IMPROVING SOIL TILTH IN RECLAIMED SOILS AT THE HIGHVALE MINE

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BACKGROUND

TransAlta Utilities Corporation is the largest investor-owned utility in Canada, operating 13 hydroelectric sites and 3 coal-fired thermal generating stations. The Highvale mine, located 65 km west of Edmonton along the south side of Lake Wabamum, produces approximately 12 million tons of coal per year as fuel for the Sundance and Keephills generating plants.

Soils in the pre-mined area are predominantly thin Black Solodized Solonetz and Gleysols developed on residual sodic clay shale bedrock. Following mining, TransAlta reclaims the disturbed land by replacing salvaged topsoil and subsoil. Their reclaimed land is then managed as farmland using agricultural management practices similar to those used by neighboring farmers.

Some of the problems encountered in the reclaimed land included: soils that puddled and were slow to dry after rainfall; soils that had poor trafficability when moist or wet; soils that were cloddy and crusted, requiring excessive cultivation to prepare a seed bed and control weeds; and uneven germination and patchy crops. These problems were considered to be the result of poor surface soil tilth and subsurface compaction incurred during subsoil and topsoil placement. In September 1986, TransAlta Utilities initiated a study to investigate the long term effectiveness of deep ripping and organic matter additions in the form of peat and manure to improve subsoil drainage, alleviate compaction and improve topsoil tilth in reclaimed fields.

METHODOLOGY

Research plots were established at three sites in two mine pits in August 1986. At each site, four treatments, each replicated twice, were randomly established: unripped (control), ripped, ripped + peat, and ripped + manure. A 3-tyne Kello-built subsoiler was used to rip the soil to a depth of 0.5 m at a spacing of 0.6 m. Plots were 50 m long and 10 m wide, separated by a 4 m buffer strip. Two sites were located on relatively flat land; the third was located on a north facing slope of approximately 3%. Peat and manure were applied at rates intended to bring the soil carbon level to approximately 2.5 to 3.0%, a level typical of local soils with good tilth. The organic materials were end-dumped, spread with a light tracked dozer and then mixed into the topsoil with a heavy breaking disc. All plots were fertilized, seeded and harrowed with conventional farm equipment. The seed mixture included six high root-to-shoot ratio forage species, tolerant of the prevailing climatic and soil conditions. Forage will be grown for four seasons after which the plots will be plowed and a barley crop grown the fifth season.

Soil samples were taken at five locations within each plot at the time of plot establishment in 15 cm depth intervals to a depth of approximately 90 cm. The surface 30 cm of the surficially amended plots were resampled after treatment. Laboratory analyses for physical properties included particle size determination by the hydrometer method and water holding capacity by pressure membrane and pressure plate methods at pressures of 33 kPa and 1500 kPa, respectively. Soil chemical properties (pH, exchangeable cations, EC, %N, %C and nutrients) were determined. Within each treatment, five access tubes were installed to a depth of approximately 85 cm for measurement of soil moisture and bulk density with a neutron probe and combination probe, respectively. Moisture readings were taken monthly, or more often as determined by precipitation. At periodic intervals, surface soil water and density were also determined. Penetration resistance was also measured at these times using a cone penetrometer. Infiltration rates were determined with double ring infiltrometers.

Crop cover, height, species composition and uniformity were periodically monitored on each plot during emergence and early growth. As the forage crop matured, yield samples were collected using ten 0.5 m x 0.5 m quadrat cuts from each plot.

RESULTS

Soil texture at all sites and depths was relatively uniform clay to clay loam. Available water holding capacity ranged from 15-20 %. Soils were generally moderately sodic, but non-saline.

Considering a given site over time, the greatest difference in total soil water among treatments occurred in the top 30 cm, particularly at Site 1. Differences among treatments became less noticeable for total water to 80 cm, although the highest total water to 80 cm at all dates was in the surficially amended treatments. The lowest total water at all sites on all dates was in the ripped treatment.

Water content with depth was examined for July 28, 1987, the date corresponding to the greatest total soil water differences among treatments. Surface water content was lowest in the unripped treatment for Sites 1 and 2; at Site 3 surface water contents were similar in the unripped, ripped and ripped+manure treatments (Fig. 1). The highest surface water was in the surficially amended treatments. Soil water increased with depth at all sites. Treatment differences in water content generally decreased with depth; at Site 2 there were only small differences among treatments at depths of 35-75 cm. At Site 3, water content for a given treatment was relatively uniform with depth below 45 cm. At Site 1, the surficially amended treatments had the highest water content at all depths. This was also evident at Site 3 below 35 cm.

Profile water contents at the time of earliest spring measurements (April 16, 1988) generally increased with depth at Site 1, but remained fairly constant with depth at Sites 2 and 3 (Fig. 2). Values at Sites 2 and 3 were approximately 40-48% by volume at depths greater than 25 cm, while those at Site 1 at depths greater than 75 cm were 50% or greater. There were no obvious treatment trends for Sites 1 and 2, indicating equivalent springmelt recharge. At Site 3, from 25 to 75 cm, water contents in the unripped and ripped treatments were similar as were those in the surficially amended treatments. At these depths, there were consistently higher water contents in the surficially amended treatments than in the other two treatments. At depths of 85 and 95 cm at this site, water contents were similar in all treatments. The low near-surface water contents at all sites on April 16, 1988, particularly Sites 1 and 3, are surprising for such an early spring reading. The low contents are likely due to low precipitation during the fall and winter.

On April 16, 1988, at Site 2, to a depth of 35 cm, bulk density was greatest in the unripped treatment, intermediate in the between-rips and lowest in the rips (Fig. 3). At depths of 45 and 55 cm, bulk density was generally similar for all three cases, but was highest for the unripped treatment at 65 and 75 cm. It appears that the effects of ripping on bulk density extended to the mid-rip location.

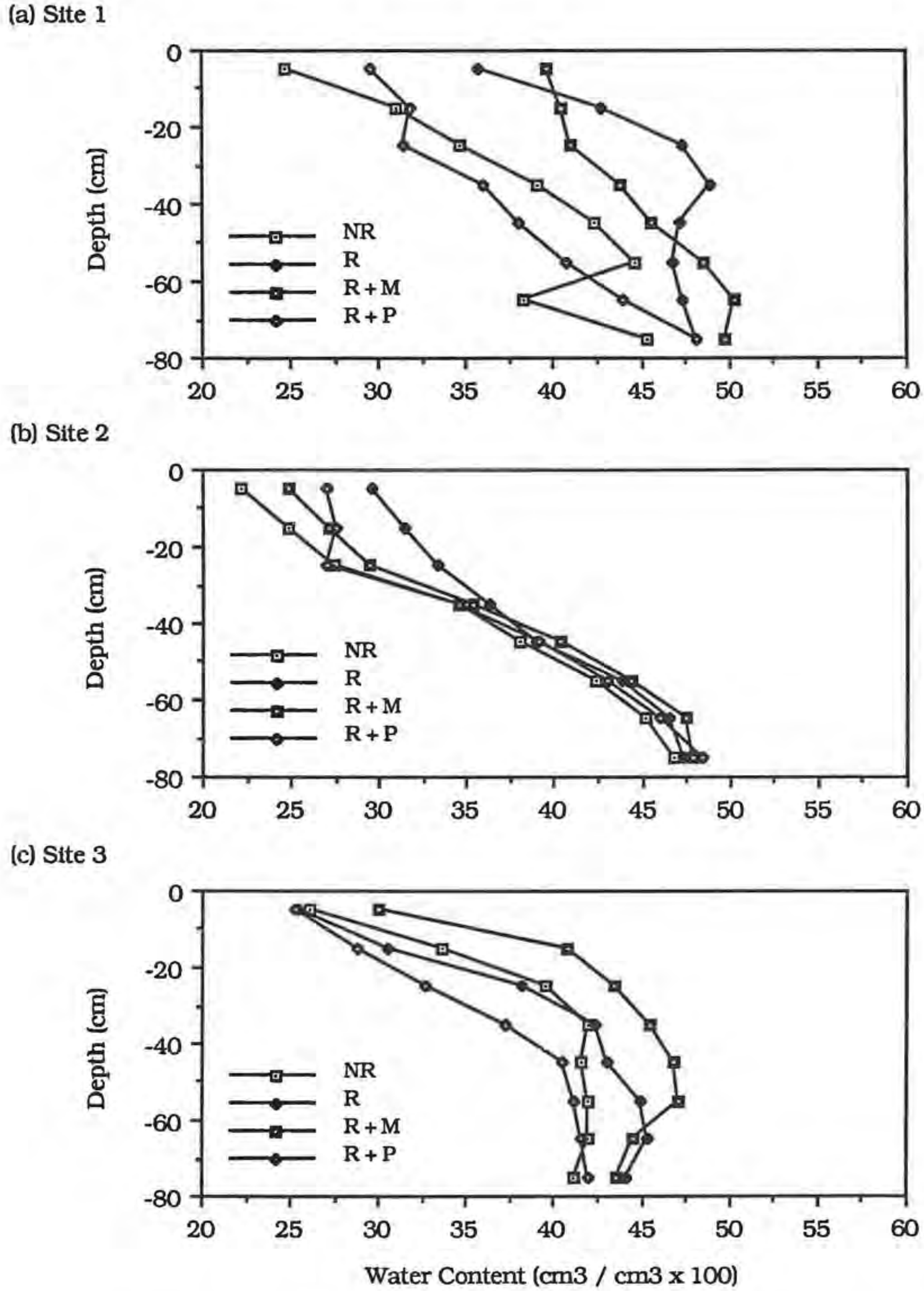

Figure 1. Soil Water Profiles: July 28, 1987, at (a) Site 1, (b) Site 2, and (c) Site 3.

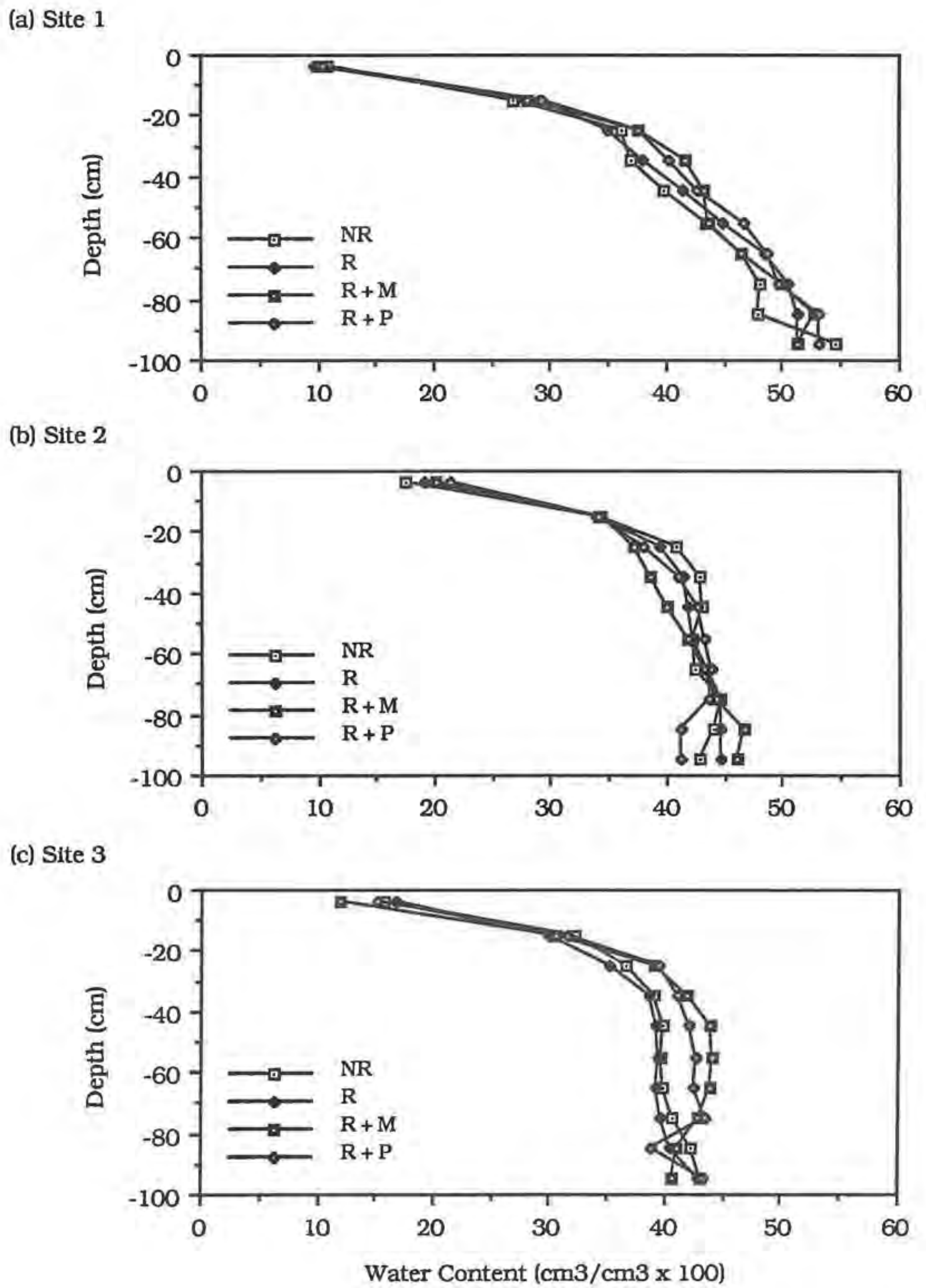

Figure 2. Soil Water Profiles: April 16, 1988, at (a) Site 1, (b) Site 2, and (c) Site 3.

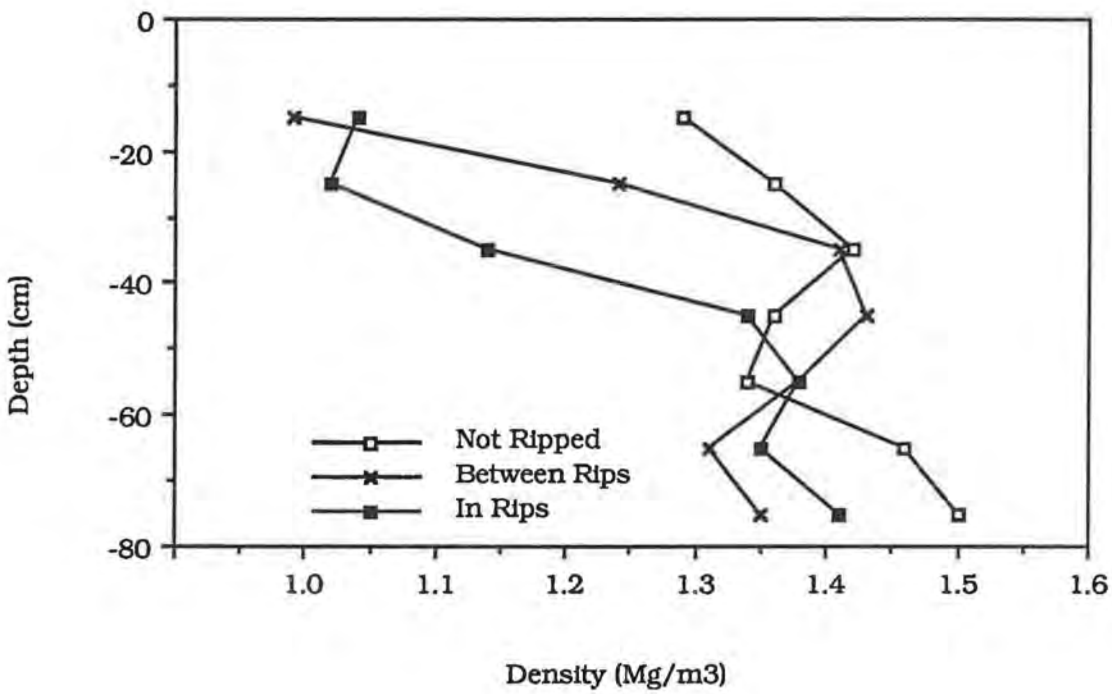

Figure 3. Soil Bulk Density: Site 2, April 16, 1988.

Penetration resistance (PR) in April, to a depth of 30 cm, was highest in the unripped treatments at all depths at all sites, although least dramatically at Site 3. The ripped + peat treatment was the most effective for decreasing PR at Sites 1 and 2; ripped+manure was the most effective at Site 3. The ripped treatments had lower PR than did the unripped treatments, although differences were small at Site 3, except at 30 cm. In July PR was highest in the unripped treatments at all depths for Sites 1 and 2, except the surface at Site 1. At Site 3, the highest PR at depths up to and including 10 cm was in the ripped plots; the PR for the unripped treatments became higher at 15 and 30 cm. The lowest PR at Sites 1 and 2 was in the ripped+manure treatment; the lowest at Site 3 was in the ripped+peat treatment.

Infiltration rates were higher in the surficially amended treatments at all times up to approximately 20 min. There was little difference between the two amended treatments and between the unripped and ripped treatments.

Ripping alone had little effect on soil chemistry or carbon:nitrogen ratio (Table I). The addition of manure had a marked effect on plant available nutrients. Nitrate-N was double, phosphate was four times greater and potassium was ten times greater compared to the other treatments. While plant available nutrients were unaffected by the addition of peat, a high C:N ratio (18:1) indicates that nitrate-N may be tied up in the microbial decomposition of the peat in this treatment.

Establishment of seeded grasses and legumes was most rapid and uniform on the ripped+peat treatments. Establishment on the ripped+manure treatment was slowest, lagging behind the other treatments by 3-4 weeks. First year plant growth at Site 2 was superior on the ripped+manure treatment. Plant cover was tallest (80 cm), most dense and dark green in color. Foliage on the peat-amended plots averaged 50 cm in height and was light green in color by late summer, suggesting nitrogen deficiency. Foliage on the ripped and unripped plots was intermediate in height (60-70 cm). First year biomass production at Site 2 (Fig. 4) was substantially higher in the ripped+manure treatment (5.1 t ha^{-1}) compared to the other treatments which ranged from 2.7 t ha^{-1} in the unripped treatment to 3.3 t ha^{-1} in the ripped one. Weeds comprised approximately 75% of the total biomass in all treatments except in the ripped+peat treatment where the percentage was slightly less (64%).

Table I. Soil Chemical Characteristics Of The 0-15 cm Layer
Study Average Spring 1987

Treatment	Nitrate ppm	Phosphate ppm	Potassium ppm	Carbon:Nitrogen
Unripped	33	14	160	10.1
Ripped	32	15	140	10.2
Ripped + Manure	67	59	1100	10.2
Ripped + Peat	36	12	130	18.3

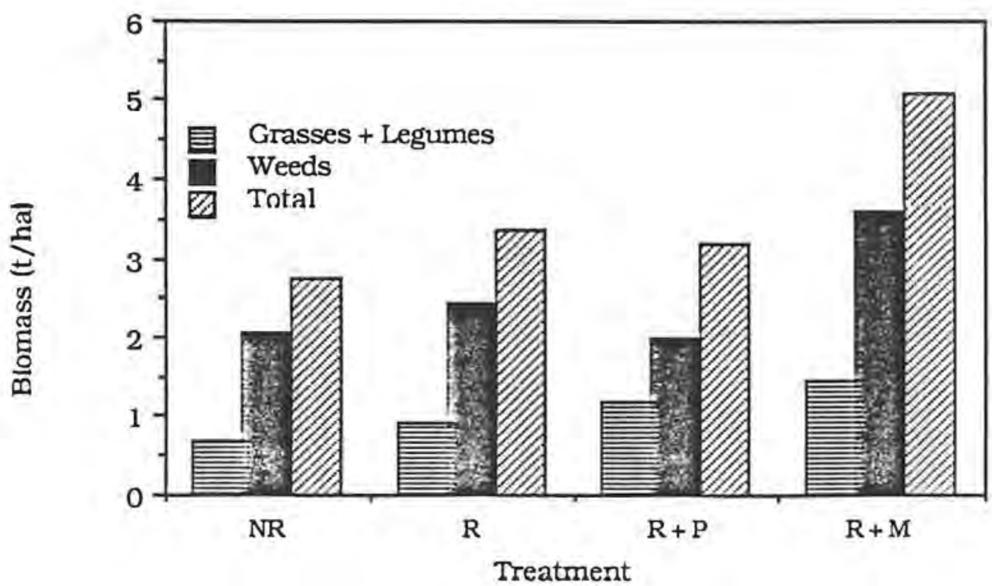

Figure 4. First Year (1987) Biomass Production At Site 2.

The first clippings in the second growing season at Site 2 were taken June 23, 1988. A uniform cover of grasses and legumes had virtually eliminated all the weeds in all treatments. Biomass production followed the same trend as the first year. Grass plus legume production on the ripped+manure treatment was 5.2 t ha^{-1}, considerably greater than the other treatments: 3.0 t ha^{-1} on ripped+peat, 3.3 t ha^{-1} on ripped only and 3.5 t ha^{-1} on the unripped treatment. The relatively poor growth on the peat treatment is most likely related to the lack of nitrate-N resulting from the addition of a high ratio C:N material.

Species composition at Site 2 in June 1988 is presented in Fig. 5. Major compositional differences among treatments were noted, including:

(1) The low proportion of alfalfa+clover in the organically amended treatments.

(2) The relative abundance of most grass species favored by mesic soil moisture conditions in the organically-amended treatments i.e. Kentucky bluegrass, bromegrass, and reed canarygrass.

(3) A similar species composition in the ripped and unripped treatments.

The low legume content on the treatments receiving organic amendments is likely related to competition from grass species. The initial rapid establishment of the grasses on the peat-amended plots reduced the legume establishment. Alfalfa+clover are present on these plots and are expected to increase in response to the subsequent poor vigor of the grasses and the apparent low availability of nitrate-N. In the treatments receiving manure, the high nitrogen levels have favored growth of grasses to the detriment of the legumes.

Grass cover was successfully established at Site 2 with the initial seeding. At Sites 1 and 3 a combination of factors (winterkill, low rainfall after reseeding) and soil properties (SAR 11 at Sites 1 and 3 versus 5 at Site 2) resulted in poor establishment. However, after two growing seasons a grass and legume cover is becoming well established at these sites. The first biomass clippings at Site 3 were taken in early September 1988. Like Site 2, the greatest biomass production was on the ripped+manure treatment (5.6 t ha^{-1}) followed by ripped (3.9 t ha^{-1}), ripped+peat (3.4 t ha^{-1}) and the unripped treatment (3.2 t ha^{-1}) (Table II). Competition from weeds has presented a problem during the establishment of a perennial forage crop on the reclaimed fields in which Sites 1 and 3 are located. Higher sodicity levels in these soils (SAR 11 versus 5) appears to give weeds a competitive edge for the first few years. After

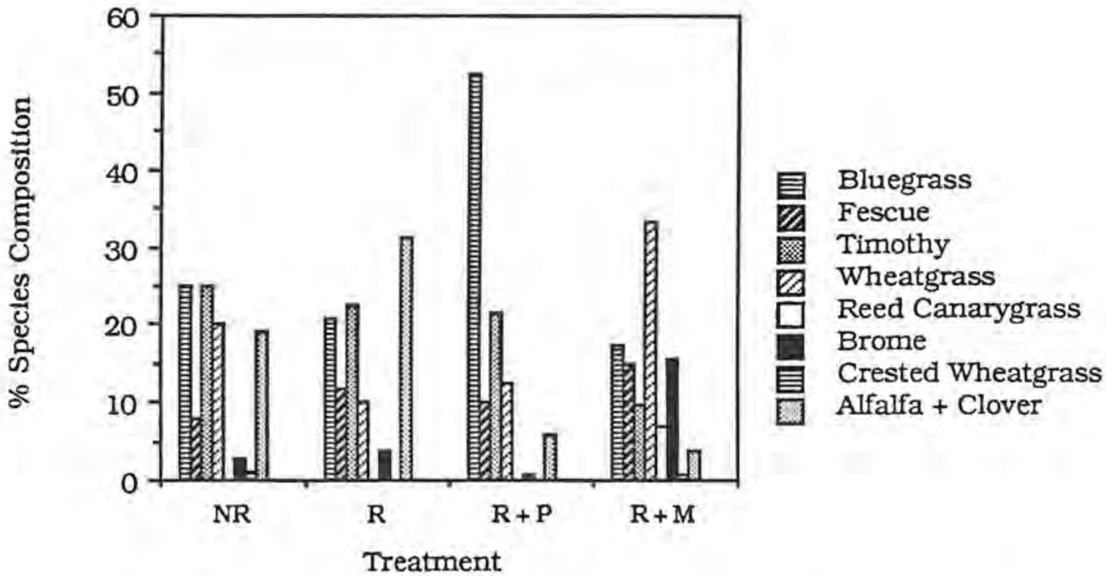

Figure 5. Percentage Species Composition: Site 2, June 23, 1988.

Table II. Biomass Production (t ha^{-1}) On Site 3, September 1988

Treatment	Weeds	Grasses	Legumes	Grasses +Legumes	Total Biomass
Unripped	1.28 (40)*	1.36 (42)	0.56 (18)	1.92	3.20
Ripped	0.74 (19)	1.94 (50)	1.21 (31)	3.15	3.89
Ripped + Manure	0.46 (08)	4.54 (82)	0.56 (10)	5.10	5.56
Ripped + Peat	0.51 (15)	1.46 (43)	1.45 (42)	2.91	3.42

* Bracketed values represent percentage of total biomass

two growing seasons at Site 3, 40% of the biomass in the unripped treatment was comprised of weeds compared to only 19% in the ripped treatment (Table II). Weed content on the organically amended plots was further reduced to 8% of the total on the ripped+manure treatment and 15% of the total on the ripped+peat treatment. Considering only seeded species, biomass production was lowest on the unripped treatment. Grass+legume biomass on the unripped treatment was 1.92 t ha^{-1} compared to 3.15, 2.91 and 5.10 t ha^{-1} on the ripped, ripped+peat, and ripped+manure treatments, respectively. Grasses provide the majority of the seeded biomass in all treatments (Table II) except in the ripped+peat treatment where legume biomass production is approximately equal to that of the grasses.

CONCLUSIONS

There was a trend for the surficially amended treatments to have more soil water at all depths, although differences were generally small. Water in the 50-80 cm zone was similar for all treatments, indicating water is not collecting at the bottom of the rips. Penetration resistance was generally reduced by surficial treatments, rising dramatically at all sites by July. Bulk density was lowest in the riplines and the effect of ripping on bulk density extended to the mid-rip position. Infiltration rates were highest in the surfically amended treatments.

The addition of peat or manure to the topsoil improved seedling establishment and growth, likely due to improved soil tilth. On soils with high sodicity, ripping alone results in an improved growth of grasses and legumes and a reduction in the growth of weeds. Surface amendments further improve forage growth and reduce the proportion of weeds.

Alberta Conservation & Reclamation Conference '88

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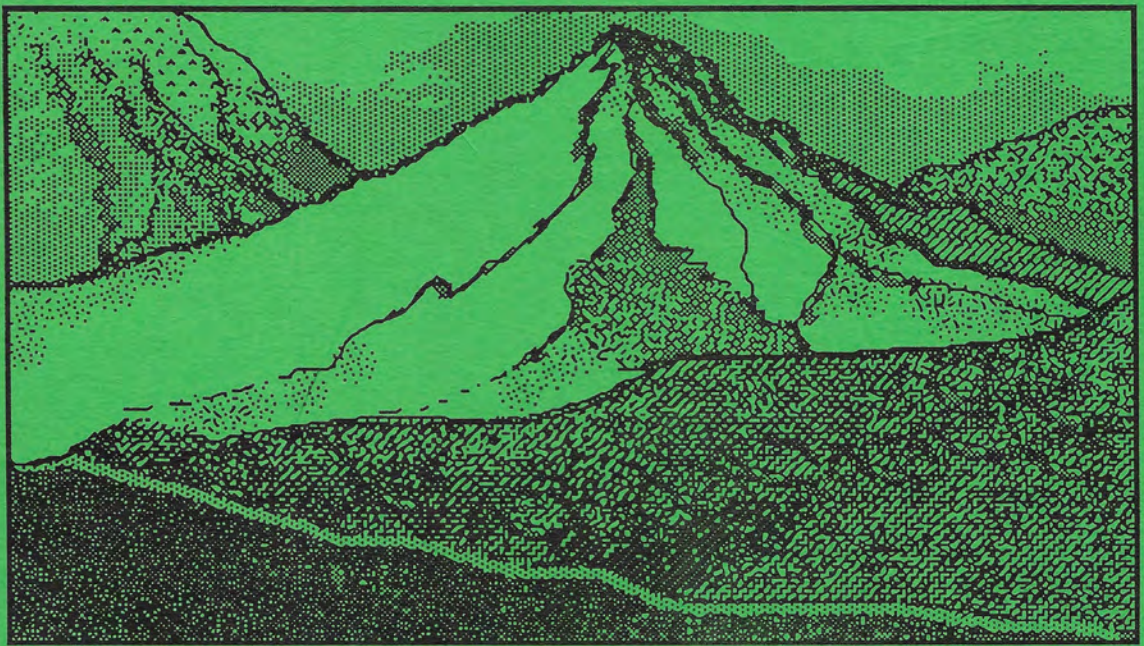

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C.B. Powter, compiler

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