RUNOFF AND SEDIMENT YIELD UNDER GRAZING IN FOOTHILLS FESCUE GRASSLANDS OF ALBERTA*

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BACKGROUND

Grazing has hydrologic impacts on Canadian foothills fescue grasslands through alteration of plant species composition, plant density, ground cover and litter (Johnston, 1961; Naeth et al., 1991a and 1991b). Livestock trample vegetation and may compact the soil (Naeth et al. 1990a), reduce infiltration (Naeth et al. 1990b), increase runoff (Johnston 1962) and alter soil water regime (Naeth et al. 1991c). Johnston (1962) found runoff and sediment yield from rainfall simulations increased with increased grazing intensity and reduced ground cover.

The objectives of this study were to quantify the effects of short duration and continuous (throughout the growing season) grazing systems on runoff and sediment yield from sloped areas of the foothills fescue grasslands of Alberta. There has been relatively little hydrologic research conducted on these or similar grasslands, particularly under snowmelt and natural precipitation conditions.

MATERIALS AND METHODS

The study site is located at the Agriculture Canada Stavely Range Substation, approximately 100 km northwest of Lethbridge, Alberta. Annual precipitation is approximately 550 mm with 40% occurring as snow (Strong and Leggat, 1981). The topography is generally hilly and slopes on the study site range from 18 to 37%. Soils are generally fertile and well drained. Black surface soil averages 8 to 10 cm in thickness with 5 cm on the uplands and 15 to 18 cm in gently rolling flats. Depth to the C horizon is approximately 60 cm. Dominant soils are Orthic Black Chernozems (Typic Cryoboroll) (Walker et al., 1991). *Festuca campestris* Rydb. (rough fescue) dominates the ungrazed and lightly grazed areas; *Danthonia parryi* Scribn. (Parry's oatgrass) dominates the heavily grazed areas and exposed sites with thin soils. There are a variety of subdominant grasses, forbs and shrubs. Lightly and heavily grazed fields were dominated by *Festuca campestris* and *Danthonia parryi*, respectively. Under very heavy grazing, *Festuca campestris* and litter were virtually eliminated. *Populus tremuloides* Michx. (trembling aspen) encroached upon lightly and moderately grazed grassland.

In 1988, research sites were established in the 40-year-old continuous grazing treatments and 4-year-old short duration grazing treatments. Treatments contrast between the historical grazing regime (continuous throughout the growing season) and short-duration, high intensity grazing. Continuous treatments were grazed from May through October; short-duration treatments were grazed for one week in mid-June. Heavy and very heavy stocking densities at 2.4 and 4.8 animal unit months (AUM) ha^{-1}, respectively, in both the short duration and continuous treatments, represent common grazing intensities for the area. The short duration treatments consisted of two 30 by 120 m grazed strips (heavy and very heavy grazing) and a 10 by 120 m control (ungrazed) each replicated three times, running downslope in a randomized split block design. The continuous treatments were located approximately 0.5 km from the short duration sites, running down the same slope but without a control. All treatments had an east facing aspect.

Runoff and sediment yield were monitored following snowmelt and after rainfall events using three 1-m^2 runoff frames per treatment (1 L of runoff corresponds to a water depth of 1 mm from the frames). The outlet end of the frames was trapezoidal in shape and was connected to a collection system consisting of a 20-L plastic pail located within a 64-L plastic pail buried in the ground. Upper-slope frames were installed in 1988 and mid-slope frames in 1989. At the time of runoff measurement, three subsamples of the runoff water, each 284 mL in size, were taken for sediment analyses. Samples were evaporated in a drying oven and the sediment weighed.

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Snow depth was measured with a meter stick at ten locations within each treatment/slope area near the runoff frames several times during the winter before snowmelt. The beginning of snowmelt was the time water started to run off from the frames. Snowmelt runoff volumes were generally determined several times during the snowmelt period and summed to give a total snowmelt value for each frame. Runoff was considered as accumulated runoff water from snowmelt and both as individual summer storm and accumulated summer runoff.

For each parameter, significant differences of the means were detected with Analysis of Variance techniques with design following the convention outlined in the SPSS-X User Manual (SPSS 1988) for split blocks. Significant effects were further evaluated using Student-Newman-Keul's (SNK) multiple comparison of means test at the 90% confidence limit (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Snow depth was greatest in the treatments with the highest amount of fallen and standing litter which effectively trapped snow. Average snowmelt runoff among treatments ranged from 3.3 to 105.7 L; this runoff was highest in 1991 and lowest in 1990. The ranking of snowmelt runoff by decreasing magnitude (1991, 1989 and 1990) parallels that of over-winter precipitation. Runoff was generally three to four times higher from mid-slope than from the upper-slope, likely due to a slightly steeper slope in the mid-slope position and more snow trapped there in the woody vegetation. There was a consistent trend across both grazing intensities of snowmelt volume with the very heavy treatments being less than those for the heavy treatments, except for the short duration treatments on the mid-slope in 1991.

Snowmelt runoff generally decreased with increasing grazing intensity from heavy to very heavy. The trend is likely due to higher litter and vegetation accumulations in the heavily grazed treatments which trapped more snow, resulting in increased runoff. Snowmelt runoff from the controls was generally similar to that from the short duration heavy treatment (average ratio of 1.01 across upper and mid slope positions and years), reflecting the trend in snow accumulation.

Sediment yields as a result of snowmelt were generally low: most were <4 g. Sediment yield was lowest in the short duration very heavy treatment, and was generally higher (average 312%) from the mid-slope position than the upper-slope position, a result of higher runoff in the former location. Sediment concentrations under snowmelt were generally similar across grazing treatments and dates, likely due to frozen soil conditions. Most concentrations were between 0.07 and 0.18 g L^{-1}. Concentrations for the upper-slope position were higher than those for the mid-slope position in all cases except two, by an average 61%.

Rainfall runoff was greatest from the short duration very heavy treatment in the mid-slope position in all three years and in one of four years in the upper-slope position. Runoff was generally lowest in the control. Runoff increased as grazing intensity increased (heavy to very heavy). On only five summer monitoring dates over four years were runoff volumes greater than 5 L: 18 August 1988, 19 June 1989, 2 and 16 August 1990, 8 October 1991. Runoff coefficients for rainstorm runoff were all below 0.11, indicating that only a small portion of rainfall results in runoff. These low runoff coefficients, even for heavily grazed areas, are likely due to the characteristic low intensity rainfall and to generally dry antecedent soil water conditions.

Total rainstorm sediment yields were generally highest for the continuous treatments and lowest for the control. There was a general trend to lower sediment yield in the upper slope position than in the mid-slope one. Of the 35 annual values reported, only 3 exceeded 10 g while 25 were less than 5 g. The majority of the total sediment yield occurred in August 1988 when 36.8 mm of rainfall fell on wet ground.

Sediment concentrations increased under grazing compared to the control and were 4 to 10 times higher under rainfall than snowmelt. Soil particle detachment occurs more easily under rainfall than snowmelt, resulting in the higher ratios under rainfall. Also detachment increases as protective vegetative cover is removed by grazing.

The highest sediment yield measured was 33.7 g; converted to a ha-basis, this gives an erosion rate of 0.337 t ha^{-1}; a very low rate. Because overland flow from above the frame was excluded, only runoff initiation processes were measured and thus sediment yields would be expected to be low. Thus, additional research is required to assess gully erosion, which occurs on a much broader scale, before definitive conclusions of the erosion susceptibility of these

rangelands can be drawn. Visual examination of these rangelands indicates the presence of gullies, probably due to the concentration of runoff flows from snowmelt and from the infrequent summer storms that cause runoff.

Annual runoff was dominated by snowmelt-induced runoff. On average, 70% of total annual runoff occurred as a result of snowmelt. Thus, snowmelt dominates annual runoff, regardless of slope position and grazing treatment, at this site. Snowmelt had previously been identified as the time of major runoff and erosion hazard for cultivated fields in the Peace River region of Alberta, with summer storms that caused significant erosion to be infrequent (Chanasyk and Woytowich, 1987).

CONCLUSIONS

The majority of annual runoff occurred during snowmelt. Snowmelt runoff decreased with increasing grazing intensity and was generally higher from the two heavy treatments and the control than from the very heavy treatments, due to the higher accumulated snow in the former treatments, in turn due to higher standing vegetation and litter there. Thus, any grazing regime that reduces vegetation markedly will also reduce snowmelt runoff in this area. Snowmelt sediment yields were generally low. Ratios of sediment yield to runoff volume under snowmelt were generally similar across grazing treatments and dates.

Few summer storms caused runoff, and runoff volumes from summer rainstorms were low. As grazing increased, so did rainstorm runoff coefficients and sediment yields. Rainstorm runoff coefficients increased over the control due to grazing, with intensity of grazing generally increasing the coefficients consistently only under short duration grazing and sometimes under continuous grazing. Rainstorm sediment concentrations increased under grazing compared to the control. Antecedent soil moisture conditions appear to play a significant role in determining whether summer runoff occurs.

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