HIGH INTENSITY, SHORT DURATION ROTATIONAL GRAZING ON RECLAIMED COOL SEASON TALL FESCUE/LEGUME PASTURES: II. FORAGE PRODUCTION, SOIL AND PLANT TISSUE COMPARISONS BETWEEN GRAZED AND UNGRAZED PASTURES[1]

K. E. Carlson, W. R. Erickson and R.C. Bonine[2]

Abstract: The Midway Mine is located 50 miles south of Kansas City, Kansas straddling the border of Kansas and Missouri. The Pittsburg & Midway Coal Mining Co. mined the area until 1989, when the mine was closed and reclaimed. Approximately 3,750 acres were topsoiled and revegetated with a cool season tall fescue/legume pasture. High intensity, short duration rotational grazing has become the preferred management practice on these pastures. This study evaluated soil and vegetation data collected on 1,250 acres of pasture which was grazed by about 550 cow/calf units. Ongoing monitoring programs are evaluating the effects of rotational grazing. Soil testing includes macro-nutrients, micro-nutrients and microbial activity. Plant tissue analyses monitor levels of principal macro-nutrients and micro-nutrients. Vegetation monitoring consists of measuring forage production. Results were contrasted between pregrazing and postgrazing, and grazed and ungrazed pasture. Agronomic data from the grazed versus ungrazed treatments documented the following results: 1) higher levels of plant tissue nitrate, phosphorous, potassium, calcium, magnesium, sodium and sulfur; 2) higher microbial activity; 3) similar levels of soil nitrate, phosphorous, potassium, calcium, magnesium, sodium and sulfur; and 4) increased biomass production.

Additional Key Words: Reclaimed Land Management, Rotational Grazing, Minesoil Fertility and Microbial Activity, Minesoil Productivity.

Introduction

Minesoils reclaimed to cool season tall fescue and legume pastureland or grazingland are common at most surface coal mines in the midwest from Kansas to the east in West Virginia. These pastures may involve significant acreage that can produce more hay than local markets can absorb. The Pittsburg & Midway Coal Mining Co.'s ("P&M") Midway Mine currently encompasses 4,065 acres of grazing land of which 3,750 acres are topsoiled and reclaimed with cool season tall fescue/legume pasture under SMCRA permanent program standards. High intensity, short duration, rotational grazing has become the preferred reclamation management practice on these pastures. This paper evaluates soil and vegetation data collected on 1,250 acres of reclaimed minesoil currently being grazed by about 550 cow/calf units.

Several U.S. grazing studies have been conducted on reclaimed mined lands and have reported positive results from grazing. Reclaimed sericea lespedeza and tall fescue pastures in Virginia were grazed for approximately six month periods on two pastures during 1980 and 1981 (Gerken and Eller, 1982). At a grazing intensity of one animal unit per five acres, the livestock maintained weight, reproduced satisfactorily and weaned calves with acceptable weaning weights.

Reclaimed mined lands in northwestern Colorado were grazed for two summers under a short duration system. The alfalfa, intermediate wheatgrass and smooth bromegrass reclaimed pastures produced up to ten times the forage produced from adjacent undisturbed sagebrush-grass pastures (Laycock and Layden, 1985).

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[2]Wayne R. Erickson is a Senior Environmental Engineer and Kenneth E. Carlson is an Environmental Engineer, The Pittsburg & Midway Coal Mining Co., Englewood, CO 80155-6518. Richard C. Bonine is President of Agri-Resource Management, Inc., Gallup, NM 87301

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Long-term grazing of reclaimed mined lands established to smooth bromegrass, crested wheatgrass, intermediate wheatgrass, alfalfa and yellow sweetclover have been studied in North Dakota (Hofmann and Ries, 1988). Grazing occurred at four stocking rates (ungrazed, light, moderate and heavy) once per year until 50% of the annual production was consumed. Ungrazed exclosures had slightly higher litter accumulations, but significantly lower annual production than the light (1.1 AUM/ha) and moderate (1.7 AUM/ha) stocking rates. Declines in production and cover were noted on the heavy (2.5 AUM/ha) stocking rate. The authors suggested that refraining from using grasslands after establishment is not the best way to bring them into productive use. These same pastures were studied from 1982 through 1985 to compare forage and beef production, and water use (Ries and Hofmann, 1993). During the three years, reclaimed pastures produced more forage per millimeter of water used than the undisturbed pastures. Reclaimed pastures continued to produce equal or better total forage than the adjacent undisturbed pastures.

Defoliation studies to simulate short duration rotational grazing on cool season grass species of orchardgrass, tall fescue x perennial ryegrass hybrid and prairie grass were conducted in West Virginia (Belesky and Fedders, 1994). The defoliation regimes included hay harvest, lenient (50%) removal of short (10 cm) canopies, and both lenient and intensive (75%) removal of tall (20 cm) canopies. The tall fescue x perennial ryegrass hybrid hay treatment yields were greater while the tall 50% treatment yields were the least. The tall fescue x perennial ryegrass hybrid's tall 75% treatment maintained excellent late-season production while minimizing excessive early-season herbage growth. This resulted in a more uniform production throughout the growing season. The intensive removal of the canopy and the prevention of inflorescence development resulted in new tiller development, and subsequently new leaf development by allowing light to penetrate to the base of the grass.

Most of the prior research dealing with grazing reclaimed mined lands has been conducted on limited areas with small numbers of animals. The ongoing commercial grazing operation on 4,065 acres of reclaimed mined land stocked with a maximum of 1,355 cow/calf units provided P&M with the opportunity to document the effects of large scale grazing on reclaimed minesoils. This paper documents how two years of high intensity, short duration rotational grazing on 1,250 acres of reclaimed minesoils has positively affected the soils, vegetation and reclamation. The nutrient status was compared among the soil and plant tissue results from the three years prior to grazing and the subsequent two years of grazing. In addition, grazed and non-grazed production and microbial activity were compared.

Materials and Methods

The following discussion briefly details the site and grazing design which is described in greater detail in Part 1 of this paper. Methods of data collection and analysis for soil and vegetation nutrients, soil microbial activity and forage production are discussed, in addition to statistical analysis of data.

Site Description

Original soils prior to disturbance at the Midway mine were a Parsons sil (fine, mixed, thermic Mollic Albaqualf), Dennis sil (fine, mixed, thermic Aquic Paleudoll), and Summit sicl (fine, montmorillonitic, thermic Vertic Argiudoll). Prior to mining, "A" and "B"-horizon soil materials were removed to a depth of 24 inches and stockpiled separately. After mining the spoil was leveled and soil materials were replaced to a total depth of 24 inches. The study area was reclaimed between 1984 and 1988 and drill-seeded to a permanent cool season pasture mix consisting of tall fescue (*Festuca arundinacea*) (15 pls/ac), orchardgrass (*Dactylis glomerata*) (5 pls/ac), Korean lespedeza (*Lespedeza stipulacea*) (5 pls/ac), and alfalfa (*Medicago sativa*) (5 pls/ac). Annual fertilizer and lime amendments for a forage production goal of 3.0 tons of dry matter per year were determined from soil and tissue tests. Average cool season forage production from the study site prior to mining was 2.08 tons per acre (SCS, 1981). The study area was fertilized with 40-45-60 (N-P-K) in 1989 through 1991, 71-72-62 in 1992, 66-54-93 in 1993 and 50-30-30 in 1994. Lime was applied in 1991 at a rate of 2.0 tons per acre with a 60% efficiency.

Precipitation data were collected for the growing season (March through October) during the study period. The growing season precipitation totals for 1992, 1993 and 1994 were 25.3, 49.9 and 37.4 inches, respectively. The twenty year average growing season precipitation is 32.5 inches.

Fencing Grazing Paddocks

In March 1993, the 1,250 acre study area was fenced into 10 grazing paddocks (Paddocks A through J) as shown on Figure 1. Single strand high tensile electric fences were installed along paddock boundaries and five strand barb wire fences were installed along property boundaries and public roads. Sixty permanent 10' x 10' grazing exclosures were randomly located in the study area. These ungrazed exclosures were mowed to a three-inch height twice per year in 1993 and 1994 to simulate a hay removal operation. In April 1993, 750 cow/calf units were introduced to the grazing study area. Except for Paddock F (215 acres) which was reserved for hay production, one complete rotation of the study area and adjacent lands was realized by March 1994. In April 1994, 550 cow/calf units began rotating through the study area paddocks. Except for hay Paddocks A, E and F which were not grazed, each paddock was grazed either 2 or 3 times during 1994.

Soil Fertility Tests

Soil tests have been taken from each reclaimed grazing paddock from 1990 through 1994. In 1993 and 1994, soil samples were collected from each grazing paddock and their associated ungrazed exclosures. Soil samples were collected from the first six inches below the surface and composited for each grazing paddock. Soil analytical parameters and methods include: Nitrate nitrogen (Kjeldahl); Phosphorous (Bray 1 and 2); Potassium, Calcium, Magnesium, Sodium and sulfate sulfur (ammonium acetate); Organic Matter (Walkley- Black colorimetric); pH and EC (1:1 extract); and CEC (calculated).

Soil Microbial Activity Tests

Soil samples were taken in 1994 to evaluate the soil microbial activity on grazed and ungrazed pastures. Soil microbial activity was measured by a formazin test which measures the enzyme activity of the dehydrogenase enzyme.

Plant Tissue Tests

Plant tissue tests on tall fescue have been conducted from 1992 through 1994. In 1993 and 1994, plant tissue samples were collected from each grazing paddock and their associated ungrazed exclosures. Plant tissue analytical parameters are as follows: Nitrate nitrogen; Phosphorous (Bray 1); Potassium; Calcium; Magnesium; Sodium; and Sulfur. All extracts were conducted with a perchloric digestion.

Forage Production

The entire study area was sampled for total live standing forage production in 1992 to assess their ability to meet SMCRA and KDHE-SMS Phase III revegetation success criteria. Cropland and pastureland land use areas were sampled and reported separately. The pastures were harvested for hay immediately after the first forage sampling was completed in early June. The forage regrowth was sampled again at the end of the growing season in early November. Live forage production was determined by harvesting a random and statistically adequate number of hand clipped 24" x 11.5" quadrats (1.9 ft^2) to a height of three inches. All live forage was bagged and oven dried at 65 °C for 48 hours and weighed to the nearest gram.

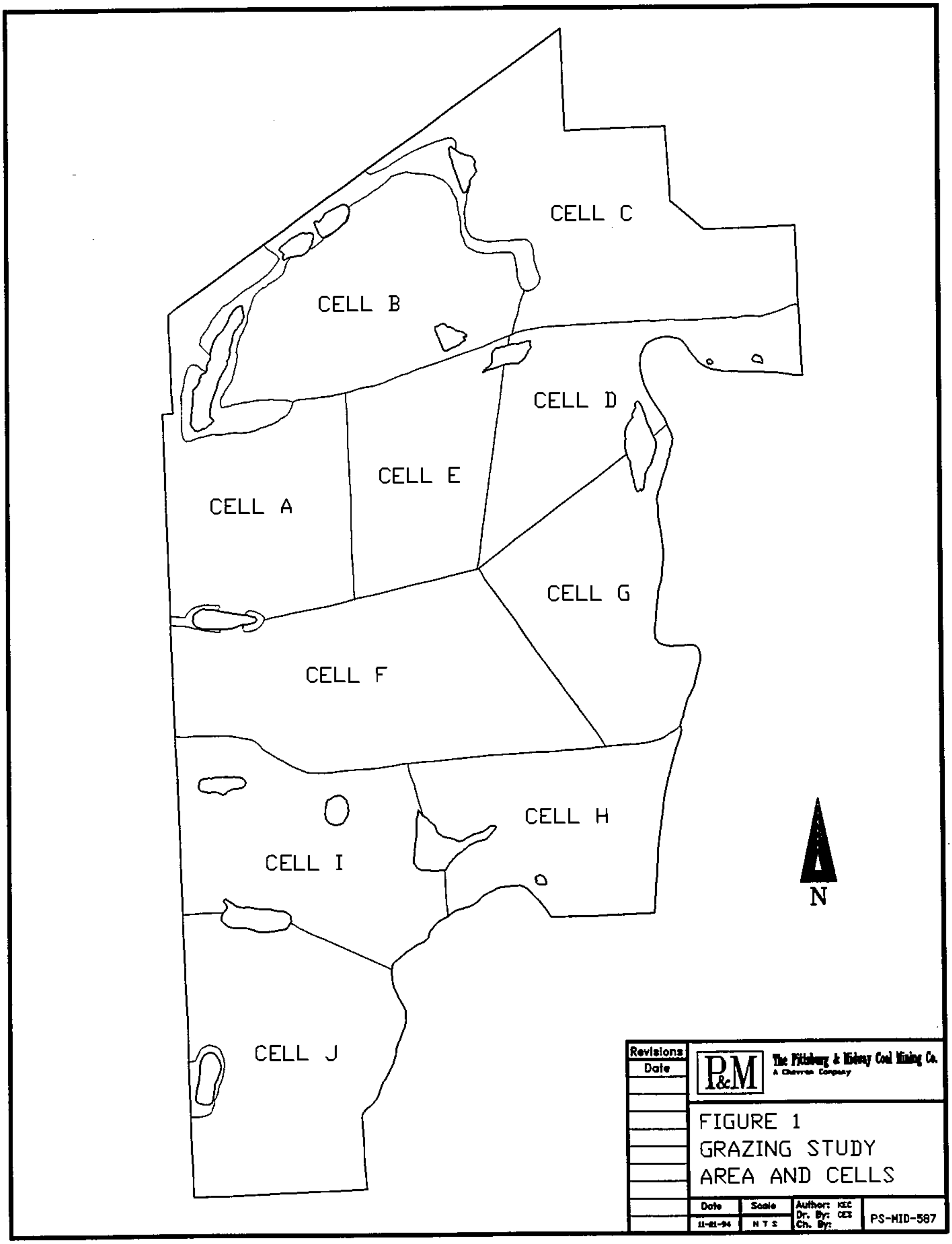

Figure 1. Midway Mine Grazing Study Area and Paddock Locations

Ungrazed exclosures within the grazing paddocks were sampled twice per year in June and November during the 1993 and 1994 growing seasons. The study area exclosures were sampled twice per year to simulate a hay removal operation. At the completion of the initial June sampling and the final November sampling, each exclosure was mowed to a height of 3 inches and the clippings removed.

In 1994, total standing forage production was measured immediately prior to the introduction of livestock to a grazing paddock during the growing season. The livestock remained in the paddock until the forage was approximately three inches in height and then moved to the next paddock. At the end of the growing season in November 1994, all grazed and ungrazed paddocks were sampled to determine total annual forage production.

Statistical Analysis

Significant ($P<= 0.05$) soil and vegetation tissue treatment effects and their interactions were identified using ANOVA procedures. When significant ($P<= 0.05$) effects occurred, means were separated using Fisher's LSD. Correlation between annual production and growing season precipitation was identified using a paired means comparison.

Results and Discussion

Soil Fertility

Although statistical comparisons on most of the soil test results were not statistically significant among the 1993 and 1994 grazed and ungrazed treatments, the contrasting results obtained warrant discussion. Soil pH and CEC values have remained steady since 1990 with average values of 6.5 and 16.27, respectively (Table 1). Soil exchangeable calcium and magnesium have also exhibited little variation since 1990.

Soil exchangeable potassium, phosphorous and total phosphorous values have been steadily increasing since 1990 which may indicate that the losses due to disturbance are being replenished. Exchangeable phosphorous values in 1993 were higher (13 ppm) on the grazed paddocks than the ungrazed paddocks (11 ppm) (Table 1). Total phosphorous values in 1993 were also higher on the grazed paddocks (21 ppm) than the ungrazed paddocks (19 ppm). However, exchangeable and total phosphorous values in 1994 were lower on the grazed paddocks than the ungrazed paddocks. The exchangeable phosphorous value for the grazed paddocks was 10 ppm and 13 ppm for the ungrazed paddocks. The total phosphorous value for the grazed paddocks was 17 ppm and 19 ppm for the ungrazed paddocks (Table 1).

Soil exchangeable sodium and EC were higher on the grazed paddocks than the ungrazed paddocks. Sodium in 1994 was significantly higher ($p=0.04$) on grazed paddocks. This may be attributed to the increased sodium inputs from livestock urine. Soil organic matter shows an overall upward trend since 1990 with the grazed paddocks the same in 1993 and higher in 1994 than the ungrazed paddocks. This increase may reflect the incorporation of plant material into the soil due to livestock trampling.

Soil sulfate sulfur values dropped from 14 ppm in 1992 to 7 ppm in 1993 and 1994 on both treatments (Table 1). This decline can be attributed to the removal of sulfur from the fertilizer mix in 1993 and 1994. Soil nitrate nitrogen steadily increased from 1990 through 1992. However, 1993 nitrate values dropped from 3.67 ppm in 1992 to 1.86 ppm on ungrazed and 2.43 on grazed. The nitrate values rebounded to 3.14 ppm on ungrazed and 2.86 ppm on grazed in 1994 (Table 1). The low nitrate values in 1993 may be attributed to the high precipitation amounts received during the growing season. This mobile nutrient appears to have either been utilized by the forage for higher production in 1993 or leached from the soil system.

Table 1: Midway Mine Permit LN-SM-502 Soil Test Results

SOIL PARAMETER	PASTURE MANAGEMENT	YEAR				
		1990	1991	1992	1993	1994
Nitrate Nitrogen (ppm)	Ungrazed	2.57	3.29	3.67	1.86	3.14
	Grazed	DNC*	DNC	DNC	2.43	2.86
Phosphorous Bray 1 (ppm) Available	Ungrazed	7	10	8	11	13
	Grazed	DNC	DNC	DNC	13	10
Phosphorous Bray 2 (ppm) Total	Ungrazed	11	16	14	19	19
	Grazed	DNC	DNC	DNC	21	17
Potassium (ppm)	Ungrazed	140	214	165	198	232
	Grazed	DNC	DNC	DNC	210	232
Calcium (ppm)	Ungrazed	1955	2098	2062	2058	2155
	Grazed	DNC	DNC	DNC	2028	2168
Magnesium (ppm)	Ungrazed	501	488	511	533	539
	Grazed	DNC	DNC	DNC	513	553
Sodium (ppm)	Ungrazed	72	62	84	86	54
	Grazed	DNC	DNC	DNC	81	74
Sulfur (ppm)	Ungrazed	10	11	14	7	7
	Grazed	DNC	DNC	DNC	7	8
pH	Ungrazed	6.5	6.3	6.7	6.6	6.5
	Grazed	DNC	DNC	DNC	6.6	6.4
EC (mmhos)	Ungrazed	0.9	1.1	1.0	0.9	0.8
	Grazed	DNC	DNC	DNC	0.9	1.0
CEC	Ungrazed	15.81	16.94	14.43	16.67	17.48
	Grazed	DNC	DNC	DNC	16.42	17.90
Organic Matter (%)	Ungrazed	2.7	3.7	2.6	3.3	3.1
	Grazed	DNC	DNC	DNC	3.3	3.5
Microbial Activity (ug/10 gms soil/day)	Ungrazed	DNC	DNC	DNC	DNC	369
	Grazed	DNC	DNC	DNC	DNC	561
Nitrogen Fertilizer (ppm/acre 6")	N Fertilizer	2.21	1.96	3.48	3.24	2.45
Phosphorous Fertilizer (ppm/acre 6")	P Fertilizer	2.21	2.21	3.53	2.65	1.47
Potassium Fertilizer (ppm/acr 6")	K Fertilizer	2.26	2.94	3.04	4.56	1.47
Lime (tons/acre)	Lime	0	2.0	0	0	0

* DNC = Data Not Collected since grazing was not initiated until 1993

Soil Microbial Activity

Soil microbial activity was initially tested in 1994. The grazed paddocks had higher levels of microbial activity at 561 ug/10 grams of soil/day than the ungrazed paddocks at 369 ug/10 grams of soil/day (Table 1). The soil analytical results suggest that grazing has not adversely affected the chemical status of the reclaimed soil and for most parameters, grazed soils were the same or higher than ungrazed soils. The lower levels of soil nitrate nitrogen and phosphorous on the grazed paddocks in 1994 may be attributed to the increase in microbial activity. This increased microbial activity may have resulted in more nutrient uptake by the vegetation which is discussed below.

Plant Tissue

Plant tissue test results in 1993 and 1994 show that tall fescue on the grazed paddocks had higher nutrient levels than the ungrazed paddocks. Macro-nutrients of nitrate nitrogen, phosphorous and potassium were higher on grazed than on ungrazed paddocks (Table 2). While these values were higher on the grazed paddocks, these differences were not statistically significant. Sodium and sulfur values were also higher on grazed than on ungrazed paddocks (Table 2). Again, these differences were not statistically significant. Plant calcium on grazed paddocks was significantly higher in 1993 ($p=0.013$) and in 1994 ($p=0.016$) than on ungrazed paddocks (Table 2). Plant magnesium was also significantly higher in 1993 ($p=0.03$) and in 1994 ($p=0.04$) than on ungrazed paddocks.

The higher nutrient values obtained on the grazed paddocks can be attributed to several factors. The increased microbial activity due to grazing suggests that more soil nutrients are available for plant uptake. This is most evident with the lower 1994 soil nitrate and phosphorous levels, but higher plant tissue nitrate and phosphorous levels on the grazed paddocks. Visual inspections of the study area since 1990 had noted virtually no fungal activity from 1990 through 1992. However, after the introduction of livestock in 1993, inspections noted large populations of mushrooms on the grazed areas. These observations suggest that the livestock grazing on adjacent unmined pastures assist in the inoculation of the reclamation with fungi, mycorrhizae and other microbes. The continued return of nutrients by animal wastes and the increased pasture vigor due to trampling and frequent removal of forage have resulted in higher nutrient levels. These observations of higher nutrient uptake, forage production and microbial/fungal activity suggest the important symbiotic relationship of grasslands with ungulates.

Forage Production

Combined 1992, 1993 and 1994 production from ungrazed cropland and pastureland was 2.6, 4.5 and 3.2 tons of air dry forage per acre respectively (Table 3). Forage production, cover and diversity met the Phase III success standard requirements for the KDHE-SMS in 1992 and 1993. Annual forage production was strongly correlated with annual growing season precipitation (0.97). Production from grazed pastures, ungrazed exclosures and ungrazed hay pastures was compared for the 1994 growing season. The air dry forage production from the grazed paddocks (3.5 tons/acre) was higher than the ungrazed exclosures (3.2 tons/acre) and ungrazed hay paddocks (1.8 tons per acre). The grazed paddocks and ungrazed exclosures production values were significantly higher than the ungrazed hay paddocks ($p < .01$). Table 4 contains the grazing duration and the production from each grazed and ungrazed paddock. The continued return of nutrients by animal wastes and the increased pasture vigor due to trampling and frequent removal of forage resulted in higher nutrient levels and higher forage production from the grazed paddocks. Trampling has resulted in improved seedling establishment and rejuvenation of decadent grass clumps, thereby improving the forage production potential. Two or more forage removals from the grazed paddocks and ungrazed exclosures resulted in the release of the forage during the spring and fall growing season by reducing shading and delaying the morphologic changes associated with seed production. As observed by Belesky and Fedders, (1994), the intensive removal of the canopy and the prevention of inflorescence development resulted in new tiller development, and subsequently new leaf development by allowing light to penetrate to the base of the grass.

Table 2: Midway Mine Permit LN-SM-502 Plant Tissue Test Results

PLANT TISSUE PARAMETER	PASTURE MANAGEMENT	YEAR			
		1991	1992	1993	1994
Nitrate Nitrogen (ppm)	Ungrazed	1.70	1.91	1.76	1.92
	Grazed	DNC*	DNC	1.86	2.18
Phosphorous Bray 1 (ppm)	Ungrazed	0.36	0.35	0.38	0.34
	Grazed	DNC	DNC	0.50	0.43
Available Potassium (ppm)	Ungrazed	2.48	2.52	2.32	1.78
	Grazed	DNC	DNC	2.33	1.88
Calcium (ppm)	Ungrazed	0.48	0.43	0.61	0.57
	Grazed	DNC	DNC	0.72	0.65
Magnesium (ppm)	Ungrazed	0.25	0.25	0.32	0.31
	Grazed	DNC	DNC	0.40	0.36
Sodium (ppm)	Ungrazed	0.02	0.05	0.05	0.02
	Grazed	DNC	DNC	0.06	0.03
Sulfur (ppm)	Ungrazed	0.38	0.31	0.28	0.26
	Grazed	DNC	DNC	0.30	0.27
Nitrogen Fertilizer (ppm/acre 6")		1.96	3.48	3.24	2.45
Phosphorous Fertilizer (ppm/acre 6")		2.21	3.53	2.65	1.47
Potassium Fertilizer (ppm/acre 6")		2.94	3.04	4.56	1.47
Lime (tons/acre)		2.0	0.0	0.0	0.0

*DNC = Data Not Collected since grazing was not initiated until 1993

Table 3: 1992-1994 Annual Ungrazed Production vs. Precipitation

YEAR	COMBINED AIR DRY PRODUCTION (tons/ac)	GROWING SEASON PRECIPITATION (inches)
1992	2.6	25.3
1993	4.5	49.9
1994	3.2	37.6

Table 4: Midway Mine Permit LN-SM-502 - 1994 Pasture Production

PADDOCK #	FIRST GRAZING			SECOND GRAZING			THIRD GRAZING			FOURTH GRAZING			OVEN DRY TOTAL GRAMS PRODUCTION*	AIR DRY TOTAL TONS PRODUCTION*	AIR DRY TOTAL GRAMS PRODUCTION*
	Production* (gms)	Date In	Date Out	Production* (gms)	Date In	Date Out	Production* (gms)	Date In	Date Out	Production* (gms)	Date In	Date Out			
A	67.8	Hay											67.8	1.9	77.0
B	45.4	7-May	23-May	74.3	22-Jul	3-Aug	37.8	12-Nov	Final				157.5	4.5	178.9
C	53.2	28-Apr	7-May	34.3	30-May	6-Jun	29.2	18-Sep	3-Oct	38.5	12-Nov	Final	155.1	4.5	176.2
D	37.7	17-Apr	28-Apr	49.3	6-Jun	15-Jun	35.7	13-Nov	Final				122.7	3.5	139.3
E	66.9	Hay											66.9	1.9	76.1
F	53.2	Hay											53.2	1.5	60.4
G	61.8	15-Jun	5-Jul	48.2	12-Nov	Final							110.0	3.2	125.0
H	63.9	3-Aug	14-Aug	41.1	12-Nov	Final							105.0	3.0	119.3
I	56.8	14-Aug	26-Aug	41.0	12-Nov	Final							97.8	2.8	111.1
J	54.9	26-Aug	18-Sep	39.8	11-Nov	Final							94.7	2.7	107.5
												HAY PADDOCKS#		1.8	71.2
												UNGRAZED EXCLOSURES^		3.21	25.4
												GRAZED PADDOCKS@		3.51	36.8

NOTE:
* Production clipped from a 24 x 11.5 inch quadrat (1.9 ft²)
# Hay paddocks include A, E and F
^ Non-Grazed exclosures from Paddocks B, C, D, G, H, I and J
@ Grazed paddocks include B, C, D, G, H, I and J

Conclusions

Minesoils reclaimed to cool season tall fescue and legume pasturelands were able to support two years of high intensity, short duration rotational grazing with no negative impacts to soil nutrients, plant tissue nutrients or annual forage production. Higher levels of soil organic matter and microbial activity were observed on the grazed paddocks. Plant tissue nutrient content was higher on grazed paddocks. Grazed paddock forage production was greater than production from ungrazed exclosures and ungrazed hayed paddocks. The continued return of nutrients by animal wastes, increased microbial activity and the increased pasture vigor due to trampling and frequent removal of forage resulted in higher plant tissue nutrient levels and higher forage production from the grazed paddocks.

The results show that mined lands similar to the Midway Mine which are reclaimed to cool season pastures can support a commercial livestock operation prior to Phase III bond release. The reclaimed land management cost savings discussed in Part I of this paper show that allowing the landowner to utilize and profit from his or her land prior to Phase III bond release can result in significant cost savings to the coal company. The land management cost savings, in addition to the improvements observed in soil and plant tissue nutrients, soil microbial activity and forage production, prove that high intensity, short duration rotational grazing is a viable management tool for the reclamation and management of mined lands.

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