# Impact of Grazing Native Prairie on Soil and Plant Nutrients in Southwestern Saskatchewan

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## Abstract

A reduction in the sage grouse population could be a result of the export of nutrients from the long term grazing management that has been in place in grassland ecosystems such as southwestern Saskatchewan for the past century. The objective of this study was to measure the supply rates of nitrogen and phosphorus in the soils and their content in the sage plants and determine what impact grazing has had on nutrient availability. Plant and soil samples were taken from five side-by-side normally grazed and ungrazed for ~20 years, native grassland sites in southwestern Saskatchewan and analyzed for nitrogen, phosphorus and selected micronutrients. PRS probes were buried *in situ* for 21 days to measure soil supply rates of nitrogen and phosphorus. Sage plants and grasses were collected and analyzed for nutrient content. At four (Butte Creek Upland and Low Sage; Frenchman Mid and Low slope) of the five sites, grazing had relatively minor, non-statistically significant effects on soil and plant nutrients. At the Consul site, a site that may be considered a drier site of poorer inherent fertility, grazing significantly reduced soil and plant P. Introduction of beef cattle into the pasture in the spring significantly increased supply rates of available N, likely due to fresh addition of N as fecal material and urine. Plant analysis revealed that calcium levels were significantly higher in the ungrazed Butte Creek low-sage and potassium levels were significantly higher in the ungrazed sage at Frenchman low slope and Consul sites. Overall, well managed grazed pastures located on good quality soils do not appear to be at risk of nutrient depletion. Cessation of grazing for ~20 years did not cause major differences in nutrient amounts and supplies compared to normally grazed pastures.

## Introduction

Approximately 25-30% of original Canadian grassland habitat is located in southeastern Alberta and southwestern Saskatchewan. The size, distribution and condition of these native grassland areas serve as indicators of the integrity and sustainability of these fragile ecosystems (Gauthier and Wiken, 2003). In arid ecosystems, such as the silver sage communities in southwestern Saskatchewan, soil nutrients such as nitrogen and phosphorus could limit plant productivity due to a reduction in nutrient cycling as a result of reduction in weathering, naturally low soil organic matter or dry soil conditions.

A ranching industry that includes grazing as part of the management of grassland areas has existed for well over 100 years, however, the reduction in size and distribution of sage plant communities could be a result of nutrient export from sites due to nutrients assimilated by cattle. The sage-grouse are permanent residents in the grasslands region and depend on the sage plant for food supply and dense nesting cover. Plant and soil analysis of selected sites will provide information on the effects of grazing on silver sage plant nutrition.

Specifically, the objective of this study was 1) to determine supply rates of available nitrogen (N) and phosphorus (P), in sage grouse habitat and to determine what impact, if any grazing has had on available nutrient supply rates and total amount of nutrient in soil and 2) to document the impact of grazing on total nutrient concentrations in plant populations at five grassland sites in southwestern Saskatchewan.

## Materials and Methods

The study was conducted in locations of the dry mixed prairie of southwestern Saskatchewan that are currently occupied or have been recently vacated by sage-grouse. Five side by side cattle grazed and ungrazed sites that have not been grazed for at least 20 years were selected for the purposes of this study. Butte Creek Upland site is a Brown Chernozem clay loam to sandy loam surface soil texture. Butte Creek sage (low slope) site is a Brown Chernozemic mixture of loamy glacial till. The Frenchman site low slope and midslope is Hillwash clay loam to heavy clay surface soil texture. The Consul-US Border site is a Brown Chernozemic clay loam to loam surface texture , with solonetzic areas.

In May of 2005, plant and soil samples were collected from the grazed and ungrazed grass (Butte Creek Upland only) and sage plants located adjacent (across a fence line) to each other at each site. Three subsample locations of approximately 10m X 10m were located for subsampling at random within each management system and within 4-5 m of one another. Soil samples taken from the 0-15 cm depth were obtained from each of the subsample locations from both the grazed and ungrazed treatments. Grass samples at the Butte Creek Upland site (no sage brush present at this site) were obtained by clipping a $0.25m^2$ sample next to the soil core locations. Sage brush plant samples were taken at the other four sites. Ion exchange membranes (Plant Root Simulator™) (PRS probes) were inserted into the soil at each of the subsampling locations at the time of soil and plant sampling and were left *in situ* for 21 days until retrieval for laboratory analysis.

In the laboratory, soil samples were air dried and ground to 2mm size. Subsamples from each soil sample were mixed and ball ground so that it could pass a 100-mesh sieve for organic carbon (C) analysis (Wang and Anderson, 1998). Electrical conductivity and soil pH were determined using the 1:2 soil-water method. Wet chemistry analysis for soil total nitrogen and total phosphorus were determined using a soil digestion procedure.

Extractable concentrations of soil phosphorus were determined using the modified Kelowna procedure as described in Qian et al. (1994). Extractable soil ammonium ($NH_4^+$) and nitrate ($NO_3^-$) concentrations were determined by extractions with 2M KCl as described in Maynard and Kaltra (1993). Selected soil samples from each of the 5 grassland sites were sent to Western Ag Labs in Saskatoon, SK for total plant micronutrient analysis using Inductively Coupled Plasma (ICP).

## Results and Discussion

### pH, E.C., and SOC

Results from the soil pH and electrical conductivity analysis show that the pH falls in a fairly narrow range near neutrality from 6.3-6.8 at each of the five Saskatchewan grassland sites (Table 1). There were no statistically significant differences in pH between the grazed and ungrazed positions at any of the five sites. The electrical conductivity (E.C.) analysis reveal that there are no salinity problems at any of the five sites (Table 1) as E.C is well below 1mS $cm^{-1}$. There were no significant differences in E.C. between grazed and ungrazed sites at all five locations.

**Table 1.** General soil characteristics of five grassland Saskatchewan grazed and ungrazed sites.

| | Soil texture | pH | | Electrical conductivity | | Organic carbon | |
|---|---|---|---|---|---|---|---|
| | | | | -----(mS $cm^{-1}$)------ | | -------(%)------- | |
| | | Grazed | Ungrazed | Grazed | Ungrazed | Grazed | Ungrazed |
| **Butte Creek Upland** | Clayloam-Sandyloam | 6.6 | 7.1 | 0.22 | 0.34 | 2.01 | 2.06 |
| **Butte Creek Low-Sage** | Sandy-loam | 6.6 | 6.7 | 0.19 | 0.20 | 2.95 | 2.64 |
| **Frenchman Midslope** | Clayloam-Heavy clay | 6.5 | 6.2 | 0.15 | 0.12 | 3.73 | 2.64 |
| **Frenchman Lowslope** | Clayloam-Heavy clay | 6.9 | 6.6 | 0.26 | 0.19 | 2.64 | 3.11 |
| **Consul - US Border** | Clayloam - Loam | 6.6 | 7.1 | 0.12 | 0.28 | 1.59 | 1.86 |

Soil organic carbon (SOC) values at Consul were found to be the lowest of any of the five Grassland sites (Table 1). Soil organic carbon concentration (0-15 cm) was found to be 1.59 % organic carbon (OC) in the grazed and 1.86 % C in the ungrazed treatments at this location (Table 1). In contrast the SOC at the Frenchman midslope was found to be 3.73% OC and 2.64% OC for the grazed and ungrazed, respectively, treatments of the sites (Table 1). Frenchman lowslope had 2.63% SOC for the grazed and 3.10% for the ungrazed treatment SOC (Table 1).

A possible reason for the significantly higher ($p \leq 0.10$) SOC value for Frenchman midslope grazed treatment could be that under a grazing management system, the grazing affected competition for soil moisture and nutrients with the sage brush plant, affecting the biomass and root additions of organic carbon to the soil. Soil organic carbon concentrations for the Butte Creek Upland site and Butte Creek low-sage site showed no significant differences ($p \leq 0.10$) between the grazed and ungrazed treatments (Table 1). Low slope or depressional areas can accumulate more moisture, thus allowing for an increase in biomass production and SOC and soil nutrients can accumulate due to deposition from erosion (Gregorich et al., 1995). Mensah et al. (2003) reported that native grassland species have a longer growing season and deeper rooting depth than annual crops, thus more plant residues are returned to the soil. Greater inputs of SOC at the Butte Creek low-sage location could also be due to the fact that it has both grass and sage brush plant biomass growing, as opposed to only grass growing on the Butte Creek Upland location.

**Soil and plant nitrogen**

The PRS probe data reveal that only at the Consul-US border site are the supply rates for $NH_4^+$ and $NO_3^-$ both significantly affected by the grazing treatment. The Consul grazed treatment $NO_3^-$ and $NH_4^+$supply rates were 1.74 and 1.77 µg N cm$^{-2}$, respectively (Figure 1) while there were very low supplies of $NO_3^-$ or $NH_4^+$ in the ungrazed treatments at the Consul site. This could be explained by the presence of bulls in the pasture during the measurement period. Urine and fecal deposition from beef cattle can cause significant increases in $NO_3^-$ and $NH_4^+$ in grassland soils (Stillwell and Woodmansee, 1981).

The PRS probe data show that the Frenchman lowslope and Butte Creek sage locations had higher supply rates of $NH_4^+$ in the ungrazed versus grazed treatments(Figure 1). Frenchman low and midslope PRS probe supply rates reveal that where $NO_3^-$ supply rates

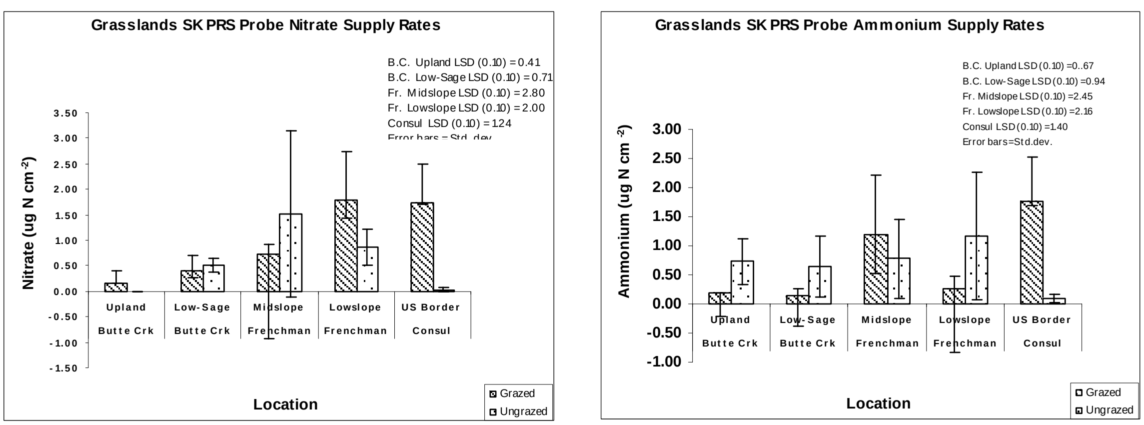



**Figure 1.** PRS Probe nitrate and ammonium supply rates for five grassland Saskatchewan sites.

are lower, $NH_4^+$ supply rates are higher and where $NO_3^-$supply rates are higher, $NH_4^+$ supply rates are lower. For example, in the Frenchman low and midslope grazed position, $NO_3^-$ supply rates are 1.78 and 0.72 µg N cm$^{-2}$, respectively, while the $NH_4^+$supply rates for the same sites and positions are 0.27 and 1.20 µg N cm$^{-2}$ for the Frenchman low and midslope grazed positions (Figure 1). This similar trend occurs at the Butte creek Upland and low-sage sites. Where there is a greater supply rate of $NH_4^+$, there may have been more conversion of organic N to $NH_4^+$ and/or less nitrification of $NH_4^+$ to $NO_3^-$. Greater $NO_3^-$ associated with reduced $NH_4^+$ suggests greater nitrification rates.

Soil $NH_4^+$ and $NO_3^-$ were found to be the lowest of all the five sites at Consul , followed by the Butte Creek Upland site (Figure 2). These samples were taken at the start of the PRS probe burial period before the bulls were allowed into the pasture at the Consul site. The total plant N concentration was quite high for Consul plants (Figure 3), while soil available $NO_3^-$ and $NH_4^+$ was low (Figure 2).

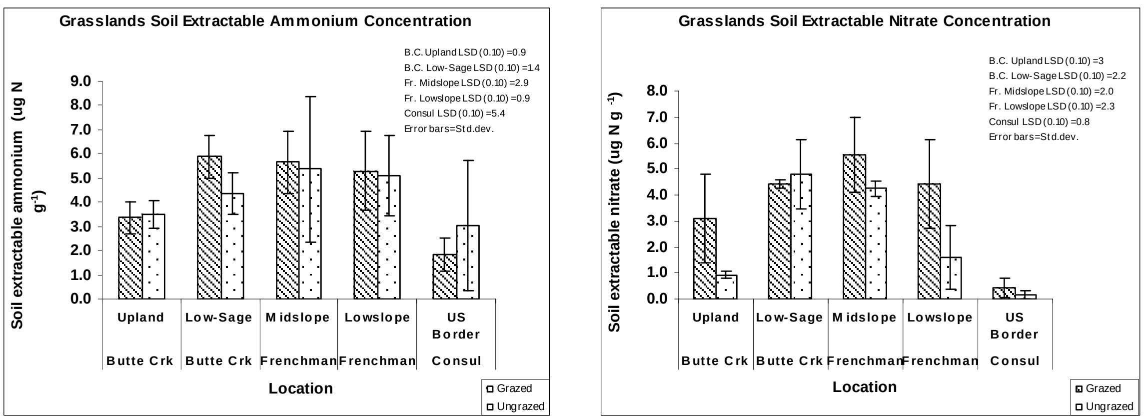



**Figure 2.** Soil extractable nitrate and soil extractable ammonium at five grassland Saskatchewan grazed and ungrazed sites.

This could be a reflection of less plant growth and less growth dilution at this site due to the dry conditions up to the time of sampling.

The total soil N ,which includes organic N in humus plus $NO_3^-$ and $NH_4^+$, was found to be higher in the Butte Creek sage site, and both Frenchman low and midslope sites (Figure 3). There were no significant differences in soil total N between the grazed and ungrazed positions at these three sites.

The soil extractable $NO_3^-$ and $NH_4^+$ was found to be higher for these three locations, and again there were no significant differences in soil extractable $NO_3^-$ between the grazed and ungrazed treatments at these three locations. The lowest total plant N concentration was found in both the grazed and ungrazed treatments (7892 and 8405 μg N $g^{-1}$, respectively) in the Butte Creek Upland site (Figure 3). The plant material samples at Butte Creek Upland site was grass, while sage was sampled at all the other sites, so the lower % N may reflect the effect of species. The Consul site had the lowest overall soil total N (1353 μg N $g^{-1}$, grazed) or (1554 μg N $g^{-1}$ , ungrazed ) treatment (Figure 3).

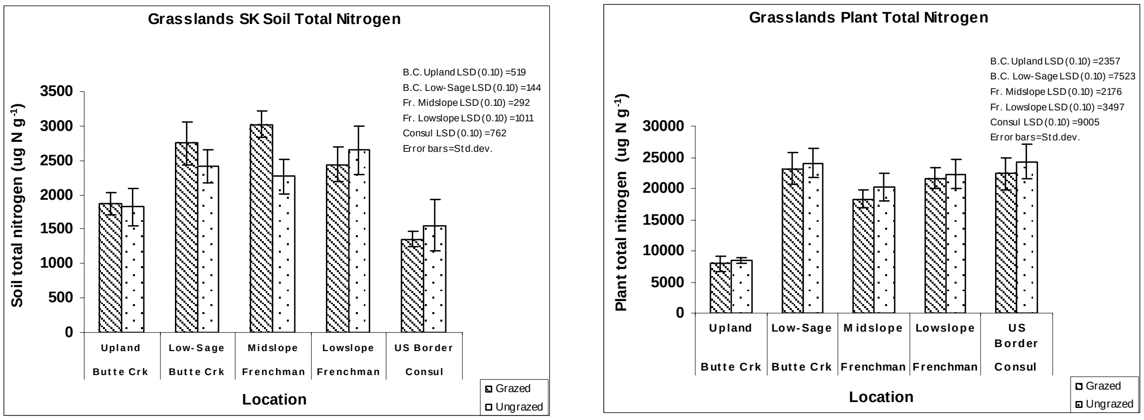



**Figure 3.** Soil total nitrogen and plant total nitrogen at five grasslands Saskatchewan grazed and ungrazed sites.

At the Frenchman locations, plant total N concentration was not significantly different between the grazed and ungrazed treatments for either slope position. The Consul site plant total N was not significantly different for the grazed (22372 µg N $g^{-1}$) and the ungrazed treatment (24264 µg N $g^{-1}$) (Figure 3). This is consistent with soil available nitrate at the Consul site which was very low in the grazed (0.4 µg N $g^{-1}$) and ungrazed (0.2 µg N $g^{-1}$) treatments (Figure 3).

## Soil and plant phosphorus

Soil extractable P was found to be the lowest at Butte Creek Upland site and is consistent with the lowest total soil P found at any of the five Grassland sites. Soil extractable P was only 10 and 9.0 µg P $g^{-1}$ for the grazed and ungrazed treatments at Butte Creek Upland, and is consistent with low PRS probe supply rates of P for the grazed (0.18 µg P $cm^{-2}$) and ungrazed (0.12 µg P $cm^{-2}$) treatments at this site (Figure 4).

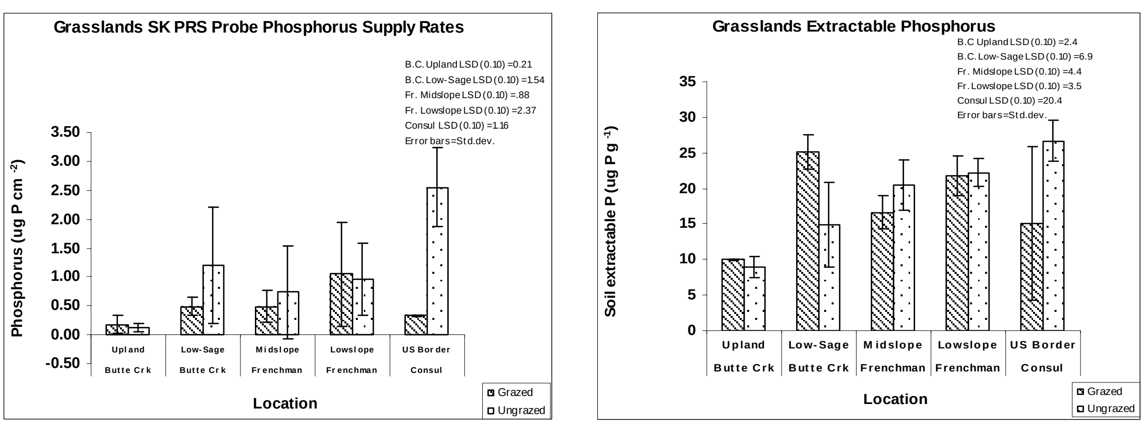
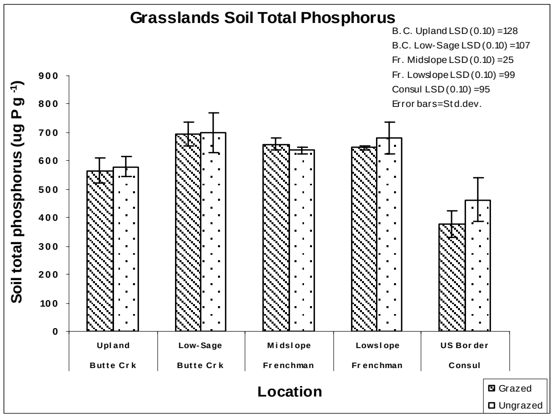



**Figure 4.** PRS probe supply rate of phosphorus and soil extractable phosphorus at five grassland Sasakatchewan grazed and ungrazed sites.

This corresponds to the lower soil total P measured at this site (Figure 5).



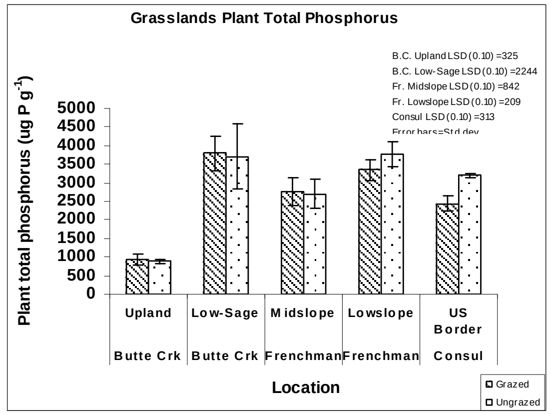




**Figure 5.** Soil total phosphorus and plant total phosphorus concentration at five grassland Sasakatchewan grazed and ungrazed sites.

The lower sage position at Butte Creek, however, has greater supply rates of available P and soil available P concentrations for both the grazed and ungrazed treatments (Figure 4).

There was no significant differences ($p \leq 0.10$) in plant total P between the grazed and ungrazed treatments for either of the two Butte Creek sites and the Frenchman low and midslope position sites (Figure 5). The total plant P in the ungrazed treatment at Consul was found to be 3197 µg P $g^{-1}$, which was significantly higher than the 2442 µg P $g^{-1}$ in the grazed treatment (Figure 5). This is consistent with the higher PRS P supply rate, higher total soil P and higher extractable P for the ungrazed position versus the grazed position at Consul (Figure 4).

The higher P fertility level in the ungrazed position at Consul could be due to the effect of grazing by cattle, in removing plant matter and P from the field site. Lower overall plant P concentration, soil total P, PRS probe P and extractable P at both the grazed and ungrazed treatments at the Butte Creek Upland site could be due to the upper slope position being inherently lower in phosphorus compared to the Butte Creek low slope site.

There was no significant difference ($p \leq 0.10$) in total soil P between the grazed and ungrazed plots at the five grassland sites (Figure 5). Total soil P was highest in Butte Creek Sage, for the grazed and ungrazed plots (696 and 700 µg P $g^{-1}$, respectively) (Figure 5). The Consul site grazed and ungrazed plots (378 and 463 µg P $g^{-1}$, respectively) had the lowest total soil P compared to the other four grassland sites (Figure 5). Total soil P was higher in the ungrazed treatment (463 µg P $g^{-1}$) at Consul and this is consistent with a significantly higher PRS probe supply rate of P (2.55 µg P $cm^{-2}$), versus the grazed treatment supply rate of P, and a higher plant P concentration (3197 µg P $g^{-1}$) (Figure 5). This would be consistent, given the sandy soil texture and less P in the parent material. The 560 -700 µg total P $g^{-1}$ found at both Butte Creek sites and both Frenchman positions is typical of Saskatchewan Chernozemic soils (Schoenau et al., 1989).

The lower soil total P and correspondingly lower supply rate of P and available P could be related to the lower amount of P found in the parent material. When these sites were brought under cultivation, there could have been a net export of P in the plant material removed by grazing animals, resulting in a net export of phosphorus. Dry environmental conditions and overgrazing could have combined to produce conditions susceptible to wind and water erosion from uplands, thus leading to a movement of soil from higher slope to lower slope positions, which could also explain the higher soil total P, supply rate and available phosphorus in the lower slope positions at Butte Creek and Frenchman.

**Potassium, Calcium, Magnesium and Micronutrients**

Plant analysis from Butte Creek Low-sage, Frenchman Low-slope and Consul sites revealed few significant differences ($p \leq 0.10$) in plant levels of calcium, potassium, manganese, copper, (Table 2). Calcium levels in the ungrazed treatment (6474 $\mu g\ g^{-1}$) at Butte Creek low-sage site were significantly higher than the grazed treatment (5626 $\mu g\ g^{-1}$) (Table 2).

**Table 2.** Plant K, Ca, Mg, Mn and Cu at three southwestern Saskatchewan grassland sites.

| Site | Treatment | K | Ca | Mg | Mn | Cu |
|---|---|---|---|---|---|---|
| | | -------------------------($\mu g\ g^{-1}$)---------------------------- | | | | |
| **Butte Creek-Low Sage** | **Grazed** | 25805 | 5626 | 2047 | 59.8 | 10.5 |
| | **Ungrazed** | 25827 | 6474 | 2186 | 66.6 | 13.4 |
| **LSD (0.10)*** | | NS | 527 | NS | NS | NS |
| **Frenchman-Low slope** | **Grazed** | 17674 | 6826 | 2636 | 43.0 | 8.5 |
| | **Ungrazed** | 26776 | 5795 | 1862 | 62.3 | 10.6 |
| **LSD (0.10)** | | 4064 | NS | NS | NS | NS |
| **Consul-US Border** | **Grazed** | 23373 | 6742 | 2405 | 77.5 | 9.6 |
| | **Ungrazed** | 28069 | 6408 | 1971 | 68.1 | 11.3 |
| **LSD (0.10)** | | 4468 | NS | NS | NS | NS |

Calcium levels were not significantly different between treatments at the Frenchman low slope and Consul-US border sites. Plant potassium levels were significantly higher in the ungrazed treatment at the Frenchman low slope and the Consul sites. Plant analysis

revealed that potassium levels were 26776 and 28069 $\mu g\ g^{-1}$ for the Frenchman low slope and Consul ungrazed treatments, respectively versus 17674 and 23373 $\mu g\ g^{-1}$ for the Frenchman low slope and Consul grazed treatments, respectively (Table 2).

**Summary and Conclusions**

Except for a significant difference in soil total N between the grazed and ungrazed treatments where the grazed total soil N was higher than the ungrazed N at Frenchman midslope, there was little difference in soil and plant total N concentrations. The effects of grazing in recycling N into available forms via urine and fecal deposition is shown in the observed enhanced N supply rates in the grazed treatment at Consul after introduction of bulls to the pasture. Only a small amount of the total N fed to beef cattle (about 10%) is retained in the animal (Bierman et al., 1999) so export of N under a grazing system is significantly less than when hay is harvested and removed.

For P, grazing appears to have resulted in a significant effect only at the Consul site, with reduced supply rates and concentrations of P in soil and plants associated with a grazing management system. This may reflect more P export off site perhaps related to unknown differences in stocking rate history compared to other sites. Overall, P appears to be more affected in the long-term than N. For other elements measured in soil and plants including K, Ca, Mg and microelements, the grazing treatment appeared to have relatively little impact in these southern Saskatchewan grassland sites. Overall, well managed grazed pastures located on good quality soils do not appear to be at great risk of nutrient depletion. Cessation of grazing for ~20 years did not cause major differences in nutrient amounts and supplies compared to normally grazed pastures.

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