# PRODUCTIVITY OF PRIME, NONPRIME AND RECLAIMED SOILS IN WESTERN NORTH DAKOTA

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State and federal stripmine reclamation laws require the separate handling of topsoil and subsoil from prime land. Prime land soil materials must be removed and separated from nonprime materials and must be respread on approximately their original location. In general, soils designated as prime in western North Dakota qualify because of landscape position. Most of these soils occur on nearly level or concave portions of the landscape which receive runoff from higher-lying surrounding soils which do not meet prime criteria. The development of prime soils in western North Dakota is apparently due more to moisture differences resulting from topographic location than to differences in parent material.

If differences in productivity between prime and nonprime soils are due largely to moisture differences resulting from topographic location, then the currently required separate removal and replacement of prime soil materials may not be justified. Rather, higher overall productive levels on reclaimed land might be attained by uniformly respreading all suitable soil materials over land reshaped to the most effective topographic configuration.

The objective of this study was to identify factors related to productivity of undisturbed prime and nonprime soils and similar areas of reclaimed soils.

## METHODS AND MATERIALS

Three experimental sites were selected at each of two locations, one near the Knife River Mine at Beulah and the other near the Baukol-Noonan Mine at Center. At each location, one site was located on an undisturbed prime soil, one on an adjacent undisturbed nonprime soil, and the third on a newly-reclaimed soil.

The prime site at Beulah was Grail clay loam, a deep, gently sloping, well-drained soil; the top 8 feet of the profile was clay loam in texture, and the 8 to 10-foot depth was loam. The nonprime site was Max clay loam, a deep, undulating, well-drained soil; the top foot was loam in texture, from 1 to 8 feet was clay loam, and the 8 to 10-foot depth was clay. The nonprime site was located approximately 300 feet from the prime site; both sites were about four miles southeast of the Knife River Mine. The reclaimed area (within the Knife River Mine) was reshaped and respread with 1 foot of first lift material over moderately sodic spoil in the spring of 1980; the texture of the first lift was clay loam and that of the spoil was clay.

The prime site at Center was Arnegard loam, a deep, nearly level, well-drained soil; the texture to the 10-foot depth was loam. The nonprime soil was Parshall sandy loam, a deep, sloping, well-drained soil; the top 3 feet and the 7 to 10-foot depth were sandy loam, with a loamy sand layer between 3 and 7 feet. The sites were located about 200 feet apart and were one mile from the Baukol-Noonan Mine. The reclaimed site in the Center Mine was reshaped and respread with 2 feet of second lift and 1 foot of first lift over nonsodic spoil in the spring of 1980. The first and second lift were loam in texture, and the underlying spoil was silt loam.

Identical plot areas were laid out at each of the six sites, using a split block design with four replications. Each plot was split with corn seeded on one-half and small grain (barley in 1980 and 1981, wheat in 1982) on the other half. Corn and small grain were rotated between subplots each year so that in 1981 and 1982, small grain was grown following corn and corn was grown following small grain. Tillage comparisons and fertility levels were also included in the experiment, but only average yields from each site are given in this report.

Neutron access tubes were installed in May 1980. Soil and/or spoil removed during access tube installation was sectioned into 1-foot increments for laboratory determinations of bulk density, wilting point percentage (15 bar pressure), particle-size, pH, electrical conductivity (EC), and sodium absorption ratio (SAR). The top 4 feet of the reclaimed site at Beulah was resampled in October, 1983.

## RESULTS AND DISCUSSION

### Soil Characterization:

At Beulah, the highest pH values at each depth were at the nonprime site except for the upper foot at the

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reclaimed site (Table 1). The acid pH of the upper 5 feet of the prime soil may have been a factor in the lower yields as compared to the nonprime soil at this site (as discussed later). All values for the nonprime (except for the upper foot) and reclaimed sites were greater than 7.0. On the undisturbed sites, EC was low except below 7 feet on the nonprime site. On the reclaimed site, EC values in 1980 were consistently greater than 5.0 above 9 feet. By 1983, the EC value of the top foot had decreased to 2.7, with lesser but appreciable decreases betwen 1 and 4 feet (Table 1). SAR values were low for the entire depth of the prime site but increased with depth on the nonprime site. At the reclaimed site, SAR values in 1980 were higher than at the undisturbed sites and were fairly constant by depth (ranging from 3.4 to 5.1). In 1983, the SAR value of the top foot was 1.9 and values between 1 and 4 feet tended to be slightly lower than in 1980. Decreases in SAR and EC values at the reclaimed site are probably due to the leaching action of rainfall and snowmelt.

At Center, pH values at each depth were higher at the nonprime site than at the prime site. The top 2 feet of the reclaimed site was more alkaline (higher pH) than the top 2 feet of either of the undisturbed sites; below 2 feet, the highest pH values were at the nonprime site. Electrical conductivity (EC) values generally increased with depth at the reclaimed site, but decreased at the other two sites. Sodium absorption ratio (SAR) values were somewhat higher at the reclaimed site than at the undisturbed sites, but all values were low.

### Crop Yields at Beulah:

Available soil water at planting for each of the three years at Beulah is given in Table 2. The higher content of available water in the nonprime site as compared to the prime site in 1980 is partly because the nonprime site was fallowed in 1979 while the prime site was cropped. Available water at planting at the nonprime site was higher than at the prime site in both 1981 and 1982. At both the prime and reclaimed site in 1980, a deficit of available water was noted at planting for both small grain and corn. This does not mean that the sites showing a deficit (negative value) at planting contained no available water but rather that because some increments of the profile were drier than the estimated wilting point (moisture at 15 bars), the total content of available water in the top 4 feet was below the cumulative estimated wilting point.

Small grain yields at Beulah were higher on the nonprime site than on the prime site in 1980 and 1981 (Table 3) but were not different in 1982. Fallowing the nonprime site in 1979 resulted in higher available water than on the nonprime site (Table 2). In 1980, severe drought after planting affected yields on the prime site more than on the nonprime site. These differences are also apparent in total water use in 1980 and 1981 (Table 4). Available water on the prime site at planting in 1981 (Table 2) as compared to the nonprime site suggests that the effects of fallowing the nonprime site in 1979 may have persisted through 1981. The lower pH of the prime

**Table 1. Measurements of pH, electrical conductivity (EC) and sodium absorption ratio (SAR) of samples obtained when access tubes were installed in May, 1980.**

| Location | Site | Depth of Sample (ft) 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | pH | | | | |
| | Prime | 5.4 | 5.4 | 5.3 | 5.6 | 5.8 | 6.0 | 6.6 | 6.4 | 7.0 | 7.4 |
| Beulah | Nonprime | 6.4 | 7.6 | 7.8 | 7.8 | 7.7 | 7.8 | 7.7 | 7.5 | 7.4 | 7.4 |
| | Reclaimed | 7.0 | 7.3 | 6.6 | 7.0 | 7.2 | 7.4 | 7.2 | 6.9 | 6.4 | 6.0 |
| | Prime | 5.8 | 6.1 | 6.0 | 6.2 | 6.4 | 6.4 | 6.9 | 6.7 | 7.0 | 7.2 |
| Center | Nonprime | 6.6 | 7.0 | 7.7 | 7.8 | 7.9 | 7.9 | 8.0 | 7.9 | 7.9 | 8.0 |
| | Reclaimed | 7.5 | 7.6 | 7.4 | 7.2 | 7.4 | 7.2 | 7.1 | -- | -- | -- |
| | | | | | | | EC (mmhos/cm) | | | | |
| | Prime | 2.4 | 1.6 | 1.1 | 1.0 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 |
| Beulah | Nonprime | 1.8 | 1.1 | 0.8 | 1.0 | 0.9 | 1.0 | 1.6 | 4.2 | 5.3 | 4.7 |
| | Reclaimed[1] | 6.1 | 6.7 | 6.2 | 6.0 | 7.0 | 6.3 | 7.4 | 5.8 | 6.1 | 5.0 |
| | | (2.7) | (5.4) | (4.6) | (5.1) | | | | | | |
| | Prime | 1.9 | 1.3 | 1.1 | 1.0 | 0.9 | 0.6 | 0.5 | 0.4 | 0.4 | 0.4 |
| Center | Nonprime | 1.2 | 1.0 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 |
| | Reclaimed | 1.5 | 1.0 | 1.7 | 2.9 | 2.7 | 2.8 | 2.8 | -- | -- | -- |
| | | | | | | | SAR (meq/a)[2] | | | | |
| | Prime | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 | 0.6 |
| Beulah | Nonprime | 0.2 | 0.3 | 0.8 | 2.2 | 3.2 | 3.6 | 3.4 | 2.5 | 2.2 | 2.4 |
| | Reclaimed[1] | 3.4 | 4.3 | 4.2 | 4.1 | 4.4 | 5.1 | 4.6 | 4.0 | 3.9 | 3.6 |
| | | (1.9) | (4.2) | (3.6) | (3.3) | | | | | | |
| | Prime | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 |
| Center | Nonprime | 0.2 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.6 | 0.6 |
| | Reclaimed | 1.2 | 1.0 | 0.9 | 1.0 | 1.0 | 0.8 | 0.8 | -- | -- | -- |

[1]Values in parentheses are from the October, 1983 sampling.

[2]Measured in saturation extract, $SAR = \frac{NA}{\sqrt{Ca + Mg.}}$

**Table 2. Available water at planting. Estimations from neutron probe data.[1]**

| Location | Site | 1980 | 1981 | 1982 |
|---|---|---|---|---|
| | | Year of data (inches) | | |
| | | Small grain | | |
| | Prime | -1.6 | 0.9 | 2.7 |
| Beulah | Nonprime | 2.6 | 2.7 | 3.0 |
| | Reclaimed[2] | -1.0 | 3.0 | 3.5 |
| | Prime | 0.0 | 2.3 | 3.8 |
| Center | Nonprime | -1.2 | 1.3 | 1.8 |
| | Reclaimed | -1.4 | 1.5 | 3.0 |
| | | Corn | | |
| | Prime | -1.4 | 1.2 | 1.8 |
| Beulah | Nonprime | 2.8 | 1.9 | 2.2 |
| | Reclaimed[2] | -1.0 | 3.2 | 2.7 |
| | Prime | 3.0 | 1.6 | 3.6 |
| Center | Nonprime | -0.4 | 0.5 | 3.2 |
| | Reclaimed | -4.3 | -0.2 | 3.3 |

[1]For 0-4 feet averaged over tillage and fertility.
[2]Planted one month after the other two sites in 1980.

**Table 3. Average yields of small grain and corn.**

| Location | Site | 1980 | 1981 | 1982 |
|---|---|---|---|---|
| | | Year of data | | |
| | | Small grains (bu/ac)[1] | | |
| | Prime | 1.4 | 12.5 | 33.2 |
| Beulah | Nonprime[4] | 19.8 | 22.4 | 34.1 |
| | Reclaimed | NH[2] | 18.4 | 21.1 |
| | LSD (.05) | 1.9 | 2.0 | 3.8 |
| | Prime | 21.4 | 39.9 | 31.0 |
| Center | Nonprime | 4.1 | 28.6 | 19.7 |
| | Reclaimed | NH[2] | 19.3 | 29.6 |
| | LSD (.05)[3] | 4.5 | 3.1 | 6.0 |
| | | Corn silage (t/ac) | | |
| | Prime | 1.7 | 6.0 | 9.0 |
| Beulah | Nonprime[4] | 2.7 | 7.2 | 8.2 |
| | Reclaimed | 1.1 | 10.8 | 7.2 |
| | LSD (.05) | 0.2 | 1.1 | 1.2 |
| | Prime | 12.7 | 10.4 | 10.2 |
| Center | Nonprime | 7.5 | 7.1 | 9.6 |
| | Reclaimed | 6.2 | 9.3 | 9.4 |
| | LSD (.05) | 1.6 | NS | NS |
| | | Corn grain (bu/ac, shelled) | | |
| | Prime | NH[2] | 40.4 | 43.4 |
| Beulah | Nonprime[4] | NH[2] | 54.7 | 51.2 |
| | Reclaimed | NH[2] | 51.7 | 31.3 |
| | LSD (.05) | -- | NS | 10.9 |
| | Prime | 82.6 | 52.8 | 47.3 |
| Center | Nonprime | 47.6 | 50.7 | 46.3 |
| | Reclaimed | 40.4 | 61.5 | 55.1 |
| | LSD (.05) | 36.5 | NS | NS |

[1]Barley in 1980-81, wheat in 1982.
[2]Not harvested due to drought and/or poor stand.
[3]Least significant difference (LSD) at 5% level, NS denotes not significantly different.
[4]Fallowed in 1979. All other undisturbed sites at both locations had been cropped.

**Table 4. Total water use by crops.[1]**

| Location | Site | 1980 | 1981 | 1982 |
|---|---|---|---|---|
| | | Year of data (inches) | | |
| | | Small grain[2] | | |
| | Prime | 5.6 | 7.4 | 12.7 |
| Beulah | Nonprime | 9.6 | 9.6 | 12.8 |
| | Reclaimed | (5.6) | 9.8 | 9.9 |
| | Prime | 10.2 | 10.3 | 14.5 |
| Center | Nonprime | 9.9 | 9.0 | 12.7 |
| | Reclaimed | (6.6) | 8.8 | 9.2 |
| | | Corn grain[2] | | |
| | Prime | (8.8) | 13.1 | 11.6 |
| Beulah | Nonprime | (11.2) | 12.0 | 12.0 |
| | Reclaimed | (8.1) | 13.1 | 13.3 |
| | Prime | 15.0 | 14.0 | 13.1 |
| Center | Nonprime | 13.6 | 12.4 | 14.2 |
| | Reclaimed | 9.2 | 12.0 | 13.1 |

[1]Precipitation from planting to harvest plus difference in total soil water (0-4 feet) from planting to harvest.
[2]Numbers in parenthesis indicate that the crop was not harvested for yield due to drought and/or poor stands,but total water use is given for comparison.

site may also have affected yields. No yields were obtained on the reclaimed site in 1980, but yields in 1981 were higher than on the prime site and lower than the nonprime site, and yields in 1982 were lower than on either of the undisturbed sites. Insect damage at the reclaimed site in 1981 and 1982 (due to its isolation) probably resulted in yield decreases; insect damage was more severe on the reclaimed site in 1982 than in 1981.

Corn silage yields at Beulah in 1980 were low due to drought and were directly related to available water at planting; highest yields were obtained from the nonprime site and lowest from the reclaimed site. In 1981 higher corn population contributed to higher yields at the reclaimed site than at the prime and nonprime sites. Yields from the nonprime site were higher than those from the prime site. No difference in yield was noted between the prime and nonprime sites in 1982, although the yield from the prime site was slightly higher. The lowest yield was obtained at the reclaimed site; however, the corn at this site was severely damaged by insects and animals. Available water at planting in both 1981 and 1982 was very similar at all three sites (Table 4).

No corn grain was harvested at Beulah in 1980 because of severe drought (Table 3). No significant differences in grain yield were noted in 1981, partially because of higher corn population at the reclaimed site and partially because of high variability among the replications at all three sites. However, the highest yield was on the nonprime site and the lowest on the prime site. Water use was fairly uniform among the three sites in 1981 (Table 4). In 1982, corn grain yields on the prime and nonprime sites were not significantly different, but yields on the nonprime site were slightly higher. Due to insect and animal damage, yields from the reclaimed site were significantly lower than at the undisturbed sites. Because available water at planting (Table 2), total water use (Table 4), and populations were fairly uniform among the three sites, it is probable that there would have been no yield differences among the sites if the damage at the reclaimed site had not occurred.

Values for SAR and EC were higher on the reclaimed site than on either of the undisturbed sites, but no noticeable salt or sodium effects were observed at any time on the reclaimed site. The results of the 1983 sampling indicate that the soluble salts are being leached to lower levels in the soil. The EC and SAR values on the plot site tended to be appreciably higher than in the remainder of the reclaimed area in which the plots were located (personal communication from Mr. D. Morman, Knife River Coal Corp.).

**Crop Yields at Center:**

At Center, both the nonprime and reclaimed sites showed a deficit of available water at planting in 1980, as did the reclaimed site for corn in 1981 (Table 2). The nonprime site, because of its coarse texture and low water-holding capacity, was always lower in available water than either the prime or reclaimed sites.

Differences in small grain yields at Center in 1980 were attributable to the amount of available water at planting, droughty growing conditions and loss of stand at the reclaimed site shortly after emergence due to a severe storm. Yields from the prime site were much higher than from the coarse-textured nonprime site. In 1981, hihest yields were obtained at the prime site and lowest yields on the reclaimed site. These yield differences were partially attributed to poor germination at the nonprime site and to insect damage at the reclaimed site. In 1982, the amount of available water at planting at the reclaimed site was almost as high as that of the prime site, and at both sites was much higher than at the nonprime site (Table 2). Lowest yields were obtained at the nonprime site, and yields from the prime and reclaimed sites were not different (Table 3).

Corn silage yields in 1980 were lower at the reclaimed and nonprime sites than at the prime site (Table 3), again related to the amount of available water at planting. All yields were low due to drought during the growing season. In 1981 and 1982 no significant differences were noted between sites. Each year, however, yields tended to be highest on the prime site; the lowest yield in 1981 was obtained on the nonprime site.

Corn grain yields at Center followed the same pattern as silage yields for the three years, with significant differences in yields only in 1980. Higher amounts of available water at planting at the prime and reclaimed sites (as previously mentioned) were directly related to yield levels. Little difference in total water use was seen among the three sites in 1981 and 1982 (Table 4).

## CONCLUSIONS

Corn and small grains were rotated so that in 1981 and 1982, corn was grown on plots which were planted to small grain in the preceding year and small grain on plots previously planted to corn. Available water at planting generally tended to be higher when small grains were planted on plots where corn was grown the preceding year (average of 2.5 inches for 1981 and 1982, Table 2) than when corn was planted following small grain (average of 2.1 inches). However, the total water use by corn (average of 12.8 inches for 1981 and 1982, Table 4) was greater than that by small grain (average of 10.6 inches). The reason for this apparent increase in available water at planting on plots where water use by the preceding crop was highest is not evident; however, these data are in agreement with unpublished research by the North Dakota Agricultural Experiment Station which indicates that yields of small grains grown following corn are often higher than when the preceding crop is small grain. Further research studying the effects of cropping sequences on (1) water use by crops and (2) moisture recharge during the nongrowing season appears to be warranted.

On the undisturbed prime and nonprime soils, yields were dependent upon the amount of available water at planting plus rainfall during the growing season. At Beulah, the nonprime soil generally contained more available water at planting than the adjacent prime soil, and crop yields were generally higher on the nonprime soil. At the same time, yields on the prime soil may have been reduced because the upper horizons were more acidic than on the nonprime soil. However, when moisture at planting was about equal on these two sites, yields also tended to be about equal. At Center, available water at planting was always lower on the coarse-textured nonprime site than on the finer-textured prime site, and yields were always higher at the prime site. There is also some indication that growing season precipitation was less effective on the nonprime site than on the prime site, presumably attributable to the textural differences.

At both locations, reclamation of the reclaimed sites was completed in the spring of 1980 just prior to the establishment of the experimental plots. In 1980, small grain yields were not obtained because of poor stands and poor growth from the reclaimed sites at both Beulah and Center, and corn grain yields were not obtained at Beulah. Corn silage yields at both sites and corn grain yields at Center were lower on the reclaimed sites than on the undisturbed sites. In 1981 and 1982, however, yields from the reclaimed sites tended to approach or equal those from the undisturbed sites. Similar yield trends have been noted when newly reclaimed soils were cropped in other experiments. Until the soil structure begins to reestablish in disturbed soils, giving rise to more favorable conditions for porosity, water infiltration and root penetration, optimum crop yields cannot be expected. At these two sites, the yields from the reclaimed soils after three years appeared to meet the "equal or better"standard for evaluation of reclaimed success.

Because of rainfall differences and insect and small animal damage on sites which were isolated from other cropped areas, a precise evaluation of the soil factors contributing to yield differences was not possible. However, these results do indicate that field classification of soils as prime or nonprime is not in itself an adequate measure of potential yield level. When moisture levels

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control animals fed no sunflower seeds. Average daily gain, however, was not different among rations. Total dry matter intake was down slightly by heifers that received the sunflower seeds but total energy intake was similar. The high concentration of fat (energy) in the seeds compensated for the lower dry matter intake, which explains the similar caloric intake. The rations containing higher fat did increase most lipid constituents in the blood with a slight lowering of blood glucose. This, however, did not affect the heifers growth performance or rate of gain.

In summary, sunflower seeds at levels up to 30 percent of the grain mix can be fed to dairy cows. High-producing cows fed high levels of grain should be restricted to 20 percent sunflower seeds in their grain or a maximum of 6 to 8 pounds seed daily to stay within maximum fat levels of 8 to 10 percent recommend for dairy cattle diets. Higher levels of fat in the total diet could cause feed refusals and digestive upsets in cows. Research indicates that sunflower seeds can be fed either whole, rolled or coarsely ground to dairy cattle.

Milk production can be expected to increase slightly because of the higher energy content of the sunflower seeds, sometimes called sunseeds. Sunflower seeds do not adversely affect ration digestibility nor were any health or feeding problems observed at these levels of intake. Milk composition was not changed substantially with consumption of sunflower seeds. The high fiber content of the whole seed, which ranges from 19 to 26 percent, may be an advantage in rations consisting of a number of low fiber feeds to help maintain a minimum crude fiber level of 17 percent in the total ration which is required for dairy cows.

Young growing heifers also respond well to sunflower seeds in the ration. Levels of 0 to 20 percent sunflower seeds in the total ration dry matter can be used to replace other feed sources when economically feasible and available, resulting in good gains and growth rates.

### REFERENCES

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were more favorable on a nonprime soil (as at Beulah), yields were higher than on adjacent prime soils. Soil textural differences (as at Center) may be more important in establishing yield level than classification as prime or nonprime. Soil chemical characteristics must also be considered, since the lower yields on the prime site as compared to the nonprime site at Beulah may have been partially related to the more acidic nature of the prime soil.

No decreases in crop yields were apparent at the reclaimed site at Beulah due to the higher initial EC and SAR values than those at the prime and nonprime sites. By 1983, appreciable downward leaching of both soluble salts and sodium was apparent.

These results suggest that mandatory separation of soil materials classified as prime or nonprime may not be necessary for optimum reclamation. Rather, the critical factors are (1) the chemical and physical characteristics of the soil materials and (2) the restoration of a postmine topography which includes "prime-land areas" in which soil moisture levels can develop which are similar to those in prime soils before mining. However, the relative contribution of moisture levels and the various soil physical and chemical factors to yield potential must be more precisely evaluated before specific reclamation guidelines can be established.

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