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Long-Term Grazing Study at Stavely, Alberta

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Summary

The Agriculture and Agri-Food Canada Stavely substation in the native fescue grasslands of south-western Alberta was established in 1949 in response to requests that grassland and range management problems in the foothills area be investigated. Around 42% of the 389 ha site is fenced into 4 pastures where the same stocking rates have been maintained for 63 years to support long-term range condition research. The substation also has winter pasturage, areas suitable for cultivation, and a permanent supply of water to support complementary research. Investigators over the years using this valuable resource have given us knowledge in the areas of soil, plant, and animal responses to different grazing pressures on native grasslands.

Introduction

In 1949, four fields were fenced at the Stavely substation (120 km south of Calgary) with fields having different land areas and stocking rates (Table 1). Each field was continuously grazed with 13 cows and their calves from mid-May to mid-November. The annual stocking rate on the very heavy field was adjusted yearly after 1959 to avoid animal losses. This resulted in a stocking rate that varied from 2.5 to 4.8 AUM · ha^{-1}.[20] Additionally, each field was paired with an ungrazed exclosure to provide a benchmark for assessing change in vegetation.

The experimental program was initiated in 1949 with the following objectives:

1. Determine the cattle grazing carrying capacity of the area.
2. Study the response of livestock to different stocking rates and methods of grazing.
3. Investigate methods of management whereby the forage cover is maintained in a productive state.
4. Determine the most suitable grasses and legumes for reseeding in the Foothills and in other areas with similar conditions.
5. Study the effects of insects and diseases that prey on the vegetation and livestock in the area.[1]

Over the years the research goals evolved to provide the ranching industry with information about existing and new problems that affect rangeland management leading to a better understanding of the native fescue grassland in order to preserve its integrity.

Major Findings

Plant Responses to Grazing Pressure

The effect of grazing on the plant community was assessed at different periods of the grazing treatment, since 1949, and various questions related to the grazing impact were studied. The major findings and observations are reported in chronological order as they appear in the sequence of publications.

The influence of grazing on the vegetative cover was first assessed 12 years after the study began by examining the vegetation in the lightly grazed field (average utilization 15 to 25 %) compared with the ungrazed exclosure. Light grazing resulted in the development of a richer flora dominated by Parry oat grass (*Danthonia parryi* Scribn.). Protection from grazing appeared to simplify the flora with a trend toward a cover consisting largely of rough fescue (*Festuca campestrist* Rydb.). Production was similar between the two sites. Cooler and moister conditions prevailed in the upper 12 inches of the soil profile in the ungrazed site as a result of a heavy accumulation of mulch. Considerably more root material was present to a depth of 140 cm on the lightly grazed site. [8]

Stocking at a light rate (1.2 AUM · ha^{-1}) for 32 years did not affect range condition. [AUM · ha^{-1}=(animal unit x months) per hectare eg 20 AU for six months=120 AUM and if they were on 10 hectares it would equate to 12 AUM per hectare]. However, a modest increase in stocking rate (1.6 AUM · ha^{-1}) led to a marked decline in range condition. This was associated with a change in the composition of rough fescue from 38 to 21% of basal area. Rough fescue was nearly eliminated with a stocking rate of 2.4 AUM · ha^{-1} and was replaced with Parry oat grass which increased from 24% at 1.2 AUM ha^{-1} to 48% at 2.4 AUM · ha^{-1}. Stocking at 4.8 AUM · ha^{-1} resulted in severe deterioration of the grassland and required annual adjustment of the stocking rate to avoid animal losses. [20]

Over a 35-year period, forage productivity was reduced at the higher stocking rates. This resulted in a shortened grazing season in the field stocked at 4.8 AUM · ha^{-1}. Although individual animals' weights decreased with increased stocking rate, cattle gains per unit area increased. Average daily gain of cows was greatest in May but declined to become a loss in September. Stocking rate affected the relative magnitude of average daily gain as well as the trend over the grazing season.[21]

Native prairie communities have evolved to produce relatively low but sustained production. Demand for greater livestock production has resulted in overgrazing and, consequently, lower and unstable annual yields and increased risk of soil erosion. Overgrazing the Rough Fescue Prairie resulted in an increase in plant species that were shallow-rooted and less productive, but more resistant to grazing. This was associated with higher soil temperatures and reduced infiltration. Productivity deteriorated rapidly with overgrazing and more than 20 years of drastically reduced stocking rates are required to enable recovery.[4]

Selective grazing, caused by palatability differences within microsites, usually leads to the formation of grazed patches. Understanding patch dynamics helps interpret the impact of grazing management. Patch formation and stability were affected by the intensity and time of grazing and the effect of patches on the grazed community was related to their stability. Spatial stability of grazed patches between consecutive years was high on sites experiencing a low stocking rate. However, on sites having a high stocking rate, spatial stability was more closely linked with production, which influenced grazing pressure and the utilization of under-grazed patches. Overgrazed patches were dominated by grazing resistant species, but under-grazed patches were dominated by species that are present on healthy rangeland. Forage production was about 35% less, on overgrazed than on under-grazed patches. Soil organic matter, carbohydrates, and depth of Ah horizon were significantly greater on under-grazed patches but urease activity (enzyme responsible breaking down urea present in cattle urine), nitrate-N, ammonium-N and available phosphorus were greater on the overgrazed patches.[19]

Knowing the amount of herbage on rangeland is basic to management decisions related to livestock grazing. However, the amount of herbage available for grazing changes seasonally. Grazing modified the species composition of the plant communities by causing a shift from one dominated by rough fescue to one dominated by Parry oat grass-Kentucky bluegrass (*Poa pratensis* L) in the moderately grazed field or Kentucky bluegrass-sedge (*Carex* spp) in the heavily grazed field. Changes in herbage biomass were examined in the 3 different communities by sampling at monthly intervals from April or May to late September. Observed trends among the rough fescue, Parry oatgrass- Kentucky bluegrass, and Kentucky bluegrass-sedge communities were, for peak current year's standing production, 3980, 3050, and 2260 kg · ha^{-1}, respectively, and for percent losses of total herbage biomass, from fall to spring, 24, 43, and 56%, respectively. Of the 3 communities examined, production on the rough fescue community was the greatest, least dependent on precipitation during the growing season, and least susceptible to weathering losses and, therefore, had the greatest forage values. The Kentucky bluegrass-sedge community had the lowest forage values.[18]

Rough fescue is highly sensitive to grazing during the growing season, which results in smaller plants and the death of some. The death of plants suggests the potential loss of genetic diversity. Therefore, the genetic diversity of rough fescue plants from heavily grazed sites and from ungrazed sites was compared to determine if grazing pressure had affected their genetic composition. Grazing affected frequency of some DNA markers but did not eliminate genes that may be linked with grazing sensitivity or tolerance. If genes were eliminated due to grazing pressure, they were not detected with the RAPD (random amplification of polymorphic DNA) primers selected. The shift in frequency of genes, but not their loss, indicates that heterozygosity would recover if grazing pressure were removed. This shift also suggests that vulnerable genotypes may be killed by an additive effect that is unrelated to grazing pressure.[14]

Rough fescue grasslands are readily damaged by heavy grazing pressure in the summer but tolerate grazing in winter during dormancy. The grasslands have physical and nutritive properties that make them suitable for winter grazing by cattle thereby reducing the cost of winter feeding while preserving the integrity of the grasslands. However, their forage value declines during winter through the degradation of biomass yield and quality. A study was conducted to determine the dynamics of litter biomass for important forage species over winter, to examine the role of leaf position in the plant on biomass loss from leaves, and to determine the associated changes in crude protein, phosphorus, and acid detergent fibre of the leaves, and carbon and nitrogen. Leaves of Parry oat grass, Idaho fescue (*F. idahoensis* Elmer), and rough fescue were sampled at monthly intervals from August to March over 3 years to determine weight and chemical composition. Decomposition of these species, together with smooth aster (*Aster laevis* L.), was also tested for decomposition in the litter mass using nylon bags. Degradation of standing litter was most rapid in late summer and tended to stabilize by December. Biomass losses in leaves from August to March were similar ($P > 0.05$) among grass species. Overwinter losses in the litter mass tended to be greatest for smooth aster. There was no evidence that leaf position in the plant affected exposure and biomass losses. Changes in the mineral and fibre concentrations of the herbage were typical of the trends expected for the period that included late senescence and weathering, and followed closely the losses of biomass for the period. [15]

Numerous studies have examined the nutritive quality of fodder plants in different seasons but few have related this seasonal response to long-term grazing intensity. Plant material from 10 species was collected at monthly intervals (May to September in 2007) from fields in the fescue grasslands that had been stocked at 0 (control), 2.4 (moderate grazing), and 4.8 (heavy grazing) AUM ha^{-1} to examine the effect of long-term grazing on the seasonal concentrations of total nitrogen, $\delta^{15}N$, and total phosphorus. Over the season, total N and P concentrations were not affected by grazing for most species, but N and P concentrations in Kentucky bluegrass were higher with grazing than in the control. These results reflect the effect of regrowth in Kentucky bluegrass, which is at a younger stage of growth than ungrazed plants. The higher $\delta^{15}N$ concentration for most species in the grazed treatments than the control is an indication of accelerated nitrogen cycling through dung and urine deposition.[11]

Watershed Studies

The topographic features of the foothills fescue grasslands in southern Alberta predispose them to runoff and soil loss via erosion. The majority of annual runoff occurs during snow melt while a few summer storms can cause runoff. A study was conducted to quantify surface runoff under three grazing intensities, (0, 2.4, and 4.8 AUM ha^{-1}). Three small watersheds were established using a combination of natural and artificial barriers in 1996–97. A further objective was to calibrate the SWAT, (Soil Water Assessment Tool), model and evaluate its ability in predicting surface runoff from these watersheds. Surface runoff hydrographs indicated large summer storm runoff rates from heavy grazed compared to other watersheds and large snow melt-induced runoff from very heavy grazed compared to other watersheds with lower grazing intensity. The volume of surface runoff varied each year (1998, 1999, and 2000) and also differed across watersheds, with lower runoff in the ungrazed compared with the heavy and very heavy grazed watersheds. In all 3 years of the study the average rainfall runoff was <10% of average daily precipitation on all 3 watersheds. In March 2000 snow melt-induced runoff accounted for 78, 96, and 92% of total annual runoff from ungrazed, heavy, and very heavy grazed watersheds respectively. The 1998 data was used to predict surface runoff in 1999 and 2000 using SWAT. An evaluation indicated the model under-estimated surface runoff from the watershed in both years.[2]

Soil moisture readings obtained every 2 weeks were taken at the soil surface and at the 15-, 25-, 35-, 45- and 55-cm depths. Total annual precipitation in 1998 and 1999 was 648 and 399 mm, respectively. In both years, grazing treatment did not affect total soil water in the 0-50 cm (TSW50) depth interval for the upper, middle and lower slope positions, but TSW50 close to the collector drain was greater for the heavy grazed compared to the very heavy grazed treatment. Within each grazing treatment, TSW50 differences among slope positions occurred mainly under the heavy grazed treatment. All measured variables differed by soil depth and watershed, indicating the transient nature of the data. Overall model fitting to the whole data for all depths, watersheds and years gave values that were indicative of a slight over-prediction by the model.[12] Spatial variation due to presence of rocks or cracks and averaging across slopes may have partly contributed to the discrepancies between model results and observed data.[3]

The water quality of the surface runoff from the watersheds under three grazing intensities was also measured. Total dissolved solids in surface runoff water ranged between 34 to 360 mg/L, and dissolved solids from the very heavy grazed watershed were greater than that of the other watersheds. The results indicated that the dominant external forces (meteorological and management) in influencing water quality were year of study, water temperature and grazing. The dominant water quality parameters were found to be total carbon, organic carbon, total dissolved solids and electrical conductivity. Overall, this study indicated that during the three years, the surface runoff volumes from the watersheds were small and grazing of these watersheds posed little risk of nutrient (e.g., nitrate, ammonia and orthophosphate) contamination of adjacent streams, but organic carbon loading and dissolved solids may be of concern. The presence of parasites was detected in two or less runoff water samples each year, and thus poses little risk of contamination of adjacent streams. However, it may be necessary to monitor parasites especially in areas under cow-calf operations.[13]

Soil Responses to Grazing Pressure

In 1959 a study was conducted to determine the effects of grazing intensity and cover on the water-intake characteristics of soils of the fescue grassland. A mobile infiltrometer was used to apply artificial rainfall at measured rates to selected study sites. The results showed that after 10 years of very heavy grazing pressure, soil erosion was about 76 times greater than with heavy grazing pressure over the same period. The water-intake rate increased with increasing amounts of standing vegetation and natural mulch.[9]

Sustainability of grazing use on fescue grasslands may be assessed by a number of key soil indicators. By 1967 increasing grazing pressures changed the color of the Ah horizon from black to dark brown and the pH from 5.7 to 6.2. Percent organic matter, percent total phosphorus, and percent soil moisture decreased while soluble phosphorus and soil temperature increased. Trends indicated that soil of the very heavily grazed field was being transformed to a soil more characteristic of a drier microclimate.[10]

In 1992, soil samples were obtained from the Ah horizon of the fields grazed under light, moderate and very heavy grazing pressure, and from the ungrazed exclosures. The thickness of the Ah horizon of the ungrazed exclosures averaged 22 cm while that of the lightly, heavily and very heavily grazed fields averaged 18, 12, and 8 cm, respectively. Soil color changed from black to dark brown to brown in response to very heavy grazing. Treatment effects on most soil parameters were most pronounced at the two heavier grazing treatments. In particular, heavy grazing pressure jeopardized the sustainability of the ecosystem by reducing fertility and soil water-holding capacity.[6]

Grazing affects the plant ecology and adds excreta, thereby influencing soil N relationships. Nitrogen is a key element in the grassland ecosystem because of its capacity to limit primary and secondary production. The level of inorganic Nitrogen in grassland soils is normally low because of its rapid utilization by range vegetation. With active grazing, N passes through the animal body, after which most of it is usually returned to the soil through excreta. Consequently, total N, mineralizable N, exchangeable N, hydrolyzable N, and urease activity were assessed in the Ah horizons after 38 years of grazing of the light and very heavy grazed fields and their exclosures. Even though total N expressed as t/ha per Ah horizon remained the same, changes in various N fractions were nevertheless evident. Grazing resulted in more ammonium-N and nitrate-N in both fields at the time of sampling and each was greater at the higher stocking rate. Although soil N was less mineralizable, it was more acid-hydrolyzable at the higher stocking rate.[7]

Plant canopy and litter can alter the composition of precipitation falling through them and consequently the chemical properties of the soil under them. Little is known about the chemical composition of throughfall, or the water that falls through the grass canopy of rough fescue grassland during the grazing season, particularly as it is affected by different grazing pressures. Litter and soil in the upper 2 cm of the Ah horizon were collected at monthly intervals in 1988 and assessed for water-extractable C, N, organic acids, and mono-saccharides. At the high grazing intensity, the soil and litter N was less water-extractable. The carbon to nitrogen ratios of the water-extractable organic matter from litter and soil averaged 11.2 and 2.3, respectively. Soil monosaccharides were essentially not water-extractable. The quality of the litter as reflected by the water-extractable constituents often differed over the season between fields. Observations at regular time intervals are essential. The effect of the quality of leachates of litter on soil was not predictable. The 3 major long-chain fatty acids identified, (palmitic, stearic, and arachidic acids), from soil in grasslands that are in good condition because of the low grazing pressure, could well contribute to the resistance of those grasslands to the encroachment of invading species. [5]

Snow Accumulation

Snow accumulation is an important process that defines the hydrological characteristics of grasslands and is mediated by vegetation structure. Grazing pressure affects those processes, but its relationship to snow accumulation is poorly understood. Snow accumulation (mass per unit area) was measured throughout the winter from 1998 to 2004 within each of 3 watersheds that had different historical grazing pressures (high, moderate, and zero). In a second study, the effect of artificially created, (clipped), grazed patch sizes (0.5-, 1.0-, and 1.5-m diameter) on snow accumulation from 1998 to 2000 was examined. The yearly average of the heavily and moderately grazed watersheds was about 42% and 20%, respectively, less snow than the ungrazed watershed. Of the meteorological variables tested, only average daily temperatures, average daily maximum temperatures, and snowfall were influenced by the watershed. Snowfall was about half as effective in predicting snow accumulation in the heavily grazed watershed as in the moderately grazed or ungrazed watersheds. Patch size was generally not effective, except at single observations in both 1998 and 1999 when the 1.0-m diameter patch captured the most snow mass per unit area. The ungrazed grassland captured a similar amount to that captured in the cut patches. The study indicates that increased grazing intensity reduces the ability of grasslands to capture snow. [17]

Seed Bank

The germinable seed bank in a grassland affects the succession of degraded range and the recolonization of disturbed sites, and must be understood to predict potential responses to management. The germinable seed bank on the fescue prairie was characterized and its relationship to grazing, season, and depth of burial determined. The study was conducted in livestock exclosures and on the light, moderate, and heavy grazed fields. Surface debris was sampled in spring, (1986, 1987, and 1988), and fall, (1986 and 1987) and soil was sampled to a depth of 6 cm in the spring. The samples were spread on vermiculite in trays and the seeds allowed to germinate over a 90-day period. In fall, total surface seed number/m^2 increased from 1,785 to 7,783 from the ungrazed to heavily grazed site, and most of the differences were accounted for by whitlow-grass (Draba spp.) and Kentucky bluegrass. These species also contributed most to differences between fall and spring on the grazed sites. Total seed numbers were similar (1,790 vs l,803) in spring and fall on ungrazed sites. The species composition of the seed bank did not change with depth. In the soil, the annual forb pygmyflower (*Androsace septentrionalis* L.) was the most common seed but was not detected in a vegetation survey. Soil disturbance in the fescue prairie is more likely to lead to a seral community dominated by annual broad-leafed plants, than a rough fescue dominated grassland.[16]

Future

The stocking rates on the Stavely Grassland fields will be maintained indefinitely. Upcoming research is funding dependant and currently there are no specific studies being conducted on these fields. Rather, the treatments are being maintained so that research can be done in the future. Research that could be done is a continuation on the effect that grazing has on ecosystem production and function. Some of these questions have been answered in previous research but this broad objective needs to be addressed as part of our understanding grazing impacts in order to manage it for the health of the ecosystem and its food-web. It is an important part of understanding the system that includes livestock and how to keep them as the primary, beneficial, disturbance factor and not as a competitor for the resource. Issues that may currently be peripheral might be crucial in the future; this makes it important that we understand the ecosystem to ensure we can counter any threats to livestock grazing.

Table 1. Description of field sizes and associated stocking pressures and rates.

Stocking Pressure	Area of Field (ha)	Stocking Rates (AUM ha^{-1})[a]
Light	65	1.2
Moderate	48	1.6
Heavy	32	2.4
Very Heavy	16	4.8

[a] AUM ha^{-1} =Animal Units per month per hectare

References

1. Campbell, J.B. 1949. The Stavely grassland sub-station of Lethbridge experimental station. Canadian Cattlemen. March: 246-247.
2. Chanasyk, D.S., E. Mapfumo and W.D. Willms. 2002. Quantification and simulation of surface runoff from fescue grassland watersheds. Agric. Water Management 59: 137-153.
3. Chanasyk, D.S., E. Mapfumo, W.D. Willms and M.A. Naeth. 2004. Quantification and simulation of soil water on grazed fescue grassland watersheds. J. Range Manage. 57: 169-177
4. Dormaar, J.F. and W.D.Willms. 1990. Sustainable production from the rough fescue prairie. J. Soil and Water Cons. 45: 137-140.
5. Dormaar, J.F. and W.D.Willms. 1992. Water-extractable organic matter from plant litter and soil of rough fescue grassland. J. Range Manage. 45:152-158.
6. Dormaar, J.F. and W.D.Willms. 1998. Effect of forty-four years of grazing on fescue grassland soils. J. Range Manage. 51: 122-126.
7. Dormaar, J.F., S.Smoliak, and W.D.Willms. 1990. Distribution of nitrogen fractions in grazed and ungrazed fescue grassland Ah Horizons. J. Range Manage. 43: 6-9.
8. Johnston, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Canadian Journal of Plant Science. 41:615-622.
9. Johnston, A. Effects of grazing intensity and cover on the water-intake rate of fescue grassland. 1962. Journal of Range Management. 15: 79-82.
10. Johnston, A., J.F. Dormaar, and S. Smoliak. 1971. Long-term grazing effects on fescue grassland soils. Journal of Range Management. 24:185-188.
11. Li, Chunli, X. Hao, W.D. Willms, Z. Mengli, and H. Guodong. 2010. Effect of long-term cattle grazing on seasonal nitrogen and phosphorus concentrations in range forage species in the fescue grassland of southwestern Alberta. J. Plant Nutr. Soil Sci. 1–6.
12. Mapfumo, E., D.S. Chanasyk, and W.D.Willms. 2004. Simulating daily soil water under foothills fescue grazing with the Soil and Water Assessment Tool model. Hydrological Processes 18: 2787-2800.
13. Mapfumo, E., W. D. Willms, and D. S. Chanasyk. 2002. Water quality of surface runoff from grazed fescue grassland watersheds in Alberta. Water Qual. Res. J. of Can. 37:543-562.
14. Mengli, Z. W.D. Willms, H. Bing, and A. Laroche. 2005. Effects of heavy grazing pressure on the random amplified polymorphic DNA marker diversity of mountain rough fescue (Festuca campestris Rydb.) in south western Alberta. Can. J. Plant Sci 85:623-629.
15. Willms, W.D, J. King, and J.F. Dormaar. 1998. Weathering losses of forage species on the fescue grassland in southwestern Alberta. Can. J. Plant Sci. 78: 265-272.
16. Willms, W.D. and D.A. Quinton. 1995. Grazing effects on germinable seeds on the fescue prairie. J. Range Manage. 48: 423-430.
17. Willms, W.D. and D.S. Chanasyk. 2006. Grazing effects on snow accumulation on rough fescue grasslands. Rangeland Ecology and Management 59: 400-405.
18. Willms, W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49: 100-104.
19. Willms, W.D., J.F. Dormaar, and G.B. Schaalje. 1988. Stability of grazed patches on rough fescue grasslands. J. Range Manage. 41: 503-508.
20. Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.
21. Willms, W.D., S. Smoliak, and G.B. Schaalje. 1986. Cattle weight gains in relation to stocking rate on rough fescue grassland. J. Range. Manage. 39: 182-87.

Other References

22. Bezeau, L.M. and A. Johnston. 1962. In vitro digestibility of range forage plants of the Fescue scabrella association. Can. J. Plant Sci. 42: 692-697.
23. Bogen, A.D., E.W. Bork, and W.D. Willms. 2002. *Festuca campestris* Rydb. response to heat injury. Can. J. Plant Sci. 82:721-729.
24. Bogen, A.D., E.W. Bork, and W.D. Willms. 2003. Defoliation impacts on Festuca campestris (Rydb.) plants exposed to wildfire. J. Range Manage. 56: 375-381.
25. Dormaar, J. F and W.D.Willms. 2000. Rangeland management impacts on soil biological indicators in southern Alberta. J. Range Manage. 53: 233-238.
26. Dormaar, J. F. and W.D. Willms. 2000. A comparison of soil chemical characteristics in modified rangeland communities. J. Range Manage. 53:453–458.
27. Dormaar, J.F. and W.D.Willms. 1993. Decomposition of blue grama and rough fescue roots in the Ah horizons of mixed prairie and rough fescue prairies. J. Range Manage. 46: 207-213.
28. Freeze, B.S., W.D. Willms and L. Rode. 1999. Economics of maintaining cow condition on fescue prairie in winter. J. Range Mgmt. 52: 113-119.
29. Johnston, A. 1961. Some factors affecting germination, emergence, and early growth of three range grasses. Can. J. Plant Sci. 41: 59-70.
30. May, K.W., W.D. Willms, Z. Mengli and T.J. Lysyk. 2003. An assessment of variation in foothills rough fescue [Festuca campestris (Rydb.)] in southern Alberta. Can. J. Plant Sci. 83:541-550.
31. Moisey, D.M., E.W. Bork, and W.D. Willms. 2005. Non-destructive assessment of cattle forage selection: a test of skim grazing in Fescue Grassland. Applied Animal Behaviour Science 94: 205-222.
32. Moisey, D.M., W.D. Willms, and E.W. Bork. 2006. Effect of standing litter on rough fescue utilization by cattle. Rangeland Ecology and Management 59: 197-203.
33. Peake, R.W. and A. Johnston. 1965. Grazing effects on fescue grassland in western Canada. In: 9th Internat. Grassl. congr., Brazil. p. 1627-1630.
34. Whalen, J.K., W.D. Willms and J.F. Dormaar. 2003. Soil carbon, nitrogen, and phosphorus in modified rangeland communities. J. Range Manage. 56: 665-672.
35. Willms, W.D, L.M. Rode, and B.S. Freeze. 1993. Winter performance of Hereford cows on fescue prairie and in drylot as influenced by fall grazing. Can. J. Anim. Sci. 73: 881-889.
36. Willms, W.D. 1988. Forage production and utilization in various topographic zones of the fescue grasslands. Can J. Anim. Sci. 68: 211-223
37. Willms, W.D. 1990. Distribution of cattle on slope without water restrictions. Can. J. Anim. Sci. 70: 1-8.
38. Willms, W.D. 1992. Influence of summer cutting and fertilizer application on Altai wild rye in winter. Can. J. Plant Sci. 72: 173-179.
39. Willms, W.D. 1991. Cutting frequency and cutting height effects on rough fescue and Parry oat grass yields. J. Range Manage. 44:82-86.
40. Willms, W.D. and K.A.Beauchemin. 1991. Cutting frequency and cutting height effects on forage quality of rough fescue and Parry oatgrass. Can. J. Anim. Sc. 71: 87-96.
41. Willms, W.D. and L.M. Rode. 1998. Forage selection by cattle on fescue prairie in summer or winter. J. Range Manage. 51: 496-500.
42. Willms, W.D., L.M.Rode, and B.S.Freeze. 1998. Protein supplementation to enhance the performance of pregnant cows on rough fescue grasslands in winter. Can. J. Anim. Sci. 78: 89-94.
43. Willms, W.D., O.R. Kenzie, T.A. Mcallister, D. Colwell, D. Veira, J.F. Wilmshurst, T. Entz and M.E. Olson. 2002. Effects of water quality on cattle performance. J. Range Manage. 55:452-460.
44. Willms, W.D., O.R. Kenzie, T.A. McAllister, D.Colwell, D.Veira, J. F. Wilmshurst, T. Entz, and M.E. Olson. 2002. Effects of water quality on cattle performance. J. Range Manage. 55:452-460.
45. Willms,W.D., S. Smoliak, and A.W. Bailey. 1986. Herbage production following litter removal on Alberta native grasslands. J. Range Manage. 39: 536-539.