

**RANGE PROGRAM
RESEARCH PROJECT
REPORT**

*Restoration of Native Mixed Grass
Prairie on Degraded Untilled Land
through Implementation of
Biologically Effective Grazing
Management*

*North Dakota State University
Dickinson Research Extension Center*

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Progress Report of Project Year Six

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The Schnell Recreation Area, located approximately 2 miles (3.22 kilometers) east of Richardton, North Dakota, in eastern Stark County, has been managed by the Bureau of Land Management (BLM) since 1993. The area comprises 1,988 acres (804.5 hectares) of degraded land dominated with undesirable introduced cool-season domesticated grasses, primarily smooth brome grass, crested wheatgrass, and Kentucky bluegrass. The area shows degradation of two types, each of which has a distinct cause: 1. land with native plant ecosystems that were first degenerated by management practices antagonistic to plant biological requirements and ecosystem biogeochemical processes and subsequently invaded with undesirable introduced species and 2. land that was seeded with cool-season domesticated grasses after native plant ecosystems were destroyed by tillage. The Bureau of Land Management's identified goals for the Schnell Recreation Area are to restore the native grassland condition and vegetation diversity of the degraded untilled areas that have been invaded by undesirable species and to convert the seeded cool-season domesticated grasses on the previously tilled haylands to a mixture of native species. The desired purpose of the restored prairie and converted grassland is to provide high-quality habitat for maintenance and production of grassland migratory birds, neo-tropical birds, and other resident wildlife.

This project was developed to test and evaluate the use of biologically effective grazing management practices in the restoration of native mixed grass prairie plant species composition and grassland ecosystem biogeochemical processes on degraded untilled land and to monitor the progress of the improvements in the ecosystem. The biologically effective management practice implemented was the twice-over rotation grazing system which coordinates two grazing periods with grass growth stages and meets the biological requirements of the plants.

Procedures

A three-pasture twice-over rotation grazing management system was used on the grasslands of the

Schnell Recreation Area from early June until mid October, with each pasture grazed for two periods. A fourth pasture at the Schnell Recreation Area was not grazed and was used as a control. Each of the three pastures in the rotation was grazed for 14 to 16 days during the first period, the 45-day interval from 1 June to 15 July. The length of the first period on each pasture is the same percentage of 45 days as the percentage of the total season's grazeable forage each pasture contributes (Manske 2000a). During the second period, after mid July and before mid October, each pasture was grazed for double the number of days it was grazed during the first period. Livestock were removed in mid October.

The coordinated defoliation improves plant health and stimulates biological and ecological processes within grass plants and the ecosystem so that beneficial changes to plant growth, soil organisms, and biogeochemical cycles in the ecosystem result (Manske 2000a). During the first grazing period, grasses are between the third-leaf and flowering stages, the stages of plant development at which grazing produces beneficial effects by stimulating the defoliation resistance mechanisms that increase tillering from axillary buds and enhance activity of rhizosphere organisms. Increased vegetative reproduction by tillering contributes to the development of greater plant basal cover and to the production of greater grass herbage weight; increased activity of the soil organisms in the rhizosphere supplies the plant with greater quantities of nutrients to support additional growth (Manske 2000a). Removing livestock from native rangeland pastures in mid October, during the early fall, allows native grasses to store nutrients that will maintain plant processes over the winter and to retain the fall vegetative growth that will become next season's lead tillers (Manske 2003a). This practice ensures healthy plants in the spring and greater herbage production during the next growing season (Manske 2000a).

Plant growth data were collected on permanent plots organized in a paired-plot design. A 16' X 32' stock panel enclosure that prevented livestock access and an adjacent area of equal size

accessible by livestock were established for nondestructive sampling on silty range sites in each of the four pastures. An additional area of similar size accessible by livestock was established for destructive sampling at each sample site location. During the grazing season, aboveground herbage biomass was collected on each pasture rotation date by the standard clipping method (Cook and Stubbendieck 1986). The herbage material from five 0.25m² quadrats (frames) at each sample site was sorted in the field by biotype categories: domesticated grasses, cool-season grasses, warm-season grasses, sedges, forbs, standing dead, and litter. The herbage of each biotype category from each frame was placed in labeled paper bags of known weight, oven dried at 140° F (60° C), and weighed. Plant species composition was determined during peak growth between mid July and mid August by the ten-pin point frame method (Cook and Stubbendieck 1986), with 2000 points collected along permanent transect segments both inside (ungrazed) and outside (grazed) each exclosure. Basal cover, relative basal cover, percent frequency, relative percent frequency, and importance value were determined for the ten-pin point frame data. Densities of forbs and shrubs were determined by counting individual stems of each plant species rooted inside twenty-five 0.1m² quadrats placed along permanent transect segments both inside (ungrazed) and outside (grazed) each exclosure. Density per 0.1m² quadrat, relative density, percent frequency, relative percent frequency, and importance value were determined for the density data. Changes in activity of rhizosphere organisms were monitored during 3 grazing season periods: pretreatment (May), first rotation (July), and second rotation (October). Total rhizosphere weight per standard volume of soil was determined for each of the four pastures from three replicated soil cores 4 inches (10.2 cm) in diameter and 4 inches (10.2 cm) in depth, collected with a gulf cup cutter. The fresh rhizosphere material, which included the rhizosphere organisms, the plant roots, and the adhered soil particles, was separated from matrix soil by hand, and both wet and dry weights were collected. A standard paired plot t-test was used to analyze differences between means (Mosteller and Rourke 1973).

Results

In the Richardton, North Dakota, area, the long-term mean (LTM) (1971-2000) annual temperature is 43.0° F (6.1° C) (table 1). January is the coldest month, with a mean temperature of 13.5° F (-10.3° C). July and August are the warmest months, with mean temperatures of 70.0° F (21.1° C) and 68.9° F (20.5° C), respectively. Plants

experience temperature stress during months with mean monthly temperatures below 32.0° F (0.0° C). From November through March each year, plants in western North Dakota cannot conduct active growth because mean temperatures are below 32.0° F (0.0° C) (table 1).

The long-term annual precipitation in the Richardton, North Dakota, area is 17.78 inches (451.61 mm) (table 1). The growing season precipitation (April through October) is 14.79 inches (375.67 mm), 83.18% of the annual precipitation. The seasonal period during which the greatest precipitation occurs is spring--April, May, and June--with 7.63 inches (193.80 mm), 42.91% of the annual precipitation. June has the greatest monthly precipitation, 3.39 inches (86.11 mm). The precipitation received during the 3-month period of May, June, and July accounts for 45.84% of the annual precipitation (8.15 inches, or 207.01 mm). The precipitation received during the 5-month period of November through March averages 2.99 inches, (75.95 mm), 16.82% of annual precipitation. The seasonal period during which the least precipitation occurs is winter--January, February, and March--with 1.79 inches (45.47 mm), 10.07% of the annual precipitation.

A technique reported by Emberger et al. (1963) was used to identify water deficiency months from temperature and precipitation data. This method graphs the mean monthly temperature (°C) and monthly precipitation (mm) on the same axis, with the scale of the precipitation data at twice that of the temperature data. The temperature and precipitation data are plotted against an axis of time. The resulting ombrothermic diagram shows general monthly trends and indicates the months with water deficiency conditions, unfavorable periods during which perennial plants experience water stress. Water deficiency exists during months when the precipitation data bar drops below the temperature data curve. Plants are under temperature stress when the temperature curve drops below the freezing mark (0° C). The long-term ombrothermic graph for the Richardton, North Dakota, area (figure 1) shows that August and September typically have near water deficiency conditions and that November, December, January, February, and March have temperature stress conditions for perennial plants.

During the sixth year of the study, precipitation during the growing season, April through October, was 17.15 inches (435.61 mm), 115.96% of the long-term mean (LTM) growing season precipitation (table 2). Water deficiency

conditions in August caused water stress that resulted in reductions of plant growth rate. Water stress can vary in degree from a small decrease in water potential to the lethal limit of desiccation. The percent reduction in peak herbage biomass caused by low precipitation is usually proportional to the levels of precipitation below the normal range. Herbage weight of perennial plants increases from early season through May, June, and July until peak herbage biomass, which occurs during the last couple weeks of July. Herbage weight then decreases as plants age and dry. The herbage biomass produced by healthy plants is affected by plant size and plant density and is related to precipitation levels during January through July (Manske 2003b). The long-term January through July seasonal precipitation in the Richardton, North Dakota, area is 11.69 inches (296.93 mm). The January through July precipitation in 2011 was 15.07 inches (382.78 mm), 128.91% of the long-term January through July precipitation. The range of normal precipitation is plus or minus 25% of the long-term mean. The 2011 January through July precipitation was 3.91% above long-term seasonal precipitation (75%, which is the low-normal long-term precipitation value). The 2011 peak herbage biomass, reached during the last couple weeks of July, would be estimated to be above the long-term mean peak herbage weight on healthy grasslands.

The aboveground herbage produced by domesticated grasses was greater than the herbage produced by native grasses on pastures 1, 3, and the control pasture 4, which was not grazed (tables 3, 4-7). Native grasses produced greater amounts of aboveground herbage than the domesticated grasses on pasture 2 (tables 3, 5). The proportion of the grass herbage produced by native grasses has tended to increase on two of the three grazed pastures. The percent native grass herbage produced was 26.5%, 32.5%, 56.5%, 45.3%, 34.9%, and 27.5% on pasture 1; and 41.7%, 36.4%, 63.8%, 76.3%, 68.5%, and 55.1% on pasture 2; respectively, during 2006, 2007, 2008, 2009, 2010, and 2011. The percent native grass herbage produced was 11.9%, 5.6%, 15.0%, 11.2%, 8.5%, and 5.8% on grazed pasture 3; and 7.9%, 12.6%, 11.0%, 16.6%, 17.6%, and 8.7% on the nongrazed control pasture 4, respectively.

Cow-calf pairs grazed the three pasture rotation system during the growing seasons of 2006, 2007, and 2008. Heifers grazed the grassland pastures during 2009 and 2010. Steers grazed the grassland pastures during 2011. Grazing behavior differences between mature cows, young heifers, and young steers is expected to cause some differences in the vegetation data.

The weight of the total live herbage was greater than the weight of the standing dead and litter on pastures 1, 2, and 3 since 2009 (tables 4, 5, and 6). The standing dead and litter weight was greater than the live herbage weight produced on the control ungrazed pasture 4 (table 7). The average live herbage weight and the average standing dead and litter weight, respectively, were 2514.11 lb/ac and 1547.39 lb/ac on pasture 1 (table 4), 1833.03 lb/ac and 1268.47 lb/ac on pasture 2 (table 5), 2447.34 lb/ac and 1349.93 lb/ac on pasture 3 (table 6), and 2742.47 lb/ac and 4407.80 lb/ac on control pasture 4 (table 7). Standing dead and litter composed 38.1%, 40.9%, 35.6%, and 61.7% of the aboveground biomass on pastures 1, 2, 3, and 4, respectively. Live herbage composed greater than 60% of the aboveground biomass on all three grazed pastures.

Percent basal cover of domesticated grasses were greater than the basal cover of native grasses and sedges on pasture 3 and control pasture 4 (tables 8, 13-16). Basal cover of native grasses and sedges were greater than basal cover of domesticated grasses on grazed pasture 2 (tables 8, 9-12). The basal cover of native grasses and sedges and the basal cover of domesticated grasses, respectively, were 8.3% and 12.7% on pasture 1 (table 10), 23.8% and 1.1% on pasture 2 (table 12), 0.9% and 15.9% on pasture 3 (table 14), and 2.3% and 15.4% on control pasture 4 (table 16). Domesticated grasses composed 58.5%, 4.2%, 93.5%, and 86.0% of the basal cover on pastures 1, 2, 3, and 4, respectively. Native grasses and sedges composed 38.0%, 94.8%, 5.3%, and 12.6% of the basal cover on pastures 1, 2, 3, and 4, respectively. During 2011, basal cover of native grasses and sedges decreased 47.5%, 5.0%, 37.9%, and 38.4% on pastures 1, 2, 3, and 4, respectively, from the basal cover during 2010. Basal cover of cool season and warm season grasses and sedges on pastures 1 and 2 averaged 57.2% greater on the grazed treatments than on the ungrazed treatments.

Plant species composition included varying quantities of early, mid, and late succession forbs (tables 17-25). Forb density was greater on the grazed treatments of pastures 1 and 2 than on the ungrazed treatments and forb density was greater on the ungrazed treatment of pasture 3 than on the grazed treatment (table 17). Early succession forbs, primarily yellow sweetclover, on pastures 1, 2, and 3 was greater on the grazed treatment than on the ungrazed treatment. Mid succession forbs, primarily blue wild lettuce, on pasture 2 was greater on the ungrazed treatment than on the grazed treatment. Late succession forbs, primarily western yarrow, white prairie aster, scarlet gaura, silver leaf scurfpea,

and american vetch, on pasture 2 was greater on the grazed treatment than on the ungrazed treatment, and on pastures 1 and 3 was lower on the grazed treatment than on the ungrazed treatment.

The weight of the rhizosphere samples in this study included the rhizosphere organisms, the plant roots, and the adhered soil particles. Rhizospheres were present on all of the degraded untilled sites sampled in grazed pastures 1, 2, and 3 and control pasture 4 (table 26). The weight of the rhizospheres started low on all sample sites in 2006 and have basically increased each year on the grazed pastures. The rhizosphere weights on pastures 1 and 2 were greater than the rhizosphere weights on pasture 3 and on the nongrazed control pasture 4 and the rhizosphere weights on pasture 3 were greater than those on pasture 4 during the six years of the study. The mean rhizosphere weights were 215.1, 207.7, 167.1, and 141.7 kg/m³ on pastures 1, 2, 3, and 4, respectively.

The weight of the rhizospheres appeared to have some relationship to the percent domesticated grasses and percent native grasses in the plant community. Pastures 1 and 2 generally had greater rhizosphere weight during the growing season than pasture 3 and control pasture 4 (table 26). Pastures 1 and 2 had greater percent native grasses and lower percent domesticated grasses in the plant communities than pasture 3 and control pasture 4 (table 27). The primary domesticated grass on control pasture 4 was Kentucky bluegrass, and the primary domesticated grass on pasture 3 was smooth brome grass in 2006 and 2007. Kentucky bluegrass had greater basal cover than smooth brome grass in 2008, 2009, 2010, and 2011 on pasture 3. During the six years of this study, relative basal cover has increased for Kentucky bluegrass and decreased for smooth brome grass on pasture 3. Rhizosphere weight on pasture 3 has increased during this six year period. The restoration of native prairie plant communities from degraded untilled land dominated with smooth brome grass appears to require an intermediary step with increased Kentucky bluegrass in order to build up the rhizosphere organism biomass.

Smooth brome grass roots do not appear to readily develop symbiotic relationships with rhizosphere organisms. During a study that evaluated the effects on the percent mycorrhizal fungi infection in grass roots from prescribed every-other-year burning treatments conducted during the period from 1978 to 1990, Manske et al. (2006) found that the percent fungal infection in smooth brome grass roots (41.8%) was significantly less than the percent

infection in western wheatgrass (67.0%) and blue grama (78.8%) roots. Very few smooth brome grass samples had fungal colonization within the root tissue. Almost all of the fungal infection observed in smooth brome grass was restricted to the root hairs. The study also found that the number of repeated burns and the seasonal period of burns did not significantly change the level of fungal infection in domesticated and native grass roots.

Biologically effective grazing management can stimulate rhizosphere organism activity when a small amount of leaf material from grass plants between the third-leaf stage and the flowering stage is removed by grazing animals (Manske 1999). The rhizosphere volume per grass plant and the total rhizosphere volume per cubic meter of soil on pastures managed with the twice-over rotation system were significantly greater following the stimulation grazing period than the rhizosphere volume per grass plant and the total rhizosphere volume per cubic meter of soil on the 4.5-month seasonlong and 6.0-month seasonlong grazing treatments and the long-term nongrazed treatment (Gorder, Manske, and Stroh 2004).

The grassland ecosystems on degraded untilled land at the Schnell Recreation Area were dominated by cool-season domesticated grasses and had low native grass herbage biomass production, low native grass basal cover, low late succession native forb density, and low rhizosphere weight. However, a few native grasses and forbs in association with rhizosphere organisms did remain. Through the use of biologically effective management practices to stimulate the defoliation resistance mechanisms of these plants it will be possible to restore the biogeochemical processes in these grassland ecosystems.

The restoration of the prairie communities on the untilled land at the Schnell Recreation Area will require several years, and because of the extensive deterioration of the grassland ecosystem, it is estimated that full recovery will require greater than ten years and perhaps longer.

Discussion

Restoration of prairie ecosystems requires an understanding of the defoliation resistance mechanisms within grass plants, the symbiotic rhizosphere organisms' relationship with ecosystem biogeochemical processes and grass plants, and the stimulation of these processes with defoliation by grazing animals.

Grass plants evolved 20 million years ago with early herbivores that are now extinct. During this time, grasses developed biological processes that help the plants withstand and recover from defoliation (Manske 2000a). This complex of processes (McNaughton 1979, 1983, Briske 1991, Briske and Richards 1995), called defoliation resistance mechanisms, accelerates both the growth rate of the grazed plant and its development of foliage and roots. Two biological processes of primary concern to grassland managers are the increased beneficial activity of soil organisms (Coleman et al. 1983) and the stimulation of vegetative reproduction by secondary tiller development from axillary buds (Briske and Richards 1995). Grazing that removes a small amount of leaf area from the grass plant between the third-leaf stage and flowering stage can trigger these beneficial responses (Manske 1999).

There is a mutually beneficial relationship between the grass plant's root system and soil organisms. The narrow zone of soil around the roots of perennial grassland plants, the rhizosphere, contains bacteria, protozoa, nematodes, mites, springtails, and endomycorrhizal fungi (Elliot 1978, Anderson et al. 1981, Harley and Smith 1983, Curl and Truelove 1986, Whipps 1990, Campbell and Greaves 1990). The grass plant's roots release carbon compounds (Campbell and Greaves 1990), including sugars, to these rhizosphere organisms, and the organisms release mineral nitrogen that the plant's roots absorb (Ingham et al. 1985, Clarholm 1985, Biondini et al. 1988, Frederick and Klein 1994, Frank and Groffman 1998). The endomycorrhizal fungi also provide phosphorus, other mineral nutrients, and water that the plant needs for growth (Moorman and Reeves 1979, Harley and Smith 1983, Allen and Allen 1990, Koide 1993, Marschner and Dell 1994, Smith and Read 1997). Activity of the soil microorganisms increases with the availability of carbon compounds in the rhizosphere (Curl and Truelove 1986, Whipps 1990), and the elevated microorganism activity results in an increase in nitrogen available to the grass plant (Coleman et al. 1983, Klein et al. 1988, Burrows and Pflieger 2002, Rillig et al. 2002, Bird et al. 2002, Driver et al. 2005).

Grazing lead tillers between the third-leaf stage and the flowering stage can increase the quantity of carbon compounds the defoliated plant releases into the rhizosphere (Hamilton III and Frank 2001). The increase in nitrogen produced by elevated rates of microorganism activity allows the plant to accelerate growth and recover more quickly from

defoliation. This beneficial activity does not seem to occur when grazing is conducted during the middle and late growth stages of the grass plant.

Long-term non-defoliation (idle) management is a management choice that withholds defoliation from a grassland for a considerable length of time. Non-defoliation treatments increase the level of shading in a grassland ecosystem and thereby reduce the intensity of the light that reaches the leaves. Long-term nongrazed grass plants shift to erect growth forms with a small number of tillers with fewer leaves because the shading from other plants reduces the light intensity reaching the lower leaves of an individual plant (Briske and Richards 1995). Grass leaves grown under shaded conditions become longer but narrower, thinner, and lower in weight (Langer 1972) than leaves in sunlight. Shaded leaves have a reduced rate of photosynthesis, which decreases the carbohydrate supply and causes a reduction in growth rate of leaves and roots (Langer 1972). Root growth is reduced because roots are very sensitive to reductions in light intensity reaching the leaves. Shading also increases the rate of senescence in the lower older leaves.

Decomposition of leaf material through microbial activity can take place only after the leaves have made contact with the soil. Standing dead material not in contact with the soil does not decompose but breaks down slowly as a result of leaching and weathering. Accumulation of standing dead leaves reduces availability of carbon and nitrogen in soil. Under nongrazed treatments, dead leaves remain standing for several years. Increased mulch biomass resulting from long-term non-defoliation (Brand and Goetz 1986, Manske 1995) negatively affects the soil. Excessive mulch reduces water infiltration and early season soil temperatures, causing reduced soil bacterial activity in the top 12 inches of soil. Excess mulch accumulation also causes conditions that decrease mycorrhizal fungal and rhizosphere organism activity, slow nutrient cycles, and reduce available nutrients. Standing dead leaves shade early leaf growth in spring, slowing the rate of growth, reducing the leaf area, and causing a reduction in the net primary productivity. Long-term effects of shading in nongrazed grasslands include reduced total plant densities and native grass species composition (Manske 1995) and increased composition of shade-tolerant or shade-adapted replacement species like smooth brome grass and Kentucky bluegrass.

Management strategies that defer grazing until after the flowering stage were intended to

enhance sexual reproduction and increase the quantity of seeds produced. However, deferred grazing does not improve grass plant density (Sarvis 1941, Manske et al. 1988). Most young grass plants in grassland ecosystems start not as seedlings but as vegetative tillers that grow from axillary buds on the crowns of an established plant. These vegetative tillers make up the majority of the plant population because they have a competitive advantage over seedlings. Tillers initially draw support from the root systems of parent tillers, while seedlings must rely only on their own less-developed structures.

Tiller development from axillary buds is regulated by lead tillers (Briske and Richards 1995) through a process called lead tiller dominance. The lead tillers produce an inhibitory hormone that prevents the growth hormone from activating growth within axillary buds (Briske and Richards 1995). Grazing that removes a small amount of young leaf tissue from the aboveground portion of lead tillers after the three-leaf stage and before the flowering stage reduces the amount of the inhibitory hormone in the plant (Briske and Richards 1994). With that inhibitory hormone reduced, the growth hormones stimulate vegetative reproduction (Murphy and Briske 1992, Briske and Richards 1994), and secondary tillers develop from the previous year's axillary buds (Langer 1972).

Positive grass plant responses to grazing depends on the timing of defoliation. Grazing grass plants prior to the third-leaf stage negatively affects grass growth (Manske 2000b). Early seasonal growth of grass plants depends on carbohydrates stored in the roots, rhizomes, and stem bases (Trlica 1977), and prematurely grazed plants are unable to replenish adequate amounts of carbohydrates to support active growth (Coyne et al. 1995, Manske 1999). Starting grazing after the third-leaf stage and before the flowering stage allows plants to establish sufficient leaf area to produce adequate photosynthetic assimilates to meet leaf growth requirements and allows all leaf bud primordia in the apical meristem to develop into leaf buds (Manske 1999).

If no defoliation occurs before the flowering stage, as on a deferred grazing strategy, the lead tiller inhibits vegetative tiller development until the inhibitory hormone production naturally declines during the flowering stage. This hormone reduction permits one axillary bud to grow and develop into a secondary tiller, which in turn produces inhibitory hormones that prevent growth of the other six to eight axillary crown buds (Mueller and Richards 1986). These dormant axillary buds are never activated and

become senescent with the lead tiller. No evidence has been found to suggest that grazing the lead tiller after it has reached the flowering stage has beneficial stimulatory effects on vegetative tiller development (Manske 2000a).

All grass species in the Northern Plains have strong lead tiller dominance except Kentucky bluegrass and meadow brome grass, which have low levels of inhibitory hormones and relatively higher levels of tiller development. Plants with these growth characteristics have greater demands for water than grasses with strong lead tillers and cease growth processes during minor water deficiency periods.

The twice-over rotation grazing management system applies defoliation treatment to grass plants at the appropriate phenological growth stages to stimulate the defoliation resistance mechanisms and the activity of the symbiotic rhizosphere microorganisms. The phenological growth stages during which these two mechanisms can be manipulated are the same, between the third-leaf stage and flowering phenophase. This stimulation increases both vegetative tiller development of grasses and nutrient flow in the rhizosphere, resulting in increased aboveground herbage biomass, increased plant basal cover, and increased rhizosphere weight.

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Table 1. Long-term (1971-2000) mean monthly temperature and monthly precipitation at Richardton, ND.

	°F	°C	in.	mm
Jan	13.50	-10.28	0.45	11.43
Feb	20.40	-6.44	0.48	12.19
Mar	30.30	-0.94	0.86	21.84
Apr	43.40	6.33	1.75	44.45
May	55.70	13.17	2.49	63.25
Jun	64.30	17.94	3.39	86.11
Jul	70.00	21.11	2.27	57.66
Aug	68.90	20.50	1.88	47.75
Sep	57.90	14.39	1.60	40.64
Oct	45.60	7.56	1.41	35.81
Nov	28.80	-1.78	0.75	19.05
Dec	17.40	-8.11	0.45	11.43
	MEAN		TOTAL	
	43.00	6.11	17.78	451.61

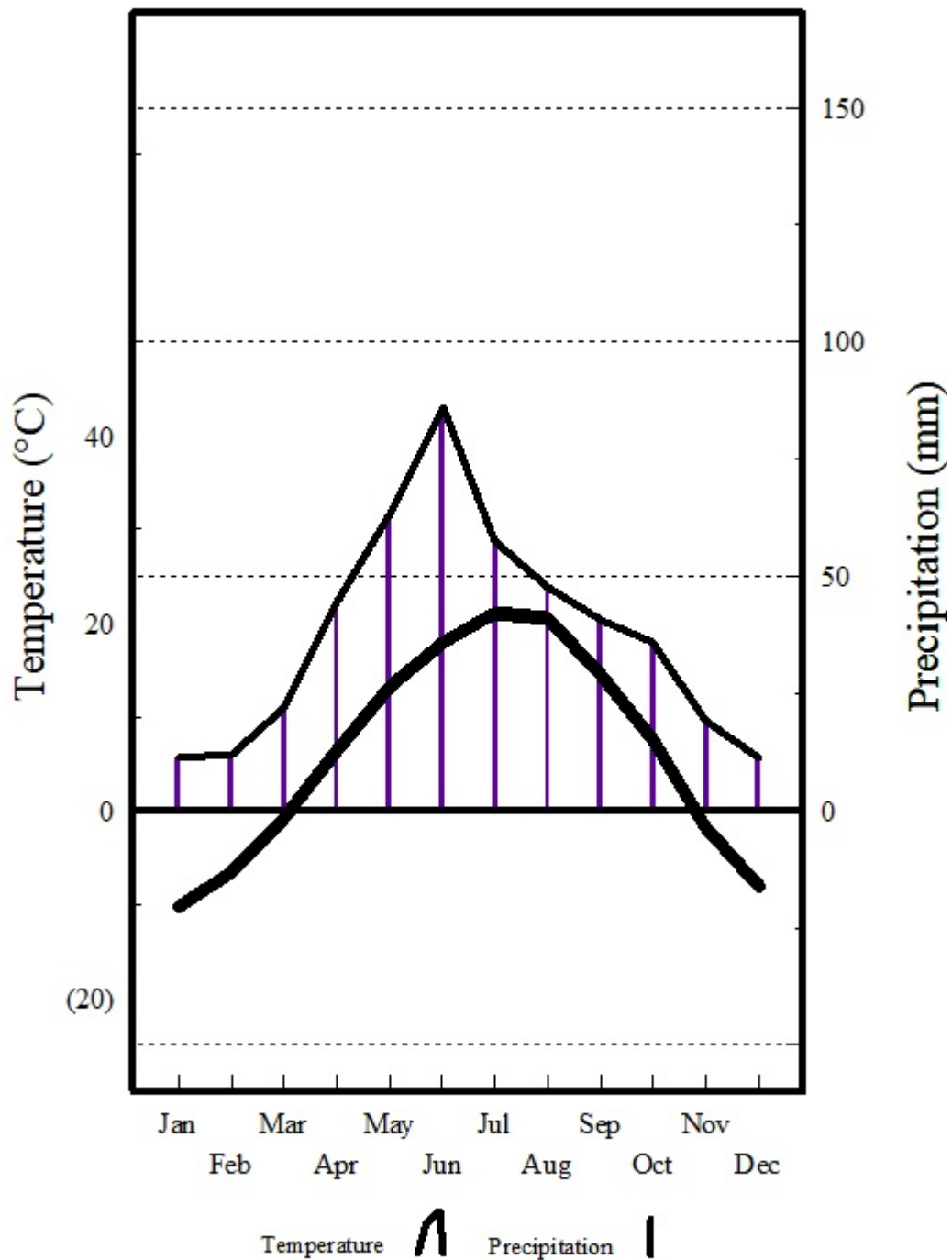


Fig. 1. Ombrothermic diagram of long-term (1971-2000) mean monthly temperature and monthly precipitation at Richardton, North Dakota.

Table 2. Precipitation in inches for growing season months for 2006-2011, Richardton, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean (1971-2000)	1.75	2.49	3.39	2.27	1.88	1.60	1.41	14.79
2006	2.53	0.60	0.37	0.79	1.40	2.33	1.40	9.42
% of LTM	144.57	24.10	10.91	34.80	74.47	145.63	99.29	63.69
2007	1.04	3.57	2.22	0.44	1.57	1.29	0.62	10.75
% of LTM	59.43	143.37	65.49	19.38	83.51	80.63	43.97	72.68
2008	0.45	1.32	3.93	2.04	0.56	1.70	1.45	11.45
% of LTM	25.71	53.01	115.93	89.87	29.79	106.25	102.84	77.42
2009	0.59	0.85	3.09	2.82	0.53	1.67	2.08	11.63
% of LTM	33.71	34.14	91.15	124.23	28.19	104.38	147.52	78.63
2010	0.71	3.29	4.35	1.42	0.90	2.30	0.46	13.43
% of LTM	40.57	132.13	128.32	62.56	47.87	143.75	32.62	90.80
2011	2.01	4.94	1.76	4.06	2.07	0.96	1.35	17.15
% of LTM	114.86	198.39	51.92	178.85	110.11	60.00	95.74	115.96
2006-2011	1.22	2.43	2.62	1.93	1.17	1.71	1.23	12.31
% of LTM	69.71	97.59	77.28	85.02	62.23	106.88	87.23	83.23

Table 3. Summary of aboveground herbage production in lbs/acre for native range on the silty sites at the Schnell Recreation Area, 2011.

	30 th May	15 th Jun	30 th Jun	15 th Jul	15 th Aug	15 th Sep	15 th Oct
NR1	grazed						
Domesticated Grass	1022.59	1274.49	1220.97	1622.01	2427.67	2336.33	2238.56
Native Grass	318.97	750.00	891.28	754.99	658.65	666.50	569.45
NR2	grazed						
Domesticated Grass	741.43	1178.87	665.79	830.63	364.65	829.92	903.42
Native Grass	500.94	802.81	1385.81	994.04	1389.38	986.19	702.18
NR3	grazed						
Domesticated Grass	1155.32	1972.39	2312.06	2156.50	2931.47	2425.53	2390.56
Native Grass	77.07	114.17	143.43	249.05	219.79	34.96	105.61
NR4	control		not grazed				
Domesticated Grass	911.98	1615.59	1894.61	2096.56	3109.87	3120.57	3588.69
Native Grass	131.29	219.78	259.75	366.08	493.81	27.84	62.79

Table 8. Summary percent basal cover for native range on the silty sites at the Schnell Recreation Area, 2011.

	NR 1 Silty		NR 2 Silty		NR 3 Silty		NR 4 Silty Control	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	not grazed
Domesticated Cool Season	9.40	12.70	4.60	1.05	14.45	15.90	13.20	15.35
Native Cool Season	2.70	2.50	3.55	5.35	0.00	0.00	0.65	0.35
Native Warm Season	0.10	0.25	1.60	4.80	0.00	0.00	0.05	0.85
Sedges	2.20	5.50	10.75	13.60	0.90	0.90	0.55	1.05
Forbs	0.30	0.75	0.35	0.25	0.35	0.20	1.30	0.20
Woody Species	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.05
Total Live	14.70	21.70	20.85	25.05	15.70	17.00	15.85	17.85
Litter	85.30	78.30	78.35	74.95	84.30	83.00	84.15	82.15

Table 17. Summary plant density for native range on the silty sites at the Schnell Recreation Area, 2011.

	NR 1 Silty		NR 2 Silty		NR 3 Silty		NR 4 Silty Control	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	not grazed
Late Succession Forbs	1.88	1.44	1.56	1.76	4.84	2.96	6.80	2.72
Mid Succession Forbs	0.52	1.96	1.56	0.24	0.36	0.84	0.16	0.80
Early Succession Forbs	2.16	10.68	3.56	6.44	0.00	0.04	0.08	0.04
Woody Species	0.04	0.20	0.00	0.00	0.00	0.00	0.44	0.16
Total Live	4.60	14.28	6.68	8.44	5.20	3.84	7.48	3.72

Table 26. Rhizosphere weight (kg) per cubic meter of soil at the Schnell Recreation Area, 2011.

Pasture, Site		Jun	Jul	Oct
NR1, Silty	kg/m ³	188.38a	268.20a	206.44a
NR2, Silty	kg/m ³	170.12a	219.93ab	232.95a
NR3, Silty	kg/m ³	164.54ab	167.55bc	169.06b
NR4, Silty	kg/m ³	123.07b	131.65c	136.94c

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 27. Summary of percent composition based on basal cover of native range plant community on the silty sites at the Schnell Recreation Area, 2011.

	NR 1 Silty grazed	NR 2 Silty grazed	NR 3 Silty grazed	NR 4 Silty Control not grazed
Domesticated Grass	58.53	4.19	93.53	85.99
Native Grass	12.67	40.52	0.00	6.72
Sedges	25.35	54.29	5.29	5.88
Forbs	3.46	1.00	1.18	1.12
Woody Species	0.00	0.00	0.00	0.28

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