Assessment of Effects of Amendments on Vegetation Performance at a Bentonite Minesite

2005 Report

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Abstract

In July 2005, vegetation growing on nine experimental plots representing three different treatments of bentonite spoils was evaluated. Canopy cover by life form within each plot was determined using the Daubenmire's cover class method; a list of plant species growing on each plot was developed; samples of above ground plant material were collected by clipping; rooting patterns were evaluated by developing excavation pits within selected plots; soil samples are collected at selected depths; digital images were collected; field notes were written; and the collected plant and soil samples were transported to the RRU laboratory. Soils were dried, disaggregated, and the < 2mm fraction was used for determinations of pH, electrical conductivity, and sodium absorption ration (SAR). Vegetation was dried and weighed and aboveground biomass calculated. This report is a summary and interpretation of these data.

Introduction

A total of 135 experimental plots [15 treatments with 3 fertilized rates nested within each treatment and replicated three times] were implemented on bentonite spoils in the 1980s by staff of the Reclamation Research Unit at Montana State University. Treatments varied from physical manipulations to additions of chemical and biological amendments. The plots were seeded with mixes of plant species. Effects of these amendments and treatments on spoil chemistry and vegetation were documented in several early RRU reports (Dollhopf et al. 1979, 1988, 1990).

In April, 2005, a reconnaissance team from the Reclamation Research Unit conducted a qualitative assessment of the vegetation status of the experimental reclamation plots on bentonite soils near Belle Fourche. One hundred and seventeen of the plots were implemented in 1980, while the remaining 18 were installed in 1986. The purpose of this assessment was to determine which of the treatments support the "best" vegetation. Based on this assessment (Neuman 2005), soils and vegetation from these "best" plots were then evaluated in July. These treatments were as follows:

- Treatment #7 – Manure at 112 Mg/ha + H_2SO_4 at 20 Mg/ha
- Treatment #9 – Gypsum at 6.7 Mg/ha + $CaCl_2$ at 17.2 Mg/ha
- $MgCl_2$ Brine

Canopy Cover

On July 12, and 13, 2005 the vegetation growing on nine experimental plots representing three different treatment of bentonite spoils was evaluated. Canopy cover by life form within each plot was determined using the Daubenmire's cover class method (Daubenmire 1959). Ten 20 x 50 cm frames were place along two diagonal transects (Image 1) on each plot. Cover class for each life form (perennial grasses, annual grasses, and perennial forbs) within the frame was recorded. The complete data set is provided in Appendix A. The mean percent canopy cover of live vegetation, by life form – perennial grasses, annual grasses and perennial forbs - is displayed in the Figure 1.

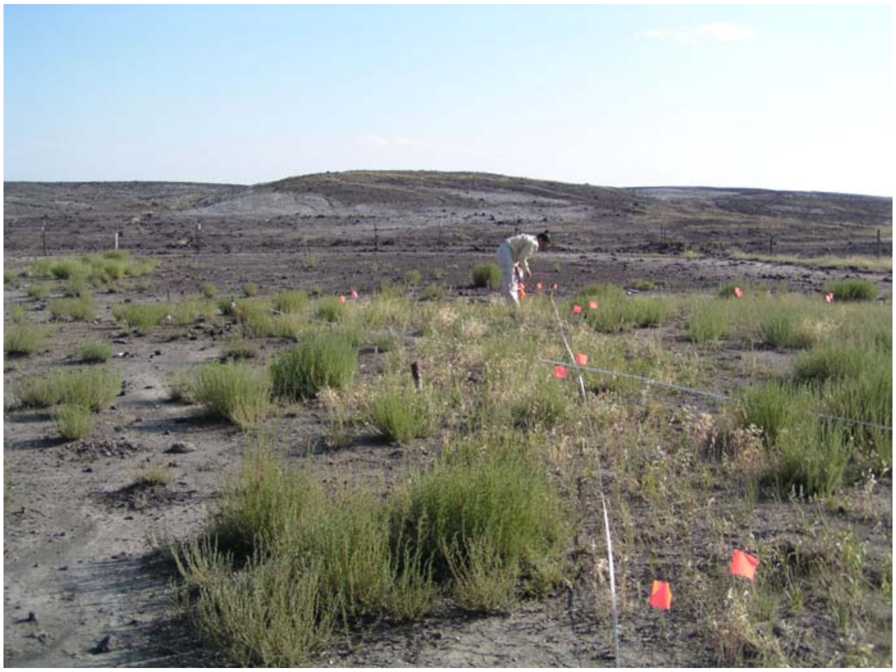

Image 1. **Randomly located sampling areas (flags) along the diagonal transects on replication plot 2 of Treatment 9 (Gypsum at 6.7 Mg/ha + $CaCl_2$ at 17.2 Mg/ha).**

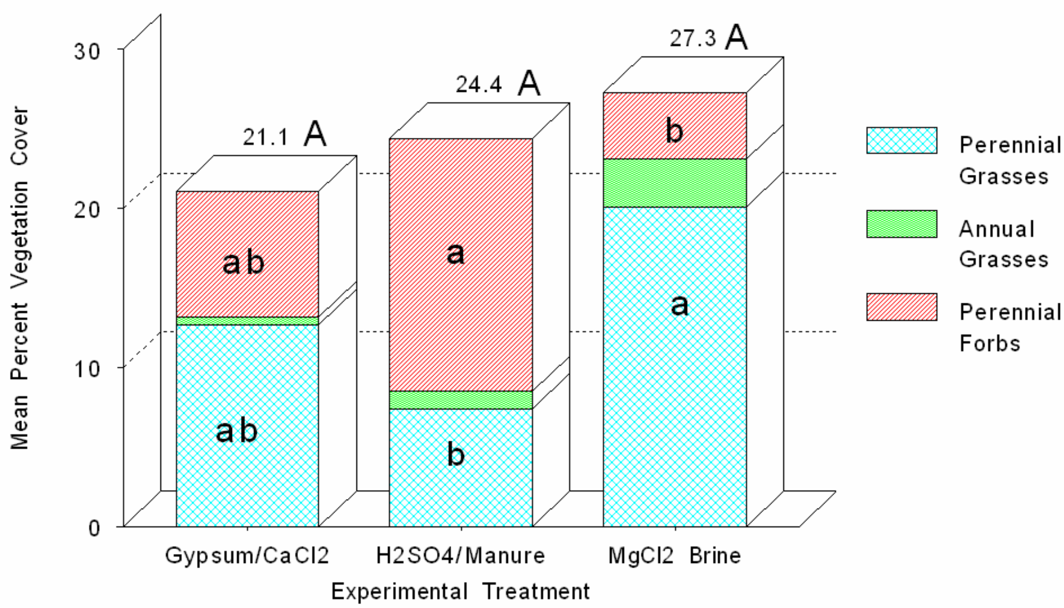

Figure 1. **Mean percent cover of vegetation growing on treated bentonite spoils.**

The mean vegetation cover values for each treatment, across all replications, were not significantly different among the three chosen treatments. Mean canopy cover values were 21.1% for spoils treated with gypsum and $CaCl_2$, 24.4% for spoils treated with H_2SO_4 and manure, and 27.3% for spoils amended with a brine of $MgCl_2$. Community composition did vary significantly ($P < 0.05$) among the treatments. Perennial grasses, specifically Alkali sacaton (*Sporobolus airoides),* dominated the vegetation community growing on the spoils treated with $MgCl_2$ brine (Image 2). Perennial forbs, chiefly Prostrate summercypress *(Kochia prostrata)* accounted for the majority of the vegetation growing on the materials initially treated with H_2SO_4 and manure (Image 3). Tables exhibiting cover percentages by life form for each plot are provided in Appendix A.

In 1987 and 1989, the mean percent canopy cover of vegetation growing on the $MgCl_2$ brine treated plots was 39.3% and 46.0%, respectively (Dollhopf et al. 1990). These cover values are greater than the mean value of 27.3% found in 2005. Species contributing the most to the cover in 1989 were Slender wheatgrass (*Agropyron trachycaulum*), Alkali sacaton (*Sporobolus airoides*), and Kochia (note this species was identified in the 1990 report as *Kochia scoparia*, but was most likely *Kochia prostrata*). In 2005, Alkali sacaton contributed most to the vegetation cover, with minor contributions from *Kochia prostrata*.

In 1986, mean vegetation cover values measured on the spoils treated with gypsum/$CaCl_2$ and those treated with H_2SO_4 and manure were 54.0 and 77.6%,

Image 2. Perennial grasses, specifically Alkali sacaton (*Sporobolus airoides***), dominated the vegetation community growing on the spoils treated with $MgCl_2$ Brine.**

Image 3. **Prostrate summercypress *(Kochia prostrata)*, accounted for the majority of the vegetation growing on the materials initially treated with H_2SO_4 and manure.**

respectively. In both treatments perennial grasses contributed most to the cover values. These mean cover percentages are much greater than those measured in 2005 (Figure 1).

Species List

Attempts were made to identify all plant species growing in each of the nine experimental plots and then to compare those species to those in the original seed mixes. Treatment plots 7 and 9 were initially seeded in 1980 (Table 1), while the plots amended with the $MgCl_2$ brine were seeded in 1986 (Table 2). The seed mixes were slightly different.

Tables 3, 4, and 5 display a species list of all plants found within each of the nine experimental plots. Many of the species growing on these plots were not part of the initial seeded species. Of the 18 species seeded into the plots treated with gypsum and $CaCl_2$, only three were found growing in these plots after twenty-five years (Table 3). Many other species have invaded these plots, but few contributed to cover or aboveground biomass (refer to the next section).

Table 1. Plant species seeded in 1980.*

Scientific Name	Common Name
Agropyron cristatum	Crested wheatgrass
Agropyron dasystachyum	Thickspike wheatgrass
Agropyron elongatum	Tall wheatgrass
Agropyron riparium	Streambank wheatgrass
Agropyron smithii	Western wheatgrass
Agropyron trachycaulum	Slender wheatgrass
Bouteloua curtipendula	Sideoats grama
Sporobolus airoides	Alkali sacaton
Achillea millefolium	Common yarrow
Helianthus spp.	Sunflower
Kochia prostrata	Prostrate summercypress
*Linum lewisi*i	Prairie flax
Ratibida columnifera	Prairie coneflower
Astragalus cicer	Cicer milkvetch
Melilotus officinalis	Yellow sweetclover
Atriplex canescens	Fourwing saltbush
Atriplex gardneri (nuttallii)	Gardner saltbush
Sarcobatus vermiculatus	Greasewood

* These plant species were seeded into Treatments 7 and 9 plots.

Table 2. Plant species seeded in 1986.*

Scientific Name	Common Name
Agropyron cristatum	Crested wheatgrass
Agropyron dasystachyum	Thickspike wheatgrass
Agropyron elongatum	Tall wheatgrass
Agropyron riparium	Streambank wheatgrass
Agropyron smithii	Western wheatgrass
Agropyron trachycaulum	Slender wheatgrass
Bouteloua curtipendula	Sideoats grama
Sporobolus airoides	Alkali sacaton
Achillea millefolium	Common Yarrow
Dalea lasiathera	Purple prairie clover
Ratibida columnaris	Prairie coneflower
Linum lewisii	Prairie flax
Astragalus cicer	Cicer milkvetch
Melilotus officinalis	Yellow sweetclover
Atriplex canescens	Fourwing saltbush
Atriplex gardneri (nuttallii)	Gardner saltbush
Atriplex confertifolia	Shadscale saltbush
Artemisia cana	Silver sagebrush

* These were seeded into the plots treated with $MgCl_2$ brine.

Table 3. **Plant species identified growing on plots treated with gypsum and $CaCl_2$. (Treatment 7).**

Scientific Name	Common Name	Rep 1	Rep 2	Rep 3	Seeded
Tetradymia canescens	Spineless horsebrush			X	No
Agropyron spp.	Wheatgrass	X	X	X	Yes
Kochia prostrata	Prostrate summercypress	X	X	X	Yes
Bromus inermis	Smooth brome		X	X	No
Bromus tectorum	Cheatgrass	X	X	X	No
Lepidium spp	Pepperweed	X		X	No
Achillea millefolium	Common yarrow	X	X	X	Yes
Distichlis spicata	Inland saltgrass		X		No
Chrysothamnus nauseosus	Rubber rabbitbrush			X	No
unknown forb/subshrub #1		X	X	X	No
unknown forb/subshrub #2		X	X	X	No
unknown forb #3			X	X	No
Sporobolus airoides	Alkali sacaton		X		No
Chenopodium album	Lambsquarters	X	X		No
Poa spp. (Secunda?)	Blue grass spp.	X			No
Artemisia tridentata	Big sagebrush	X			No
Unknown annual grass		X			No

Table 4. **Plant species identified growing on plots treated with H_2SO_4 and manure (Treatment 9).**

Scientific Name	Common Name	Rep 1	Rep 2	Rep 3	Seeded
Agropyron spp.	Wheatgrass	X	X		Yes
Agropyron cristatum	Crested wheatgrass			X	Yes
Agropyron elongatum	Tall wheatgrass		X		Yes
Artemisia tridentata	Big sagebrush			X	No
Bromus inermis	Smooth brome	X	X	X	No
Bromus tectorum	Cheatgrass		X	X	No
Agropyron dasystachyum	Thickspike wheatgrass	X	X		Yes
Taraxacum officinale	Common dandelion	X			No
Polygonum spp.	Knotweed spp.	X			No
Melilotus officinalis	Yellow sweetclover	X			Yes
Poa spp. (Secunda?)	Bluegrass spp.	X		X	No
Chrysothamnus nauseosus	Rubber rabbitbrush	X			No
Bromus tectorum	Smooth brome	X			No
Hordeum jubatum	Foxtail barley	X			No
Lepidium spp.	Pepperweed	X	X	X	No
Agropyron smithii	Western wheatgrass	X			Yes
Distichlis spicata	Inland saltgrass	X			No
Kochia prostrata	Prostrate summercypress	X	X		Yes
unknown forb/subshrub #1		X	X	X	No
unknown forb/subshrub #2		X	X	X	No
Unknown forb #3			X		No
Unknown annual grass		X			No

Table 5. Plant species identified growing on plots treated with $MgCl_2$ brine.

Scientific Name	Common Name	Rep 1	Rep 2	Rep 3	Seeded
Agropyron cristatum	Crested wheatgrass		X	X	Yes
Agropyron elongatum	Tall wheatgrass		X		Yes
Agropyron spp.	Wheatgrass spp.		X		Yes
Achillea millefolium	Common yarrow	X			Yes
Artemisia tridentata	Big sagebrush	X			No
Bromus tectorum	Cheatgrass	X	X	X	No
Chrysothamnus nauseosus	Rubber rabbitbrush	X			No
Festuca spp.	Fescue spp.		X		No
Sporobolus airoides	Alkali sacaton	X	X	X	Yes
Kochia prostrata	Prostrate summercypress	X	X	X	No
Atriplex gardneri (nuttallii)	Gardner saltbush	X	X	X	Yes
Hordeum jubatum	Foxtail barley			X	No
Lepidium spp.	Pepperweed	X		X	No
unknown forb/subshrub #1		X	X	X	No
unknown forb/subshrub #2		X	X	X	No
unknown forb #3		X	X	X	No
unknown annual grass		X	X	X	No
unknown lichen	Ground lichens	X			No

Table 4 shows the plant species found growing on the three experimental plots treated with sulfuric acid and manure in 1980. Of the 18 species seeded in 1980, seven were found growing on these plots in 2005. Five of these were wheatgrasses, and the other two were Yellow sweetclover, and Prostrate summercypress. Fifteen species including grasses, forbs, and shrubs have invaded these plots, but none of them contribute appreciably to the vegetative cover or biomass.

A slightly different seed mix (Table 2) use used in 1986 when additional experimental plots, including those treated with MgCl2 brine were implemented. Six species, wheatgrasses, yarrow, Alkali sacaton, and Gardner saltbush, of the initial mix of eighteen species were found after 19 years. These plots were dominated by Alkali sacaton It is interesting to noted that Prostrate summercypress was not seeded, but it has invaded these plots.

Above Ground Biomass

A 25 x 25 cm frame was placed in the same location as each of the cover frame (Image 4) and vegetation with each frame was clipped and segregated by life form and placed into separate labeled paper bags for transport to the RRU labs. The samples were oven dried (70º C) for 24 to 36 hours. The vegetation mass in each bag was weighed to the nearest 0.01 gram. These data were used to calculate above ground biomass as shown in Figure 2. The complete data set is exhibited in Appendix B.

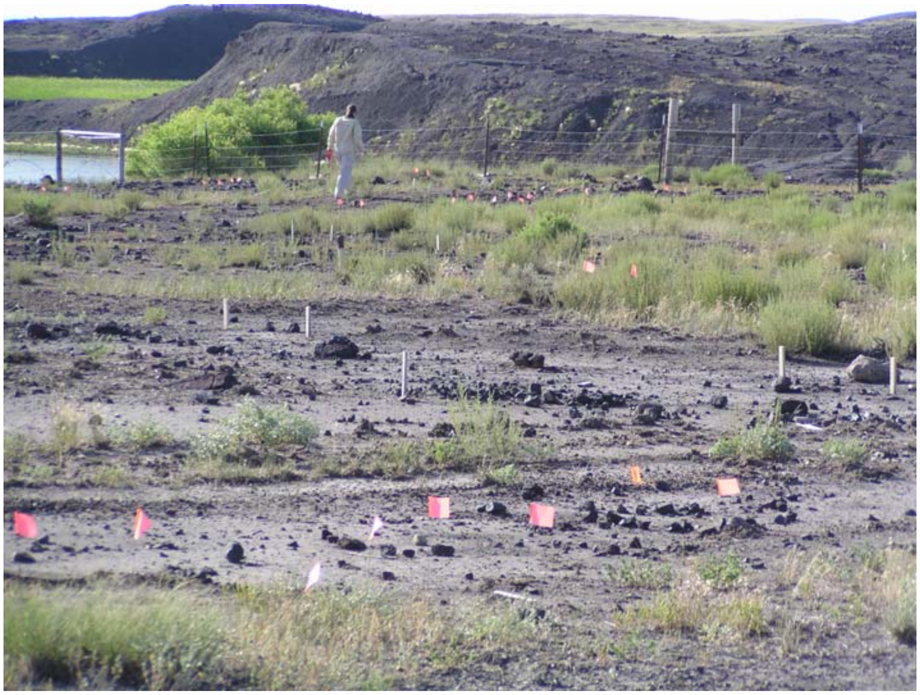

Image 4. **Plots marked for clipping of vegetation.**

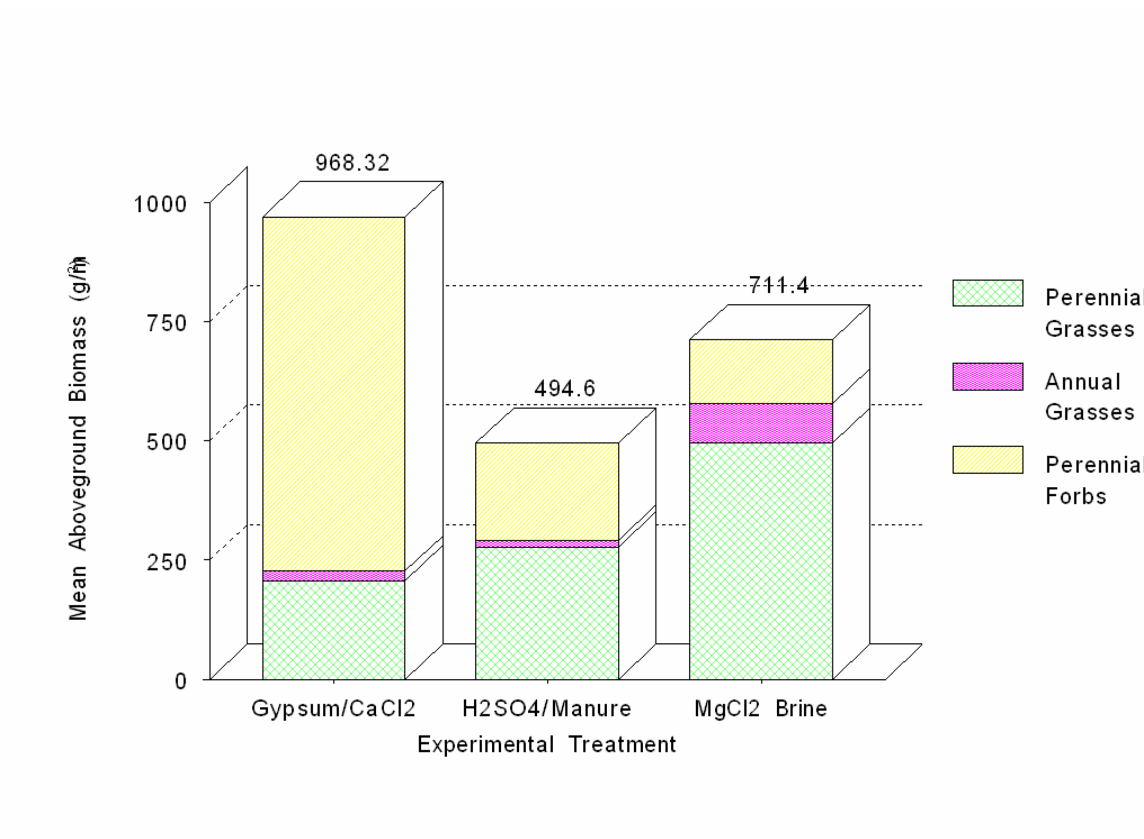

Figure 2. **Mean (g/m^2) aboveground biomass of vegetation growing on treated bentonite spoils.**

Soil Samples

Initially a truck-mounted Giddings Soil Core apparatus was to be used for the collection of multiple soil samples at various depths within the soil profile in each experimental plot. However, this machine was unable to penetrate the bentonite spoils to the depths required. A small backhoe (Image 5) was employed to excavate soil pits in replication 2 of each of the three treatments, and in an offsite non-treated location (experimental control).

Samples were collected from the following depths: 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, 20 to 38 cm, 38-76 cm, and 76 to 152 cm. These sampling depths are the same as those evaluated in previous studies. The samples were placed in new polybags and transported to RRU/MSU laboratories where they were dried, disaggregated, and the following attributes (Table 6) were determined: pH, electrical conductivity (EC), and soluble concentrations of calcium, magnesium, and sodium. The sodium absorption ratio was then calculated from the cation concentrations.

The pH levels in the collected soils were very similar, with a relatively narrow range of 6.78 to 8.04. Spoils treated with H_2SO_4 and manure revealed similar pH levels to untreated spoil materials collected from an off site area adjacent to the test plots. The electrical conductivity (EC) of spoil (top 20 cm) treated with H_2SO_4 and manure was markedly reduced compared to either the control samples or the soils collected from the other treated plots. Correspondingly, the soluble concentrations of calcium, magnesium,

Image 5. **Excavation in replication plot 2 of Treatment 7 in preparation for soil sampling and root evaluations.**

Table 6. Chemical characteristics of collected bentonite spoils from each treatment.

Treatment	Depth (cm)	Lab ID	pH	EC (µS)	Soluble Ca mg/L	Soluble Mg mg/L	Soluble Na mg/L	SAR
Control	0—5	16	8.00	2356	37	7	492	19.6
Control	5—10	13	7.44	8020	239	67	1730	25.5
Control	10—20	18	7.6	9910	314	100	2160	27.2
Control	20—38	20	7.58	8930	154	60	2060	35.6
Control	38—76	24	7.69	7780	149	77	1690	28.0
Control	76—143	8	7.25	10970	458	259	2130	19.7
$MgCl_2$ brine	0—5	21	7.41	11090	177	144	2060	27.8
$MgCl_2$ brine	5—10	1	6.78	17830	541	340	3650	30.3
$MgCl_2$ brine	10—20	25	7.34	16370	439	256	3330	31.2
$MgCl_2$ brine	20—35	22	7.84	9750	143	90	2100	33.9
$MgCl_2$ brine	35—70	9	7.18	9190	140	102	1900	29.8
$MgCl_2$ brine	70—140	14	7.51	6710	82	78	1400	26.5
Gypsum/ $CaCl_2$	0—5	2	7.06	1829	80	23	254	6.4
Gypsum/ $CaCl_2$	5—10	6	8.02	1732	31	8	324	13.4
Gypsum/ $CaCl_2$	10—20	7	7.82	1528	30	8	341	14.5
Gypsum/ $CaCl_2$	20—38	4	7.41	7460	269	102	1480	19.5
Gypsum/ $CaCl_2$	38—76	3	7.15	12830	429	211	2750	27.1
Gypsum/ $CaCl_2$	76—152	5	7.05	7460	377	183	1360	14.4
H_2SO_4/manure	0—5	17	8.04	331.2	15	2	61	4.0
H_2SO_4/manure	5—10	12	7.93	328.8	9	1	64	5.2
H_2SO_4/manure	5—10 (duplicate)	15	8.02	299	9	2	60	5.0
H_2SO_4/manure	10—20	19	7.9	344.1	6	1	63	6.2
H_2SO_4/manure	20—38	10	7.48	4007	132	35	790	15.8
H_2SO_4/manure	38—76	11	7.33	10010	322	146	2110	24.5
H_2SO_4/manure	76—152	23	7.61	11730	405	227	2450	24.1

and sodium as well as the sodium absorption ratios of the top 20 cm of the acid/manure treated spoils are less than all other samples. The EC values for the $MgCl_2$ brine-treated spoils have not changed since they were last measured in 1989 (Dollhopf et al. 1990). SAR levels for the $MgCl_2$ brine-treated spoils as measured in 1986, 1987, and 1989 ranged from 19.8 to 35.2. This range is nearly identical to values found in 2005 as shown in Table 6.

In 1980, the SAR levels of spoils treated with $CaCl_2$ and gypsum ranged from 16.8 to 47.7 (Dollhopf et al. 1988). Slightly lower SAR levels were found in 2005. Also in 1980, the SAR values of spoils treated with H_2SO_4 and manure ranged from 26.0 to

34.8, while data from 2005 revealed much lower SAR levels especially in the top 20 cm of the treated materials (Table 6).

Rooting Patterns

While the excavations were open and soil samples were being collected, the rooting patterns of the vegetation were evaluated for depth of rooting, density of roots as a function of depth, and evidence of the depth of treatment. The following text summarizes this information.

Treatment 7, Replication 2

The manure incorporated into this treatment (H_2SO_4 and manure) was clearly visible in the soils profile (Image 6). However, much of the manure had not decomposed since it was added to the spoils 25 years ago. The depth of treatment was not observable. There were abundant roots to a depth of 45 cm, with fewer root observed at deeper depths. The maximum rooting depth was approximately 103 cm.

Treatment 9, Replication 2

The depth of the amended zone (gypsum and $CaCl_{2)}$ was clearly defined at 45 cm, and copious roots were found in the soil profile to this depth. The maximum rooting depth was between 116 and 131 cm (Image 7).

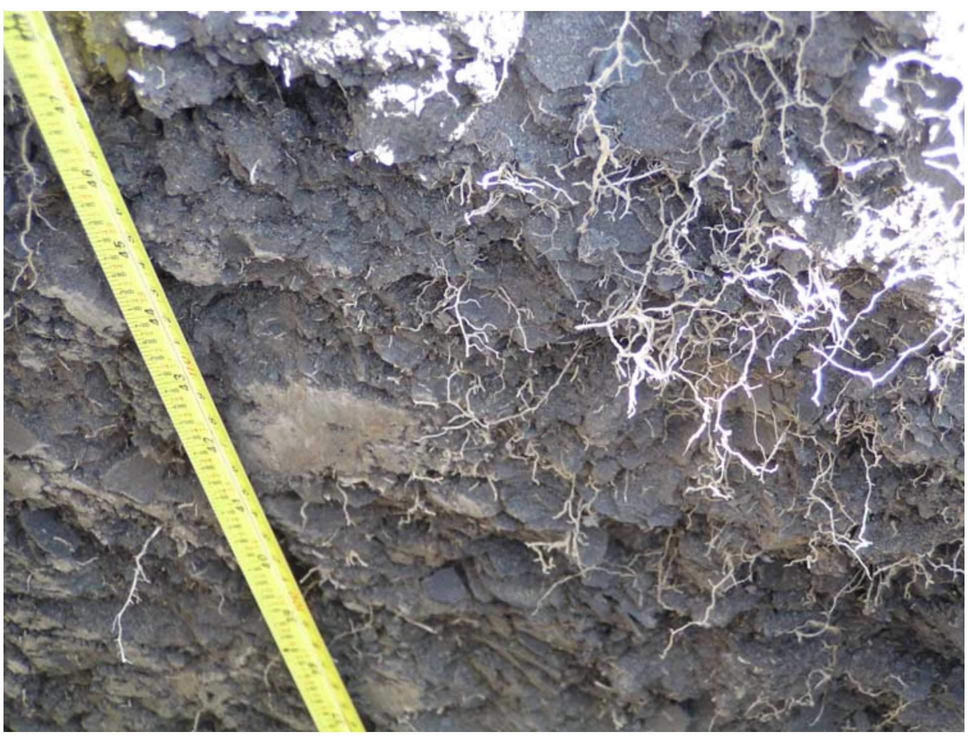

Image 6. Rooting patterns within spoils treated with H_2SO_4 and manure.

Image 7. **Rooting patterns within spoils treated with gypsum and $CaCl_2$.**

Treatment $MgCl_2$ Brine, Replication 2

The amended zone was visible to a depth of approximately 56 cm. Roots were abundant to 20 cm with fewer observed below this depth in the profile. The maximum rooting depth was measured at approximately 104 cm (Image 8).

Image 8. **Rooting patterns within spoils treated with $MgCl_2$ Brine.**

Conclusions

- In the 1980s, bentonite spoils were treated with 15 different physical, chemical, and biological amendments in a replicated experimental design.

- In 2005, three of the initial 15 experimental treatments were qualitatively deemed to support the "best" vegetation. There treatments were:
    1. Gypsum and $CaCl_2$;
    2. H_2SO_4 manure;
    3. $MgCl_2$ brine

- Quantitative evaluation of the vegetation growing on these experimental plots in 2005 revealed the following:
    1. The mean vegetation cover values for each treatment, across all replications, were not significantly different among the three chosen treatments. Mean canopy cover values were 21.1% for spoils treated with gypsum and $CaCl_2$, 24.4% for spoils treated with H_2SO_4 and manure, and 27.3% for spoils amended with a brine of $MgCl_2$. These cover values were markedly lower than those measured in previous years. In 1987 and 1989, the mean percent canopy cover of vegetation growing on the $MgCl_2$ brine treated plots was 39.3% and 46.0%, respectively (Dollhopf et al. 1990). These cover values are greater than the mean value of 27.3% found in 2005. In 1986, mean vegetation cover values measured on the spoils

treated with gypsum/$CaCl_2$ and those treated with H_2SO_4 and manure were 54.0 and 77.6%,

2. Community composition did vary significantly ($P < 0.05$) among the treatments. Perennial grasses, specifically Alkali sacaton (*Sporobolus airoides),* dominated the vegetation community growing on the spoils treated with $MgCl_2$ brine (Image 2). Perennial forbs, chiefly Prostrate summercypress *(Kochia prostrata)* accounted for the majority of the vegetation growing on the materials initially treated with H_2SO_4 and manure.
3. Few of the seeded species were found growing on the experimental plots. Many other species have colonized the plots, but they contributed little to vegetation cover or biomass.
4. Mean Aboveground biomass varied from 494 g/m^2 for plant of the acid/manure plots to 968 g/m^2 for vegetation on the plots treated with $CaCl_2$ and gypsum. Like vegetation cover, the composition of plants contributing to aboveground biomass varied among the three treatments.
5. Level of soil pH across all treatment and depths were very similar with a range of 6.78 to 8.04.
6. The electrical conductivity (EC) of spoil (top 20 cm) treated with H_2SO_4 and manure was markedly reduced compared to either the control samples or the soils collected from the other treated plots. Correspondingly, the soluble concentrations of calcium, magnesium, and sodium as well as the sodium absorption ratios of the top 20 cm of the acid/manure treated spoils are less than all other samples.
7. The EC and SAR values for the $MgCl_2$ brine-treated spoils have not changed since they were last measured in 1989 (Dollhopf et al. 1990).
8. In 1980, the SAR levels of spoils treated with $CaCl_2$ and gypsum ranged from 16.8 to 47.7 (Dollhopf et al. 1988). Slightly lower SAR levels were found in 2005.
9. The manure incorporated into this treatment (H_2SO_4 and manure) was clearly visible in the soils profile. However, much of the manure had not decomposed since it was added to the spoils 25 years ago. Roots were abundant to a depth of 45 cm.
10. The depth of the amended zone (gypsum and $CaCl_{2)}$ was clearly defined at 45 cm, and copious roots were found in the soil profile to this depth. The amended zone was visible to a depth of approximately 56 cm. Roots were abundant to 20 cm with fewer observed below this depth in the profile.

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Appendix A

Vegetation Canopy Cover

Table A-1. Vegetation Cover at BLM Bentonite Experimental Plots, July 12/13, 2005.

Treatment 7 (Manure and H_2SO_4)

Frame		Perennial Grasses	Mid-point	Annual Grasses	Mid-point	Forbs	Mid-point	Total Vegetation	Rock	Mid-point	Litter	Mid-point	Bare Ground	Mid-point	Total Cover
BLOCK 2															
1		-	0	-	0	-	0	0	2	15	1	2.5	5	85	
2		2	15.0	-	0	-	0	15	1	2.5	1	2.5	5	85	
3		3	37.5	-	0	-	0	37.5	1	2.5	1	2.5	3	37.5	
4		2	15.0	-	0	-	0	15	1	2.5	2	15	4	62.5	
5		3	37.5	-	0	-	0	37.5	1	2.5	2	15	3	37.5	
6		2	15.0	-	0	2	15	30	1	2.5	2	15	4	62.5	
7		2	15.0	1	2.5	-	0	17.5	2	15	2	15	3	37.5	
8		2	15.0	-	0	2	15	30	2	15	3	37.5	2	15	
9		3	37.5	-	0	-	0	37.5	1	2.5	3	37.5	2	15	
10		3	37.5	1	2.5	1	15	55	2	15	3	37.5	2	15	
	Average		**22.5**		**0.5**		**4.5**	**27.5**		**7.5**		**18.0**		**45.3**	**53.0**
BLOCK 3															
1		1	2.5	-	0	-	0	2.5	2	15	1	2.5	5	85	
2		-	0	-	0	-	0	0	2	15	1	2.5	5	85	
3		2	15	-	0	1	2.5	17.5	1	2.5	1	2.5	4	62.5	
4		2	15	-	0	-	0	15	1	2.5	2	15	4	62.5	
5		2	15	1	2.5	-	0	17.5	1	2.5	2	15	4	62.5	
6		-	0	-	0	1	2.5	2.5	1	2.5	1	2.5	6	97.5	
7		2	15	-	0	-	0	15	1	2.5	2	15	3	37.5	
8		3	37.5	1	2.5	1	2.5	42.5	1	2.5	3	37.5	3	37.5	
9		3	37.5	1	2.5	-	0	40	1	2.5	3	37.5	2	15	
10		-	0	-	0	-	0	0	1	2.5	1	2.5	6	97.5	
	Average		**13.75**		**0.75**		**0.75**	**15.25**		**5**		**13.25**		**64.25**	**33.5**

Table A-1. Vegetation Cover at BLM Bentonite Experimental Plots, July 12/13, 2005.

Treatment 7 (Manure and H_2SO_4)

Frame		Perennial Grasses	Mid-point	Annual Grasses	Mid-point	Forbs	Mid-point	Total Vegetation	Rock	Mid-point	Litter	Mid-point	Bare Ground	Mid-point	Total Cover
BLOCK 1															
1		-	0	-	0	3	37.5	37.5	1	2.5	1	2.5	4	62.5	
2		-	0	-	0	-	0	0	1	2.5	1	2.5	6	97.5	
3		-	0	-	0	4	62.5	62.5	1	2.5	1	2.5	3	37.5	
4		1	2.5	1	2.5	2	15	20	1	2.5	1	2.5	4	62.5	
5		-	0	-	0	-	0	0	1	2.5	1	2.5	6	97.5	
6		-	0	-	0	2	15	15	1	2.5	1	2.5	4	62.5	
7		2	15	-	0	2	15	30	1	2.5	2	15	4	62.5	
8		-	0	-	0	-	0	0	2	15	1	2.5	5	85.0	
9		-	0	-	0	3	37.5	37.5	3	37.5	1	2.5	3	37.5	
10		-	0	-	0	1	2.5	2.5	2	15	1	2.5	5	85.0	
															0
	Average		**1.75**		**0.25**		**18.5**	**20.5**		**8.5**		**3.75**		**69.0**	**32.8**

Table A-2. Vegetation Canopy Cover at BLM Experimental Plots, July 12/13, 2005															
Treatment 9 (Gypsum and $CaCl_2$)															
Frame		**Perennial Grasses**	**Mid-point**	**Annual Grasses**	**Mid-point**	**Forbs**	**Mid-point**	**Total Vegetation**	**Rock**	**Mid-point**	**Litter**	**Mid-point**	**Bare Ground**	**Mid-point**	**Total Cover**
BLOCK 2															
1		-	0.0	-	0.0	3	37.5	37.5	2	15.0	1	2.5	4	62.5	
2		1	2.5	-	0.0	4	62.5	65	1	2.5	1	2.5	3	37.5	
3		2	15.0	-	0.0	2	15	30	1	2.5	1	2.5	5	85	
4		2	15.0	-	0.0	1	2.5	17.5	1	2.5	2	15	4	62.5	
5		-	0.0	-	0.0	-	0	0	2	15.0	2	15	5	85	
6		2	15.0	-	0.0	1	2.5	17.5	2	15.0	2	15	4	62.5	
7		2	15.0	1	2.5	3	37.5	55	1	2.5	2	15	2	15	
8		3	37.5	2	15.0	2	15	67.5	1	2.5	2	15	3	37.5	
9		1	2.5	-	0.0	-	0	2.5	1	2.5	2	15	5	85	
10		-	0.0	-	0.0	1	2.5	2.5	1	2.5	1	2.5	6	97.5	
	Average		**10.3**		**1.8**		**17.5**	**29.5**		**6.3**		**10.0**		**63.0**	**45.8**
BLOCK 3															
1		-	0.0	-	0.0	-	0.0	0	2	15.0	1	2.5	5	85	
2		-	0.0	-	0.0	-	0.0	0	1	2.5	1	2.5	6	97.5	
3		3	37.5	-	0.0	-	0.0	37.5	1	2.5	3	37.5	4	62.5	
4		1	2.5	1	2.5	2	15.0	20	1	2.5	1	2.5	5	85	
5		1	2.5	-	0.0	3	37.5	40	1	2.5	1	2.5	4	62.5	
6		2	15.0	-	0.0	1	2.5	17.5	1	2.5	2	15.0	5	85	
7		1	2.5	1	2.5	1	2.5	7.5	1	2.5	2	15.0	5	85	
8		1	2.5	1	2.5	2	15.0	20	2	15.0	2	15.0	4	62.5	
9		2	15.0	-	0.0	-	0.0	15	2	15.0	1	2.5	5	85	
10		-	0.0	1	2.5	-	0.0	2.5	1	2.5	1	2.5	6	97.5	
	Average		**7.8**		**1.0**		**7.3**	**16.0**		**6.3**		**9.8**		**80.8**	**32.0**

Table A-2. Vegetation Canopy Cover at BLM Experimental Plots, July 12/13, 2005															
Treatment 9 (Gypsum and $CaCl_2$)															
Frame		**Perennial Grasses**	**Mid-point**	**Annual Grasses**	**Mid-point**	**Forbs**	**Mid-point**	**Total Vegetation**	**Rock**	**Mid-point**	**Litter**	**Mid-point**	**Bare Ground**	**Mid-point**	**Total Cover**
BLOCK 1															
1		1	2.5	-	0	3	37.5	40	1	2.5	1	2.5	4	62.5	
2		2	15.0	1	2.5	1	2.5	20	1	2.5	3	37.5	4	62.5	
3		1	2.5	1	2.5	1	2.5	7.5	2	15	1	2.5	5	85	
4		-	0.0	-	0	4	62.5	62.5	1	2.5	1	2.5	3	37.5	
5		-	0.0	-	0	-	0.0	0	2	15	1	2.5	5	85	
6		-	0.0	-	0	-	0.0	0	2	15	1	2.5	5	85	
7		1	2.5	-	0	4	62.5	65	1	2.5	1	2.5	3	37.5	
8		2	15.0	-	0	-	0.0	15	1	2.5	1	2.5	3	37.5	
9		1	2.5	-	0	4	62.5	65	1	2.5	1	2.5	3	37.5	
10		-	0.0		0	-	0.0	0	1	2.5	1	2.5	6	97.5	
	Average		**4.0**		**0.5**		**23.0**	**27.5**		**6.3**		**6.0**		**62.8**	**39.8**

Table A-3. Vegetation Canopy Cover at BLM Experimental Plots, July 12/13, 2005.

Treatment 14 ($MgCl_2$ Brine)

Frame		Perennial Grasses	Mid-point	Annual Grasses	Mid-point	Forbs	Mid-point	Total Vegetation	Rock	Mid-point	Litter	Mid-point	Bare Ground	Mid-point	Total Cover
BLOCK 2															
1		2	15.0	-	0.0	-	0	15.0	3	37.5	1	2.5	3	37.5	
2		4	62.5	1	2.5	-	0	65.0	3	37.5	1	2.5	1	2.5	
3		1	2.5	-	0.0	1	2.5	5.0	1	2.5	1	2.5	6	97.5	
4		2	15.0	-	0.0	-	0	15.0	2	15.0	2	15.0	3	37.5	
5		3	37.5	-	0.0	1	2.5	40.0	4	62.5	1	2.5	2	15	
6		2	15.0	1	2.5	1	2.5	20.0	2	15.0	2	15.0	3	37.5	
7		3	37.5	1	2.5	1	2.5	42.5	2	15.0	2	15.0	4	62.5	
8		-	0.0	-	0.0	-	0	0.0	2	15.0	1	2.5	6	97.5	
9		1	2.5	-	0.0	1	2.5	5.0	2	15.0	1	2.5	5	85	
10		1	2.5	1	2.5	1	2.5	7.5	3	37.5	1	2.5	4	62.5	
	Average		**19.0**		**1.0**		**1.5**	**21.5**		**25.3**		**6.3**		**53.5**	**53.0**
BLOCK 3															
1		3	37.5	-	0.0	-	0	37.5	1	2.5	1	2.5	4	62.5	
2		-	0.0	-	0.0	-	0	0.0	3	37.5	-	0.0	5	85.0	
3		-	0.0	-	0.0	-	0	0.0	2	15.0	-	0.0	5	85.0	
4		-	0.0	-	0.0	5	85	85.0	1	2.5	1	2.5	2	15.0	
5		-	0.0	-	0.0	-	0	0.0	2	15.0	-	0.0	5	85.0	
6		2	15.0	1	2.5	1	2.5	20.0	1	2.5	2	15.0	4	62.5	
7		4	62.5	1	2.5	-	0	65.0	1	2.5	3	37.5	1	2.5	
8		-	0.0	-	0.0	-	0	0.0	2	15.0	-	0.0	5	85.0	
9		-	0.0	-	0.0	-	0	0.0	2	15.0	1	2.5	5	85.0	
10		1	2.5	-	0.0	-	0	2.5	3	37.5	1	2.5	4	62.5	
	Average		**11.8**		**0.5**		**8.8**	**21.0**		**14.5**		**6.3**		**63.0**	**41.8**

Table A-3. Vegetation Canopy Cover at BLM Experimental Plots, July 12/13, 2005.

Treatment 14 ($MgCl_2$ Brine)

Frame		Perennial Grasses	Mid-point	Annual Grasses	Mid-point	Forbs	Mid-point	Total Vegetation	Rock	Mid-point	Litter	Mid-point	Bare Ground	Mid-point	Total Cover
BLOCK 1															
1		3	37.5	1	2.5	1	2.5	42.5	2	15.0	2	15	2	15	
2		3	37.5	2	15.0	1	2.5	55.0	2	15.0	3	15.0	1	2.5	
3		3	37.5	1	2.5	1	2.5	42.5	2	15.0	2	15.0	2	15	
4		2	15.0	2	15.0	1	2.5	32.5	1	2.5	3	37.5	2	15	
5		1	2.5	1	2.5	1	2.5	7.5	1	2.5	1	2.5	5	85	
6		3	37.5	1	2.5	1	2.5	42.5	1	2.5	2	15.0	3	37.5	
7		3	37.5	1	2.5	1	2.5	42.5	1	2.5	2	15.0	2	15	
8		3	37.5	2	15.0	1	2.5	55.0	2	15.0	3	37.5	1	2.5	
9		3	37.5	2	15.0	-	0.0	52.5	2	15.0	2	15.0	2	15	
10		2	15	1	2.5	1	2.5	20.0	3	37.5	1	2.5	2	15	
	Average		**29.5**		**7.5**		**2.3**	**39.3**		**12.3**		**17.0**		**21.8**	**68.5**

Appendix B

Above Vegetation Biomass

Table A-4. Vegetation Aboveground Biomass at BLM Bentonite Experimental Plots, July 12/13, 2005						
Life Form	Total weight of plants in five 25 x 25 cm frames/Block					Mean Total Biomass
	Block 1	Block 2	Block 3	Total	Mean	(grams/m^2)
Treatment 7 (Manure and H_2SO_4)						
Perennial Grasses	3.1	28.74	20.08	51.92	17.31	276.91
Annual Grasses	0.27	1.88	0.6	2.75	0.92	14.67
Forbs	33.36	4.7	0.01	38.07	12.69	203.04
Total live vegetation	36.73	35.32	20.69	92.74	30.91	494.61
Litter	9.98	19.81	14.62	44.41	14.80	236.85
Treatment 9 (Gypsum and $CaCl_2$)						
Perennial Grasses	9.17	11.2	18.42	38.79	12.93	206.88
Annual Grasses	0.09	2.39	1.18	3.66	1.22	19.52
Forbs	29.31	94.59	15.21	139.11	46.37	741.92
Total live vegetation	38.57	108.18	34.81	181.56	60.52	968.32
Litter	8.94	20.63	59.32	88.89	29.63	474.08
Treatment 14 (MgCl2 Brine)						
Perennial Grasses	55.29	20.61	16.94	92.84	30.95	495.15
Annual Grasses	12.99	0.65	1.68	15.32	5.11	81.71
Forbs	1.57	2.02	21.63	25.22	8.41	134.51
Total live vegetation	69.85	23.28	40.25	133.38	44.46	711.36
Litter	254.06	12.57	86.63	353.26	117.75	1884.05