# FORAGE PRODUCTION AND UTILIZATION IN VARIOUS TOPOGRAPHIC ZONES OF THE FESCUE GRASSLANDS

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WILLMS, W. D. 1988. Forage production and utilization in various topographic zones of the fescue grasslands. Can. J. Anim. Sci. **68**: 211–223.



The effects of topography and litter on forage production and utilization were studied on Rough Fescue Grasslands in the foothills region of southwestern Alberta. Forage production and utilization were estimated, at monthly intervals during the grazing seasons over 4 yr, in six topographic zones of two fields stocked at a moderate or a high rate representing 2.4 or 3.2 animal unit months per hectare (AUM $ha^{-1}$), respectively. The higher rate could not be achieved in the first 3 yr of the study because available forage was limiting. The topographic zones were represented by the west, east, south, and flat aspects of the upland areas, and by the lowland zone subdivided into a subirrigated zone and the interface between the latter and upland zones. Forage production was about 50% more in the subirrigated zone than in the upland zones. Among the upland zones, forage production tended to be greatest on the south aspect. Forage utilization was greatest in the subirrigated zone but least on the south aspect. Topographic preference was highest for the subirrigated zone early in the grazing season. The effect of a high stocking rate was to minimize the preference differences among topographic zones. Litter had a significant positive effect on both forage production and the amount of residual forage after the grazing season but had a significant negative effect on percent utilization. Litter provided a buffer which enabled the maintenance of anticipated stocking rate by providing emergency forage and enhancing production during drought.

Key words: Litter, residual forage, preference, aspect, stocking rate, cattle, distribution

[Production et utilisation des fourrages dans diverses zones topographiques des prairies à fétuque.]
Titre abrégé: Production et utilisation dans les prairies à fétuque.
On a étudié les effets de la topographie et de la litière sur la production et l'utilisation des fourrages dans les prairies à fétuque scabre situées dans la région des avant-monts du sud-ouest de l'Alberta. La production et l'utilisation des fourrages ont été évaluées chaque mois de la saison de pâturage pendant 4 ans dans six zones topographiques réparties dans deux champs modérément ou fortement peuplés à raison de 2,4 ou 3,2 unités animal-mois par hectare (UAM $ha^{-1}$) respectivement. Le taux le plus élevé n'a pu être atteint au cours des 3 premières années de l'étude en raison de la disponibilité limitée de fourrages. Les zones topographiques étaient réparties comme suit: les parties orientées à l'ouest, à l'est et au sud, et la partie plane des hautes terres et, dans les terres basses, une zone irriguée par voie souterraine et la zone entre cette dernière et les hautes terres. La production fourragère dans la zone irriguée par voie souterraine dépassait d'environ 50% celle des hautes terres. Dans les zones des hautes terres, la production fourragère avait tendance à être la meilleure dans la partie orientée au sud. L'utilisation des fourrages était la plus élevée dans la zone irriguée par voie souterraine mais la moins élevée dans la partie orientée au sud. Au début de la saison de paissance, les animaux préféraient brouter la zone irriguée par voie souterraine. L'intensité élevée de pâturage avait pour effet de minimiser les différences de

préférence entre les zones topographiques. La litière avait un effet positif significatif sur la production fourragère et sur la quantité de fourrages résiduels après la saison de pâturage mais un effet négatif significatif sur le pourcentage d'utilisation des fourrages. La litière servait de tampon qui permettait de conserver l'intensité de pâturage prévue en fournissant du fourrage d'urgence et en favorisant la production au cours de la sécheresse.

Mots clés: Litière, fourrages résiduels, préférence, orientation, intensité de pâturage, bovins, distribution



Maximum production from native grasslands can be maintained by delaying grazing in spring until the plants are in their rapid growth phase and by avoiding excessive removal of leaf tissue. On pastures that are grazed the entire season, livestock behavior contributes to inefficiency in forage or livestock production by grazing some areas too heavily and leaving others ungrazed. This may occur either within or among topographic zones and is modified by grazing pressure and other factors affecting cattle distribution. Cattle distribution is affected by a variety of factors that include social, topographic, and forage characteristics (Arnold and Dudzinski 1978). Cook (1966) identified slope, distance to water, and forage quality as some of the more important site attributes affecting distribution. Forage quality is largely determined by the proportion of litter present in the herbage. In a controlled study, cattle selected plants of bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. + Smith) where litter had previously been removed by clipping during dormancy and avoided plants with litter (Willms et al. 1980).

Forage production and species phenology are affected by aspect and elevation since the latter relate to climate. On mountain grasslands in western Montana, herbage production was about two times greater, and initial growth about 1 wk later, on the northeast exposure than on the southwest exposure (Mueggler 1983). Van Ryswyck et al. (1966) reported an abrupt sequence of vegetation zones in relation to elevation, which correlated with a climatic gradient.

Forage production is also influenced by litter, both in its suppression of tiller regeneration and in its water conservation properties. Litter is defined as that component of available forage produced prior to the current year. Available forage remaining after the grazing season in one year becomes the litter component in the following year. Removing litter during dormancy resulted in a 60% reduction in forage yield on the Mixed Prairie, where soil moisture limits production (Hopkins 1954), and had an insignificant effect, of either increasing or reducing yields, on the Fescue Prairie where soil moisture is normally adequate (Willms et al. 1986). However, tiller densities of grasses almost doubled when litter was removed thereby increasing their production potential. Hopkins (1954) reported a 50% reduction in water loss from a bare soil surface when 2.5 cm of litter was added.

The variable topography of the Rough Fescue Grasslands in the foothills region of southwestern Alberta results in areas with potential differences in forage production and utilization by cattle. Advantage could be taken of site differences, by fencing to control distribution and time of use, in order to increase production efficiency from native grasslands. This information is not available for the foothills region. Consequently, a study was made to determine the effects of topographic zone, the largest unit with uniform site characteristics in the foothills region, and litter on forage production and utilization by cattle in relation to grazing pressure.

## MATERIALS AND METHODS

### Site Description

The study was made from 1983 to 1986 at the Agriculture Canada Range Research Substation, which is located in the Rough Fescue Grasslands in the foothills region of southwestern Alberta near

Stavely, about 85 km NW of Lethbridge. The topography is undulating, varying in elevation from 1280 to 1420 m above sea level (Fig. 1). Average precipitation over 34 yr, for the growing season from April to August, was 348 mm at the substation. Average annual precipitation was not measured at the substation, but at two similar sites it averaged 614 mm.

The vegetation is representative of the Rough Fescue Association described by Moss and Campbell (1947). Rough fescue (*Festuca campestris* Rydb., or *F. scabrella* Torr. var. *major* Vasey) is the dominant species in the community with Parry oat grass (*Danthonia parryi* Scribn.) as the co-dominant. Rough fescue is sensitive to grazing and is replaced by Parry oat grass if high grazing pressure is sustained. In the subirrigated lowlands, native species have been replaced with timothy (*Phleum pratense* L.), Kentucky bluegrass (*Poa pratensis* L.), white clover (*Trifolium repens* L.), and dandelion (*Taraxacum officinale* Weber). The soils are classified as Orthic Black Chernozemic (Udic Haploboroll) developed on till overlying sandstone.

The two contiguous fields selected for the study were 16.2 and 32.4 ha in area and each had been stocked with 13 animal units (AU) for the spring and summer grazing period since 1949. Over a 6-month grazing period, from May to November, this would achieve stocking rates of 4.8 and 2.4 animal unit month (AUM) ha$^{-1}$, making one a heavily stocked field (field H) and one a moderately stocked field (field M). However, this rate was not achieved on field H after 1960 when it was stocked for shorter periods, which varied with the forage supply, and averaged 3.2 AUM ha$^{-1}$. Field M was stocked at the upper rate recommended for range in good condition (Wroe et al. 1981).

The different stocking rates produced two distinct plant communities. The proportion of forbs was approximately 23% in field M and approximately 37% in field H (Willms et al. 1985). The difference was compensated largely by a decrease in the proportion of grasses. Rough fescue comprised approximately 8% in field M and 2% in field H while Parry oat grass represented 48 and 35% for the two fields, respectively. Although the previous stocking rates caused the plant communities in both fields to deteriorate, through a reduction in the composition of productive species, the effect was most severe in field H where production was 63% of field M.

The areas of fields M and H were stratified into six topographic zones defined by aspect and topographic position. The topographic zones recognized were: the upland zone with aspects of west (1), east (2), south (3), and flat (4); and the lowland zone subdivided into a subirrigated zone (5) and an interface between the subirrigated zone and the upland slopes (6). The subirrigated zone represents drainage channels which are normally dry but subject to flooding during snow-melt. Their high moisture regime is indicated by the dominance of timothy, Kentucky bluegrass, and white clover which invade and persist under heavy grazing pressure. Topographic zone 3 was not recognized in field H. The average slopes and areas of each zone are given in Table 1. The east and west aspects are the most common in the foothills region because the orientation of the foothills is in a north-south direction.

**Stocking Rates**

The study was made over a 4-y period from 1983 to 1986. In each year, 13 cows with calves were conditioned on adjacent native grassland for 1 mo prior to being put into each field in mid-May. The cattle were removed by mid-November. Although an effort was made to achieve a stocking rate of 2.4 AUM ha$^{-1}$ on field M and a stocking rate of 3.2 AUM ha$^{-1}$ on field H, these rates were not achieved in most years because drought resulted in a loss of drinking water or forage production. Available forage was always sufficient in field M but the grazing season was shortened in 1983 to 4 mo when drinking water became limiting. This resulted in a stocking rate of 1.75 AUM ha$^{-1}$. The stocking rates in 1984, 1985, and 1986 were 2.23, 2.19, and 2.46 AUM ha$^{-1}$, respectively. Forage supply was the only limiting factor in field H. The stocking rates achieved in each year of the study, from 1983 to 1986, were 2.24, 1.85, 1.74, and 3.2 AUM ha$^{-1}$, respectively. Both cows and calves were weighed before and after the grazing period to determine weight gain.

**Sampling and Analysis**

Portable exclosures, 46 in field M and 28 in field H, were allocated among zones in approximate proportion to their area represented in each field. The exclosures were randomly distributed within a zone and 0.5-m$^{-2}$ plots were clipped both inside and outside each exclosure. The plots were first harvested in mid-June and at monthly intervals as long as cattle were in the field in each year of the study. The exclosures were moved after each clipping. The location of the clipped plot outside the exclosure and the new location of the exclosure

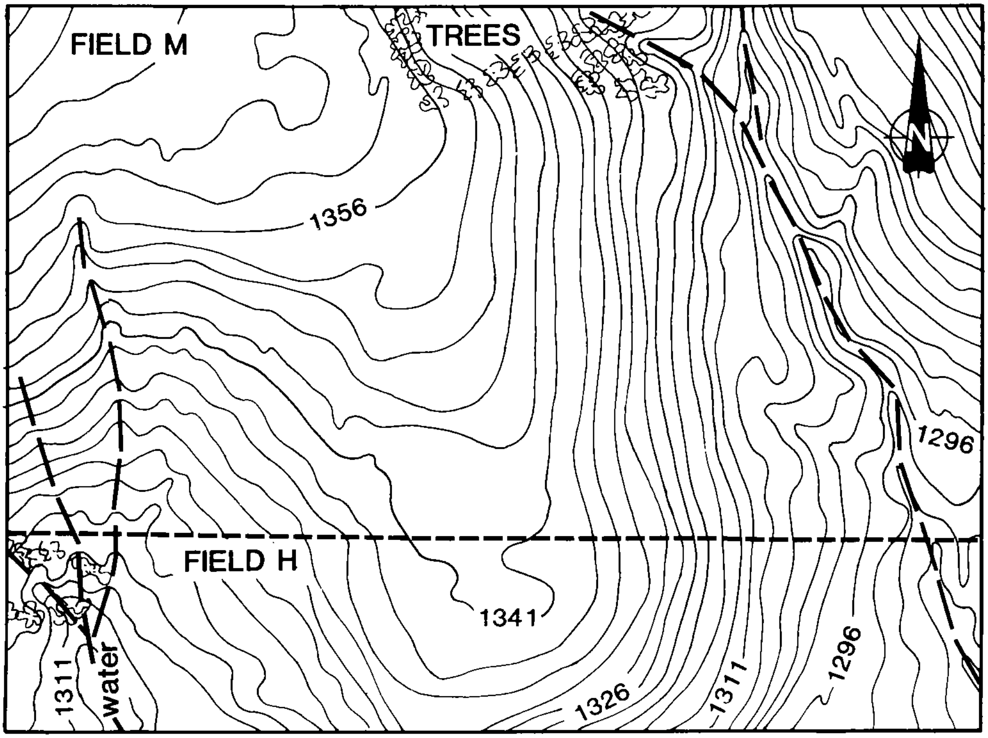


Fig. 1. Topographic map of study site showing 3-m contours, drainage pattern, and water locations.

Table 1. Average slope and proportion of area occupied by each topographic zone on fields of the study area

| | Field M | | Field H | |
|---|---|---|---|---|
| | Slope | Proportion | Slope | Proportion |
| | (%) | | | |
| Upland | | | | |
| (1) West | 20 | 13.9 | 16 | 16.0 |
| (2) East | 21 | 25.0 | 22 | 29.2 |
| (3) South | 16 | 14.6 | not present | |
| (4) Flat | 4 | 34.3 | 4 | 22.9 |
| Lowland | | | | |
| (5) Subirrigated | 1 | 4.2 | 1 | 7.4 |
| (6) Interface | 11 | 8.0 | 11 | 24.5 |

were determined systematically to avoid repeated clipping of the same area over time.

Forages were harvested by cutting at ground level using electric clippers. The forages were oven-dried and weighed. A double sampling procedure was used to determine the proportion of currently produced forage to total available forage. This was done by visually estimating the proportion of currently produced forage in each sample, removing subsamples from 15 to 20% of the samples, hand-sorting the subsamples to currently produced forage and litter, developing bias corrections by calculating regression equations of estimated proportions to actual proportions of currently produced forage in total available forage, and applying the corrections to the sample estimates. This procedure was followed with each monthly harvest until October when currently produced forage and litter were impossible to distinguish.

Utilization was determined as the difference between total dry matter harvested inside and outside the exclosure. As such, it represented dry matter disappearance which also includes losses from trampling and utilization by other herbivores. Total use was the accumulated value over the grazing season. In 1984 and 1985, a persistent cover of snow prevented the final harvest. Consequently, total use was extrapolated from average daily utilization as calculated to the final harvest date. This problem affected only the estimate in field M. The extrapolated correction was not applied to an estimate of utilization among habitats, since that would assume uniform distribution, but only to the estimate of total use among years.

Growth was based on the estimates of currently produced forage between harvests. It was determined as the difference in the quantity of currently produced forage outside the exclosure in one month and the amount of currently produced forage inside the exclosure the next month. The first estimate of growth was made in June and consisted of all the new forage present in the exclosure. This estimate would represent production from early April when above-ground growth normally begins.

The production and utilization variables were analyzed for the effects of topographic zone, field, year, and their interactions (Table 2). Year was treated as a fixed variable because precipitation throughout the study was below average. Since one topographic zone (south aspect) was not represented in field H, least square means and linear contrasts among selected means (Steel and Torrie 1980) were determined from analyses of individual fields.

The effect of litter on various components of growth and utilization was determined with regression analysis using simple and quadratic polynomials. Preference for each topographic zone was calculated as:

$$\frac{\text{\% utilized of total utilized}}{\text{\% area of total area}}$$

(Senft et al. 1985). Preferences were determined for two periods representing: (1) 15 May–15 July, and (2) 15 July–15 September. These periods represent one of growth and another of senescence.

## RESULTS

Total precipitation between April and August was less than 50% of normal in 1983, 1984, and 1985 (Table 3) and, in 1985, most precipitation occurred in August. In 1986, seasonal precipitation was only 74% of normal but the majority was available from May to July. Snow accumulation was normal (about 250 cm) in 1982–1983, 1984–1985, and 1985–1986 but nearly absent in 1983–1984.

Forage production by mid-June, as a proportion of the total, was about 85% and 70% on the upland and lowland zones, respectively. Forage production was similar among most upland zones (Table 4). However, by mid-June the south slope had produced more forage than the east- and west-facing slopes. Significantly more forage was produced in the subirrigated zone than on the upland; growth in the former extended into September but only to July in the latter. The interface zone produced less forage in field M but more forage in field H than the upland zones.

The litter component of available forage was significantly less in the lowland than in the upland zones of field M but similar between the zones of field H (Table 4). In field M, litter accumulation on the south slope was about 65% more than in the other upland zones.

Available forage comprises current growth and accumulated litter. In field M, available forage, on a unit area basis, was greatest on the south slope of the upland zone and least on the interface zone (Table 4). However, the subirrigated zone in field H had the most available forage.

Utilization, also defined on a unit area basis, was significantly greater in the subirrigated zone than in the other zones (Table 4). The south slope was utilized less than the east or west slopes ($P > 0.20$).

The interactions of year and topographic zone were not significant ($P > 0.20$) for variables of forage production and utilization within a field (Table 2). However, the year effect was significant for most forage variables. Forage production by mid-June was least in 1985 and greatest in 1986 (Table 5), but total annual production was least in 1984. The litter component increased from 1983 to 1984 but decreased successively in 1985 and 1986 (Table 5). In field M, available forage

Table 2. Analysis of variance of selected forage characteristics among topographic zones (Z) on fields (F) M and H from years (Y) 1983 to 1986

| Source | df | Growth | | Litter | Total forage | |
|---|---|---|---|---|---|---|
| | | 5 June | Annual | | Available | Utilization |
| | | | | *Probability* | | |
| F | 1 | <0.001 | 0.006 | <0.001 | <0.001 | <0.001 |
| Z | 9 | 0.054 | 0.001 | <0.001 | 0.005 | 0.005 |
| Error a - Plot(F•Z) | 62 | | | | | |
| Y | 3 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| F•Y | 3 | <0.001 | 0.585 | <0.001 | 0.019 | 0.019 |
| Y•Z(F) | 27 | 0.468 | 0.292 | 0.027 | 0.026 | 0.027 |
| Error b - Y•Plot(F•Z) | 176 | | | | | |

Table 3. Precipitation (mm) during the growing season at the Stavely Range Research Substation over a 4-y period

| | April | May | June | July | August | Total |
|---|---|---|---|---|---|---|
| 1983 | 30 | 21 | 28 | 57 | 32 | 168 |
| 1984 | 23 | 46 | 71 | 27 | 1 | 168 |
| 1985 | 20 | 23 | 0 | 31 | 99 | 173 |
| 1986 | 11 | 52 | 78 | 77 | 38 | 256 |
| 34-yr average | 64 | 70 | 99 | 55 | 60 | 348 |

was generally constant over all years but, in field H, it was similar in 1984 and 1985 and about 40% greater in 1986.

On a unit area basis, field M produced more forage ($P < 0.01$) and more forage was utilized ($P < 0.01$) than in field H (Table 5). Average proportion of available forage utilized was 56 and 76% while residual forage after the grazing season averaged 1565 and 577 kg ha$^{-1}$ on fields M and H, respectively. Average individual weight gains of cattle, from May to August in fields M and H, were, for cows, 37 and 27 kg, respectively, and for calves, 101 and 85 kg, respectively. The gains in field H represented total gains while cattle were in the field. However, since cattle were kept on field M until November, the weights represent partial gains. Over the entire grazing season, on field M, cows and calves gained 30 and 137 kg, respectively.

Cattle exhibited the greatest preference for the subirrigated zone in both periods in field M but only in the first period in field H (Fig. 2). Of the upland zones in field M, cattle exhibited higher preference for the west slope and an avoidance of the south slope. Preferences for the upland zones generally increased in the second period in both fields. Preference for the interface zone followed that of the upland zones. The effect of a high stocking rate was to moderate the preference differences among zones within each period. It should be pointed out that preference differences are speculative since variation within field and zone was considerable in some cases (Fig. 2).

Litter quantity (g m$^{-2}$) among harvest sites, over all topographic zones with the exception of the subirrigated, in field M varied from 4 to 286 with a mean of 100.6 and a standard deviation of $\pm$ 73.0 and, in field H, varied from 2 to 76 with a mean of 27.2 and a standard deviation of $\pm$ 14.8. Litter quantity had a significant effect on forage production, percent utilization and the residue left after the grazing season in field M (Table 6). Total forage production was positively ($P < 0.10$) correlated with litter in 1983, 1984, and 1985 but was not significant ($P > 0.20$) in 1986. Proportion utilized was negatively correlated ($P < 0.05$) while residual forage was positively correlated

Table 4. Forage characteristics, averaged over a 4-yr period, in relation to topographic zone and stocking rate (fields M and H) with probability values for tests of specific comparisons

| Topographic zone | Production: 15 June M | Production: 15 June H | Production: Annual M | Production: Annual H | Litter M | Litter H | Total available forage M | Total available forage H | Utilization M | Utilization H |
|---|---|---|---|---|---|---|---|---|---|---|
| | (kg ha$^{-1}$) | | | | | | | | | |
| Upland | | | | | | | | | | |
| West (1) | 1933 | 1371 | 2416 | 1646 | 1054 | 364 | 3470 | 2010 | 2044 | 1452 |
| East (2) | 1844 | 1562 | 2170 | 1826 | 1181 | 327 | 3351 | 2154 | 1734 | 1599 |
| South (3) | 2420 | NP† | 2874 | NP | 1791 | NP | 4665 | NP | 1383 | NP |
| Flat (4) | 2052 | 1701 | 2350 | 1940 | 1144 | 288 | 3493 | 2228 | 1843 | 1754 |
| Lowland | | | | | | | | | | |
| Subirrigated (5) | 2561 | 1907 | 3696 | 2709 | 308 | 309 | 4004 | 3018 | 3638 | 2540 |
| Interface (6) | 1691 | 1769 | 1974 | 2369 | 438 | 264 | 2412 | 2633 | 1420 | 1958 |
| Contrasts | | | | | | | | | | |
| 1,2,3,4 vs. 5 | 0.04 | 0.13 | <0.01 | 0.02 | <0.01 | NS | NS | 0.02 | 0.01 | 0.01 |
| 1,2,3,4 vs. 6 | 0.06 | NS | 0.06 | 0.15 | <0.01 | NS | 0.01 | 0.20 | NS | NS |
| 1 vs. 2 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 1,2,3 vs.4 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 1,2 vs.3 | 0.04 | NP | 0.09 | NP | 0.04 | NP | 0.01 | NP | NS | NP |

†NP = not present in dataset.
NS = $P>0.20$.

Table 5. Forage production and utilization (weighted by area of topographic zone) in relation to year and stocking rate (fields M and H), with probability values for tests of specific comparisons

| | Production | | | | | | Total available forage | | Utilization | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15 June | | Annual | | Litter | | | | | |
| Topographic | M | H | M | H | M | H | M | H | M | H |
| | (kg ha$^{-1}$) | | | | | | | | | |
| Year | | | | | | | | | | |
| 1983 | 2135 | 1834 | 2368 | 2165 | 1252 | 161 | 3620 | 2326 | 1526 | 1798 |
| 1984 | 1857 | 1059 | 1967 | 1414 | 1654 | 630 | 3628 | 2037 | 2095 | 1577 |
| 1985 | 1521 | 1214 | 2257 | 1809 | 1248 | 249 | 3505 | 2058 | 2110 | 1323 |
| 1986 | 2619 | 2501 | 3047 | 2717 | 446 | 186 | 3493 | 2903 | 2253 | 2399 |
| Mean | 2033 | 1652 | 2410 | 2026 | 1150 | 306 | 3562 | 2331 | 1996 | 1774 |
| Contrasts | | | | | | | | | | |
| 83 vs. 84 | 0.12 | <0.01 | 0.07 | <0.01 | 0.05 | <0.01 | NS | 0.08 | NS | 0.18 |
| 83 vs. 85 | <0.01 | <0.01 | NS | 0.03 | NS | 0.13 | NS | 0.16 | NS | 0.01 |
| 83 vs. 86 | 0.01 | <0.01 | 0.01 | <0.01 | <0.01 | NS | NS | <0.01 | 0.08 | 0.01 |
| 84 vs. 85 | 0.05 | NS | NS | 0.01 | 0.04 | <0.01 | NS | NS | NS | NS |
| 84 vs. 86 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | NS | <0.01 | 0.11 | <0.01 |
| 85 vs. 86 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | NS | NS | <0.01 | NS | <0.01 |

NS = $P>0.20$.

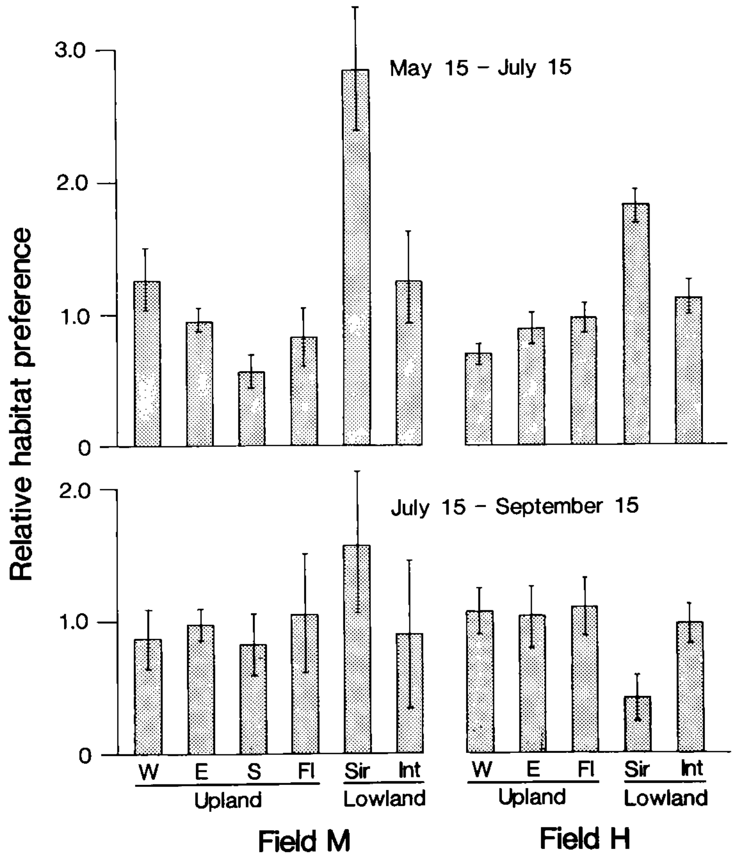


Fig. 2. Relative preferences for topographic zones at monthly intervals on fields M and H (W, west slope; E, east slope; S, south slope, Fl, flat; Sir, subirrigated; Int, interface; vertical bars denote 1 SEM, $n=4$).

($P < 0.01$) with litter in each year. The correlation of litter with proportion utilized and residual forage after grazing decreased from 1983 to 1986.

Litter had an insignificant effect ($P > 0.20$) in most years, in field H, on forage production, utilization, and residual forage after grazing (Table 7). Litter had a positive effect ($P < 0.06$) on forage production in 1984 and a positive effect ($P < 0.04$) on residual forage in 1983 and 1984.

## DISCUSSION

Average stocking rates over the 4-y period were similar on both fields M and H. However, grazing pressure was considerably greater on the latter field as a result of lower production and the practice of leaving the cattle on the field until most available forage was removed and they began to lose weight. This occurred when residual forage was less than approximately 560 kg ha$^{-1}$. On field M, forage was not limiting and residual

Table 6. Regression coefficients, standard errors (SE), coefficients of determination ($R^2$ as %), and probability level of simple polynomials describing the influence of litter (independent variable) on forage production, utilization (actual and proportion of total), and residual after grazing (dependent variables) on field M

| | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| Production | | | | |
| Coefficient | 0.32 | 0.28 | 0.45 | −0.38 |
| SE | 0.18 | 0.14 | 0.14 | 0.47 |
| $R^2$ (%) | 8 | 10 | 22 | 2 |
| *P* | 0.077 | 0.042 | 0.002 | NS |
| Utilization | | | | |
| Actual | | | | |
| Coefficient | −0.37 | −0.41 | 0.49 | −0.03 |
| SE | 0.24 | 0.28 | 0.20 | 0.50 |
| $R^2$ (%) | 6 | 5 | 13 | 0 |
| *P* | 0.141 | 0.151 | 0.022 | NS |
| Proportion (% of total available) | | | | |
| Coefficient | −0.68 | −0.58 | −0.24 | −0.25 |
| SE | 0.10 | 0.11 | 0.11 | 0.12 |
| $R^2$ (%) | 55 | 41 | 11 | 10 |
| *P* | <0.001 | <0.001 | 0.036 | 0.045 |
| Residual | | | | |
| Coefficient | 1.74 | 1.56 | 1.11 | 0.51 |
| SE | 0.15 | 0.14 | 0.17 | 0.19 |
| $R^2$ (%) | 79 | 76 | 51 | 16 |
| *P* | <0.001 | <0.001 | <0.001 | 0.009 |

NS = $P > 0.20$.

Table 7. Regression coefficients, standard errors (SE), coefficients of determination ($R^2$ as %), and probability level of simple polynomials describing the influence of litter (independent variable) on forage production, utilization (actual and proportion of total), and residual after grazing (dependent variables) on field H

| | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| Production | | | | |
| Coefficient | 1.08 | 1.36 | −1.62 | −2.26 |
| SE | 1.67 | 0.69 | 2.20 | 3.56 |
| $R^2$ (%) | 2 | 18 | 3 | 2 |
| *P* | NS | 0.06 | NS | NS |
| Utilization | | | | |
| Actual | | | | |
| Coefficient | 0.64 | 2.27 | −1.08 | −3.38 |
| SE | 1.38 | 0.79 | 1.98 | 3.56 |
| $R^2$ (%) | 1 | 31 | 1 | 4 |
| *P* | NS | 0.01 | NS | NS |
| Proportion (% of total available) | | | | |
| Coefficient | −0.98 | 0.06 | −0.94 | −1.01 |
| SE | 0.60 | 0.48 | 1.20 | 0.61 |
| $R^2$ (%) | 13 | 0 | 3 | 12 |
| *P* | 0.12 | NS | NS | 0.12 |
| Residual | | | | |
| Coefficient | 1.43 | 0.80 | 1.19 | 0.98 |
| SE | 0.63 | 0.36 | 0.94 | 0.70 |
| $R^2$ (%) | 22 | 21 | 7 | 9 |
| *P* | 0.04 | 0.04 | NS | 0.18 |

NS = $P>0.20$.

forage after the grazing season was about three times greater than on field H. Cows on field M lost weight, however, after August as a result of a reduction in forage quality.

Forage production differences among topographic zones were distinguished primarily between the upland zones and the subirrigated zone and secondarily between the south aspect and other upland zones. In each comparison, available soil moisture appeared to be the major factor affecting the differences. Soil moisture would be enhanced in the subirrigated zone through the addition of water from runoff or, on the south aspect, through the conservation of water by insulation of the soil surface with litter. Mueggler and Stewart (1981) suggest that soil moisture is the primary factor affecting production differences within as well as between topographic zones. Production was achieved by an extended growing period in the subirrigated zone and by more rapid growth prior to mid-June on the south aspect (Table 4).

The beneficial effects of litter in conserving soil moisture were evident only in years of drought. From 1983 to 1985, each unit of litter was related to approximately one-third unit of additional forage produced (Table 6). However, when rainfall was less limiting, litter had no effect on production.

Litter was important in modifying the effects of drought and maintaining greater stability in forage production. Field M, which had significantly more litter than field H, had a maximum variation of 55% production between the poorest and best production years while field H had a variation of 92% (Table 5). Similarly, within the upland zones of field M, variation on the south slope was 25% while variation on others averaged 73%. Litter was uniformly removed from field H (Table 4) and, consequently, was not a factor affecting production in the upland zones.

Forage utilization varied directly with annual production among topographic zones, except on the south aspect in field M where use was less but production greater than on the east and west aspects (Table 4). The south aspect was also least preferred in early summer and was not substantially different from other upland zones in late summer (Fig. 2).

Cattle utilized most of the available forage (90%) in the subirrigated zone and showed greatest preference for that zone early in the grazing season (Fig. 2) but avoided it, in field H, later in the grazing season. This pattern was also observed by Senft et al. (1985), on shortgrass steppe, who attributed the shift from bottomlands to uplands to abandonment of the cool season grasses which occupied the bottomlands and were preferred early in the year. In our study, species preference may have been a factor determining topographic preference between the upland and subirrigated zones early in the grazing season although the effect could not be quantified since it was confounded with availability, phenology, and quality as influenced by litter. However, the shift in preference to the upland zone later in the grazing season appeared to be related to availability. By the end of the grazing season, residual forage, which is approximately equal to the difference between available and utilized forage (Table 4), on the subirrigated zone was less than one-quarter that of the upland zones in field M. Furthermore, the subirrigated zone in field M had approximately twice the amount of residual forage as in field H. This suggests that a higher stocking rate (field H) was responsible for greater foraging pressure on the subirrigated zone earlier in the grazing season which resulted in avoidance of that zone later in the season.

The presence of litter had a significant impact on the distribution of forage use both within and among upland zones in field M (Table 6). Since cattle will preferentially select forage without litter (Willms et al. 1980), its high abundance on the south aspect would increase avoidance for that zone. Reduced forage production as a consequence of drought, and the concomitant increase of grazing pressure on available forage, resulted in less avoidance of litter from 1983 to 1985 (Table 6) and a substantial reduction of litter by 1986 (Table 5).

The accumulation of litter on the south aspect may be related to earlier growth and senescence in that zone. Early growth would not be an attraction to cattle at the beginning of the grazing season when most pressure is on the subirrigated zone. By the time cattle shift their emphasis to other zones, growth on the south aspect will have become more mature than on alternate zones. This effect, combined with an avoidance of litter, would ensure less utilization of the south aspect. Furthermore, since residual forage is positively related to the presence of litter (Table 6), the effect of litter is perpetuated and amplified when grazing pressure is released in years when forage production is normal.

Forage production and utilization were affected by topographic zone and by the occurrence of litter within the zone. Differences among zones were characterized by greater production and higher use of the subirrigated zone and earlier production in spring on the south aspect. These differences may be exploited, by fencing to control both the temporal and spatial distribution of livestock, to achieve maximum production efficiency. The lowlands produce forage early in spring from grazing-resistant species and should be utilized first while grazing of the upland zones is delayed. Delayed grazing on the upland zone is beneficial to the health of the native grasses which are sensitive to defoliation during the growing season. Among the upland zones, the south aspect should be grazed first because phenological development of the grasses is more advanced. Production efficiency is, therefore, improved by grazing when plants are better able to withstand defoliation and by distributing use more uniformly among zones.

However, within the upland zones, the litter component should be maintained to ensure annual stability in grazing management. Although litter appears to be a wasted resource in the grasslands, this study demonstrated its importance during periods of drought when it enhances production and provides emergency forage to maintain a fixed stocking rate. Field H did not have this buffer and, as a result, both available forage and stocking rate fluctuated widely among years.



## ACKNOWLEDGMENTS

The author gratefully acknowledges the advice of T. Entz and G. Kozub, statisticians with Agriculture Canada Research Station, Lethbridge.

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