spring to summer/late summer, both it and yellow sweetclover possessed much higher Mo concentrations than grasses throughout the season. These relationships, in concert with Cu responses, caused Cu:Mo ratios to decline from spring through late summer for smooth bromegrass and, less markedly, crested wheatgrass; Cu:Mo ratios were consistently low for both alfalfa and sweetclover season-long.

The observed seasonal decline in overall forage quality was not considered unusual in light of similar temporal changes in forages grown on non-mined lands of the area (e.g., Munshower and Neuman 1978, Houston and Urick 1972). Munshower and Neuman (1980) found higher concentrations of several macronutrients in forages grown on topsoiled mined lands than those on non-topsoiled sites. It is therefore quite possible that plant

Table 4. Selected forage quality attributes of dominant plant species and classes in mined land pastures during spring, summer and late summer grazing seasons.[1]

		Grazing Season		
Attribute	Plant Species/Class[2]	Spring	Summer	Late Summer
PROTEIN (%)	*A. cristatum*	14 a	3 c	6 b
	A. elongatum	15 a	6 b	4 b
	B. inermis	15 a	8 b	8 b
	Legumes	27 a	11 b	12 b
TOTAL DIGESTIBLE NUTRIENTS (%)	*A. cristatum*	74 a	61 ab	51 b
	A. elongatum	66 a	66 a	46 b
	B. inermis	70 a	52 b	43 b
	Legumes	65 a	63 ab	52 b
CRUDE FIBER (%)	*A. cristatum*	25 b	38 a	37 a
	A. elongatum	29 b	40 a	39 a
	B. inermis	25 b	33 a	31 ab
	Legumes	19 b	30 a	35 a
PHOSPHORUS (%)	*A. cristatum*	0.18 a	0.06 b	0.12 ab
	A. elongatum	0.14 a	0.09 ab	0.06 b
	B. inermis	0.23 a	0.10 b	0.11 b
	M. sativa	0.22 a	0.08 b	0.12 b
	M. officinalis	nd[3]	0.10 a	0.10 a
CALCIUM (%)	*A. cristatum*	0.24 b	0.24 b	0.46 a
	A. elongatum	0.27 a	0.16 a	0.26 a
	B. inermis	0.25 b	0.38 ab	0.56 a
	M. sativa	1.18 b	1.04 b	1.48 a
	M. officinalis	nd	0.88 b	1.45 a
COPPER (ug/g)	*A. cristatum*	5.8 a	3.2 b	3.4 b
	A. elongatum	6.1 a	4.1 b	3.5 b
	B. inermis	6.7 a	4.3 b	4.3 b
	M. sativa	8.4 a	6.7 a	7.1 a
	M. officinalis	nd	6.0 a	5.0 a
MOLYBDENUM (ug/g)	*A. cristatum*	0.7 a	0.6 a	0.9 a
	A. elongatum	1.0 a	0.8 a	0.6 a
	B. inermis	0.8 b	1.0 ab	1.4 a
	M. sativa	3.0 a	2.0 b	2.2 b
	M. officinalis	nd	2.5 a	2.1 a
COPPER/MOLYBDENUM RATIO	*A. cristatum*	8.3 a	5.3 ab	3.8 b
	A. elongatum	6.1 a	5.1 a	5.8 a
	B. inermis	8.4 a	4.3 b	3.0 b
	M. sativa	2.8 a	3.4 a	3.2 a
	M. officinalis	nd	2.4 a	2.4 a
SULFUR (%)	Per. grasses	0.25 a	0.18 b	0.20 ab
	Legumes	0.30 a	0.25 b	0.27 ab
ZINC (ug/g)	Per. grasses	23 a	18 a	23 a
	Legumes	36 a	25 b	26 b
MANGANESE (ug/g)	Per. grasses	40 b	46 b	93 a
	Legumes	32 a	39 a	45 a
IRON (ug/g)	Per. grasses	176 b	163 b	509 a
	Legumes	115 b	201 ab	351 a

[1] Within species/classes and attributes, means followed by same letter are not significantly different at $P < 0.10$

[2] Plant class data for legumes are means between *M. sativa* and *M. officinalis*, and for perennial grasses are means among *A. cristatum*, *A. elongatum* and *B. inermis*; species differences within these classes were minor for associated attributes (DePuit and Coenenberg 1980)

[3] nd = not determined

forage quality in the present study would have been higher if the site had been topsoiled, as is currently practiced on mined lands of the area. For example, subsequent findings of Neuman and Munshower (1984) indicated that spoil coverage with topsoil effectively precluded depressed Cu:Mo ratios for most plant species -- including the Mo-accumulating legumes alfalfa and yellow sweetclover. With respect to copper, it should also be noted that limited availabilty in forage is commonplace in certain species and/or later in the growing season on non-mined rangeland as well as mined lands in the area (Munshower and Neuman 1978). Furthermore, Cu:Mo ratios and Mo content of forages in the present study were never expressed at critical levels (i.e., Cu:Mo < 2 and Mo > 5 ug/g) for any plant species in any season, and no copper deficiency symptoms were apparent in cattle even during the late summer grazing period. The latter fact supports the contention of Neuman and Munshower (1984) that when relatively limited copper availability does develop for certain species (i.e., legumes) in mixed stands on mined lands, it may be compensated by higher copper availability to livestock from other, concurrently grazed species.

Animal Performance. Figure 1 contrasts average daily weight changes for yearling steers under season-long rotational grazing exclusively on mined land pastures (System 1) versus complementary rotational grazing of mined land pastures in spring, native rangeland pastures in summer and mined land pastures again in late summer (System 2).

Figure 1(A) indicates no difference in animal performance between steers destined for the two grazing systems during the spring (May through mid-June) grazing period, suggesting no variation in condition/ inherent responsiveness between animal groups. Steer gains proved higher in spring than in all other grazing seasons. Steer gains declined from spring to summer under both grazing systems, but were most reduced for animals in mined land pastures in System 1; average daily gains proved significantly higher in native rangeland than in mined land pastures during the summer. Additional, interim cattle weight data collected within the summer grazing periods of 1977 and 1978 (DePuit and Coenenberg 1980) indicated the greatest depression of animal gain to have occurred during the latter part of the summer period (August) in mined land pastures. Steers performed the poorest in both systems on mined land pastures during the late summer grazing period; indeed, steers in System 2 actually lost weight after being rotated from rangeland back into mined land pastures.

Although possibly influenced by differences in animal condition through the season, the above relationships suggest forage value of mined land pasture vegetation to have been highest during spring followed by a progressive decline through late summer, in general agreement with plant nutritional quality data and results of many previous seasonal grazing trials on non-mined lands. It is noteworthy, however, that later (October) grazing in 1977 with a second group of experimental animals yielded much higher average daily gains (0.8 kg/animal/day, DePuit and Coenenberg 1980), suggesting enhanced forage value of mined land vegetation for later fall grazing following appreciable regrowth.

The higher steer gains in the native rangeland pasture during summer (Figure 1[A]) demonstrate the given mix of introduced plant species in mined land pastures to have been inferior to native species for mid-season grazing. Figure 1(B) accordingly indicates steer gains over the combined spring-summer periods to have been significantly higher under System 2 than under System 1, suggesting the superiority of the complementary mined land/rangeland system. However, system comparison over all three periods combined (i.e., spring through late summer, Figure 1[C]) yielded no significant difference in gains between Systems 1 and 2 -- largely because of the net loss in weight for System 2 steers when reintroduced to mined land pastures in

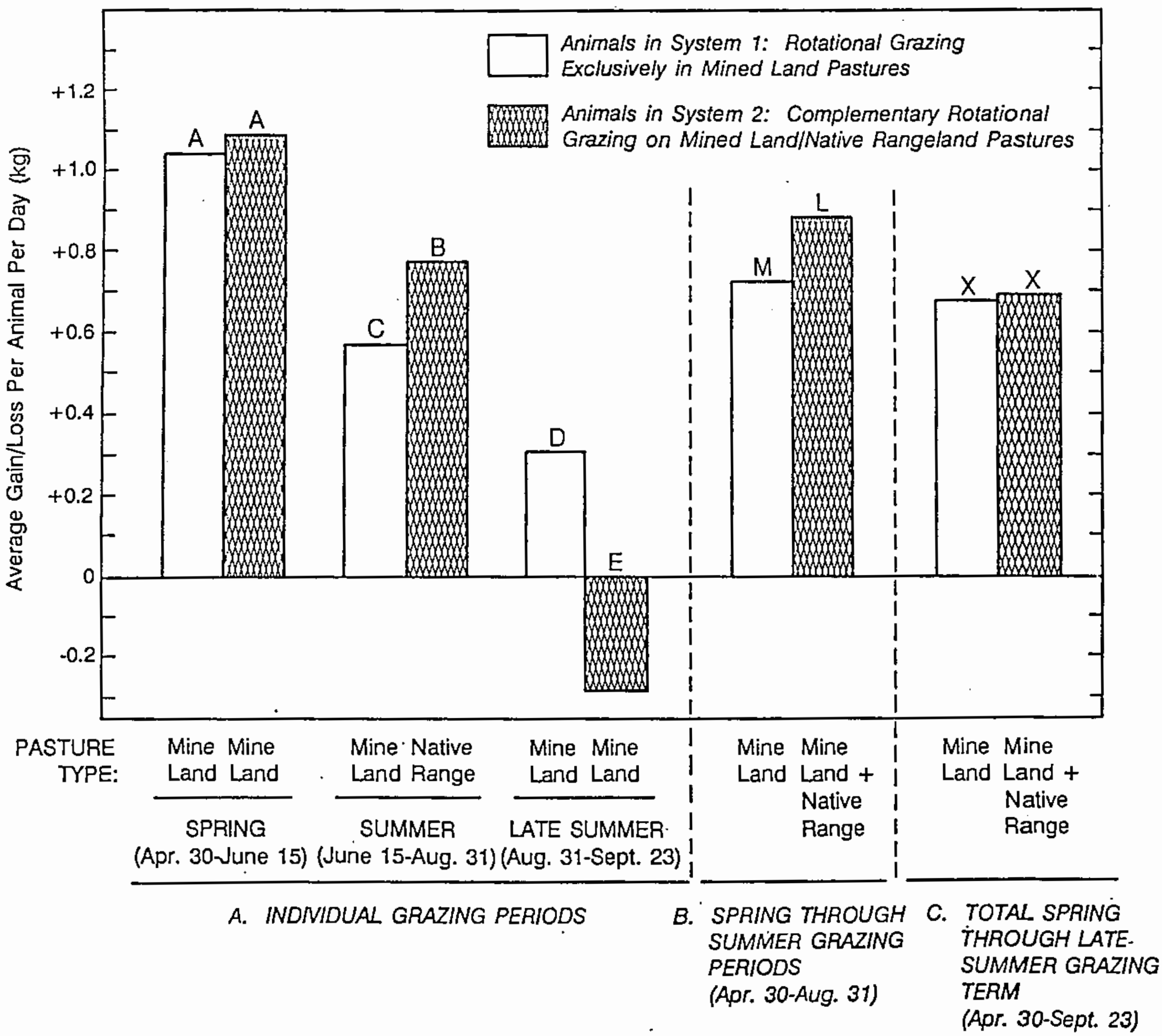

Figure 1. Average daily gain or loss of yearling steers under two grazing systems, A) in each grazing period, B) from spring through summer, and C) from spring through late summer; 1976-1978. Within A, B and C, bars with same letter are not significantly different at P < 0.10.

late summer. Therefore, while complementary grazing of introduced mined land plant species in spring and native rangeland species in summer may be recommended, late summer rotation back to mined land pastures would appear counterproductive.

Discussion

In summarizing his recent review of mined land grazing, Laycock (1989) concluded that livestock can be grazed successfully on reclaimed lands with no detrimental influence on vegetation or surface hydrology -- if proper grazing management is practiced. Our findings support this conclusion, since the given rotational system and moderate intensity of grazing in fact enhanced total vegetation productivity, appeared to increase structural diversity of the plant community and improve distribution of certain species, and had neutral to positive impacts on soils.

Hart and Norton (1988) noted that grazing may sometimes increase forage production directly through physiologic stimulation of additional plant growth, or indirectly through beneficial effects on nutrient cycling and/or growth environment characteristics. In terms of the latter, the reduction of massive plant litter accumulation in grazed mined land pastures may have been a major contributor to enhanced vegetation condition. Natural mulch can significantly influence the function of rangeland plant communities in complex and often varying ways (Tomanek 1969); excessive litter in ungrazed rangeland communities has sometimes been noted to depress productivity (and diversity) of vegetation (Weaver and Rowland 1952, and others). Increased soil incorporation of plant litter through livestock activity also may have accelerated carbon and nutrient cycling (e.g., the eventually lowered soil C:N ratios) and improved other soil characteristics (e.g., the increased soil cation exchange capacity), hence promoting soil development and, indirectly, plant growth. Thus, grazing may comprise a managerial approach to enhance pedogenesis on minespoils.

However, Hart and Norton (1988) also pointed out the difficulty of separating the effects of grazing on forage productivity from those on botannical composition. Indeed, changes in species composition occurred in response to grazing in the present study. These compositional changes were presumably related to differences in grazing pressure on and resultant reaction among species, which may in turn have altered interspecific competition regimes. For example, crested wheatgrass remained apparently unaffected by three consecutive years of grazing despite relatively high utilization during the spring, in accordance with its long-known capability to withstand grazing (Smoliak 1968, Houston and Urick 1972, Frischknecht and Harris 1968). Conversely, the less palatable and utilized tall wheatgrass was beneficially affected, while the more palatable and heavily utilized (in both spring and late summer) smooth bromegrass was detrimentally influenced by repeated spring/late summer grazing. These differing responses among species suggest a potential role of grazing for manipulating species composition on mined lands, as proposed by DePuit (1988) and sometimes demonstrated by others (e.g., Williamson 1981).

Forage nutritional quality and animal weight responses indicated highest grazing value of the given mix of introduced plant species in the spring and declining value later in the season, as expected based upon results of previous studies of non-mined land pastures with similar composition elsewhere in the northern great plains (Houston and Urick 1972, and others). Spring gains of steers on mined land pastures (1.06 kg/animal/day) were very similar to early-season gains of yearling cattle reported by a number of grazing studies of introduced species on non-mined lands (e.g., 0.91 to 1.16 kg/animal/day; Malechek 1986, Frischknecht and Harris 1968). The reduced forage quality of the introduced species following spring resulted in better animal performance on native vegetation during the summer, and an apparent superiority of the complementary mined land-rangeland grazing system from spring through summer (although not through late summer). Thus, the given mixture of introduced species would appear to have greatest utility for special-use, early season grazing rather than for season-long, general grazing. Such optimal use has been often suggested for crested wheatgrass, one of the dominant components of mined land pasture vegetation, whether on mined lands (DePuit 1986) or on non-mined rangeland (Malechek 1986).

It should be noted, however, that average steer daily gains over the entire season with exclusive grazing on mined land vegetation (0.68 kg/animal/day) were similar to or better than gains typical for season-long grazing of native rangeland in the region (Smoliak 1960, Hart et al. 1983). Furthermore, no symptoms of malnutrition were apparent in cattle in mined land pastures even in late summer when certain nutritional attributes (i.e., protein, phosphorus, copper) were lowest in certain plant species. These findings suggest that although - again - they may be optimally suited for use in the spring under complementary grazing, the given mix of mined land plant species nonetheless can adequately support cattle season-long. The latter conclusion is supported by initial findings of a seasonality of use study on North Dakota mined lands revegetated to introduced cool-season species (Ries and Hofmann 1984), in which no differences in season-long cattle gains were noted between mined land and adjacent native rangeland pastures.

Although late summer rotation of cattle back into mined land pastures was not beneficial, the improved animal performance in 1977 under later fall grazing suggests the given mixture of species might have value for rotational grazing during that period, at least in years with adequate fall regrowth of the cool-season species. In retrospect, the third period of the complementary grazing rotation was probably scheduled too early in 1976 and 1978 (i.e., late summer) to yield any chance of positive animal response.

Conclusions

Results of this study were positive in terms of our first broad goal of evaluating the capability of the reclaimed site to withstand repeated spring and late summer grazing. Grazing enhanced overall productivity and, to a lesser extent, diversity of vegetation. No negative effects of grazing were evident on soils, and grazing positively influenced plant litter dynamics and certain facets of soil development. Changes in plant species composition occurred in consequence of grazing, suggesting a role of grazing for manipulating the nature of vegetation on mined lands.

The second broad goal of research was to evaluate the suitability of the given mixture of introduced, early season phenology plant species on mined lands for supporting cattle under complementary versus season-long use. Results indicated greatest value for spring use within a complementary mined land-native rangeland grazing system, in general agreement with past research with such species on non-mined lands. However, the mined land vegetation did prove capable of adequately supporting cattle even when grazed exclusively throughout the spring-late summer rotation. Forage quality and animal performance, in most respects, compared very favorably with results of other research on non-mined lands. The fact that such positive results occurred on a non-topsoiled site suggests the potential for even better grazing value on mined lands topsoiled and reclaimed under present, more advanced technology.

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