VARIATION IN GRASSLAND IN RELATION
TO SLOPE ASPECT IN CENTRAL
SASKATCHEWAN

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VARIATION IN GRASSLAND IN RELATION TO SLOPE ASPECT IN CENTRAL SASKATCHEWAN

INTRODUCTION

Topography, through causing differential insolation has such a marked effect on climate, that to the ancient Greeks exposure climate was the climate (Geiger, 1950). Differences in slope orientation and angle are least important when the sun is vertical, and become increasingly critical with distance from the equator, except at very high latitudes where the component of diffuse radiation is greater than that of solar radiation.

Previous studies in the grassland of central Canada have been mainly concerned with delimiting the norm, that is with those communities which are considered to be growing in average environments. In such environments, microclimate is believed to be producing its fullest effect. Coupland (1950) in his extensive survey of the Mixed Prairie in Saskatchewan states that the summits and hollows were avoided when sampling in a hilly region, and general notes on the effect of slope on the vegetation were deemed sufficient as a preliminary survey. Moss (1944) and Moss and Campbell (1947) commented on the variations in the composition of vegetation on slopes in some regions of Alberta. Again no quantitative data were given.

This investigation was made, therefore, to amplify the general conclusions with objective results obtained by sampling vegetation on slopes of different aspect, the depressions being omitted. Some information as to the microclimate of the areas was also obtained, although this was of only a preliminary nature.

LITERATURE REVIEW

The areas investigated are situated in the Dark Brown Soil Zone adjacent to the Black Soil Zone, where Coupland (1950) suggests the following distribution of species on rolling land: Bouteloua gracilis and Stipa comata on the tops of the knolls, Stipa spartea var. curtiseta and Agropyron dasystachyum on the intermediate slopes, with Festuca scabrella at the lower levels. No mention is made of slope orientation. In Alberta the steeper north-facing slopes in the Dark Brown Soil Zone are said to support mainly Festuca spp., whilst the steeper south-facing slopes in the Black Soil Zone are occupied by a Bouteloua gracilis - Stipa spp. community (Moss, 1944). Thus, the more southerly communities reach their northern limits on the steep south-facing slopes and the tops of knolls, whilst on the north-facing slopes the communities of cool situations extend further south than their range on level areas.

The value of slope was recognized by Alter (1912). He stated that due to the earth's curvature, a slope of 1° to the north has a similar solar climate as that of a level surface 70 miles further north. The relationship was applied to Utah (37°N - 42°N) and Alter did not say whether it would be the same in all latitudes. It does seem logical to suggest that the distance to a level surface with equivalent solar climate from a given angle of slope to the north would decrease towards, and increase away from the equator.

Byram and Jemison (1943) deduced equations for calculation of the intensity of solar radiation as a fraction of the maximum intensity (i.e. the incidence on a horizontal surface at the top of the atmosphere). With these equations they compared the insolation received on north and south exposures of 20, 40, and 100 percent slopes at the winter and summer solstices. On June 21st. there was little difference between the two 20 percent slopes at that latitude (35°N.), but the south-facing 40 and 100 percent slopes received more insolation than those on the north face. On December 21st. the 100 percent northern slope was in complete shade whilst that on the southern aspect received more insolation than the less steep slopes.

An investigation of the effect of slope orientation on climatic factors (chiefly temperature) was made by Aikman (1941) in southern Iowa. He recorded temperatures on the north, south, east and west faces of a conical hill during July 1939. With regard to air temperature, and soil temperature (depth 2 inches) the west slope had the highest average over the period considered. The following are the average air and soil temperatures for the respective faces: (The values are means of readings at two-hour intervals from thermograph charts).

	Air temperature (°F.)	Soil temperature 2 in. depth (°F.)
West:	78.5	85.8
North:	78.0	78.8
East:	76.8	81.2
South:	75.4	80.2

The station on the north face was 60 ft. higher than those on the other faces, and this may contribute to the high average air temperature. Aikman considered that the low temperature on the south slope might be due to the prevention of cold air drainage by a stand of trees situated below the station on this slope. Geiger (1950) states that a northerly slope direction is the coldest, but that (as in Aikman's results) the westerly directions are often warmer than easterly ones, since heat from the morning sun received on the latter is used to evaporate dew. In the afternoon conditions are drier and more heat can go to raising the temperature of the ground and the air above it.

The most extensive consideration of microclimatic variation with topography is that given by Geiger (1950). Besides differences in insolation in which slope orientation is important (as in the examples given above) called by Geiger the day effect, there is also a night effect. This is the effect on cold air drainage of variation in slope elevation and angle. It is independent of slope orientation. That cold air drainage is important was shown by Geiger. A difference in elevation of only a few centimeters was found to result in a great difference in night temperature, and was the probable cause of "frost areas" in pine woods.

Such variations in cold air drainage are probably very important in thermoperiodic phenomena. Went (1944) found that tomato plants made the best growth and gave the best fruit yield when maintained in a fluctuating rather than a constant temperature, a lower temperature during the dark period being beneficial. The night temperature seemed to be the main factor controlling the type of growth. His discussion includes extensive references indicating that thermoperiodicity may be a very general phenomenon in higher plants. Hiesey (1953) and Juhren, Hiesey and Went (1953) have conducted experiments on various species of grasses with controlled temperature, which indicated that not only did flowering depend on night temperature, but also that the tolerance range for the difference between day and night temperatures differed for the species concerned.

Temperature differences result in differences of evaporation and moisture content of the soil and litter, and these therefore will vary according to slope aspect even where there is no variation in precipitation (Byram and Jemison, 1943).

Daubenmire (1947) states that the high humidities found in dense vegetation are porportional to the lowered temperatures and that, therefore, temperature is more important in governing moisture relations than is the loss of water through transpiration. Bartels (1933, as quoted by Geiger, 1950) in comparing evaporation from bare sand, open water, and a close cut sod, concluded that evaporation from the sod was always greater than that from the sand, and especially so during drought, in spite of the higher temperature in the sand. This indicates that transpiration is more important than temperature. However, Bartels was using a close cut sod rather than a dense vegetation, and loss of water could also have been increased by cutting in so far as for a time naked cells would be exposed. Variation in moisture may also arise on a slope due to runoff, the depth of the water table, and the nature of the soil. Duvdevani (1952) working in Israel, has found topography to have a pronounced effect on dew deposition. On one slope there was considerable difference between the dew formed at two stations only 11 meters apart. He considers dew formation and allied condensation of moisture in the soil to be very important in arid areas. High summer temperatures dry the surface soil and cause it to act as a dessicating agent and thus may be of significance in maintaining soil moisture. Although in the present investigation, the soil constituents were not determined, the following table, taken from Mitchell, Moss and Clayton (1944) shows the variation in nitrogen content (in percent) with slope position.

	Knoll	Lower Slope	Depression
Haverhill Loam (Brown)	0.19	0.27	0.37
Weyburn Loam (Dark Brown)	0.25	0.28	0.45
Oxbow Loam (Black)	0.28	0.41	0.55

No mention of orientation is made, but it is probable that the values for north and south facing slopes would be different.

According to Daubenmire (1947) the light aspect of the effect of slope on insolation is probably unimportant, since intensity is unlikely to be limiting, and since variations in quality of light have never been demonstrated to be sufficiently great to be critical in natural environments. Sprague (1956), on the other hand, says that the fact that some species grow best in long wave lengths may help to explain the different behavior of some species and varieties on different slopes. In the present study, no data on light intensity or quality were obtained. However, since the slopes were short and were fairly close together, variation in light quality is probably not significant. Variation in quality would presumably arise from differential screening by dust, water vapour and the amount of atmosphere through which the rays must travel.

These are some of the factors which show microclimatic variation, and by their varied interaction produce differences in the composition of vegetation on slopes. The effect is reciprocal, however, because the vegetation serves to modify the climatic factors. Thus the relationships between the community and its position on the slope becomes very complicated and will only be elucidated with more detailed studies not only of the microclimate but also of the ecosystem, (as this is defined by Tansley, 1935)

GENERAL DESCRIPTION OF THE AREA

The areas selected for study were in the area of Weyburn loam east of Saskatoon. According to Mitchell, Moss and Clayton (1944), Weyburn loam is a medium textured, dark brown soil developed on undifferentiated glacial till. It

Fig. 1. Sketch-map of the area in which the investigation was made. Sutherland is just within the northeast boundary of Saskatoon, the vertical lines on the map running north-south.

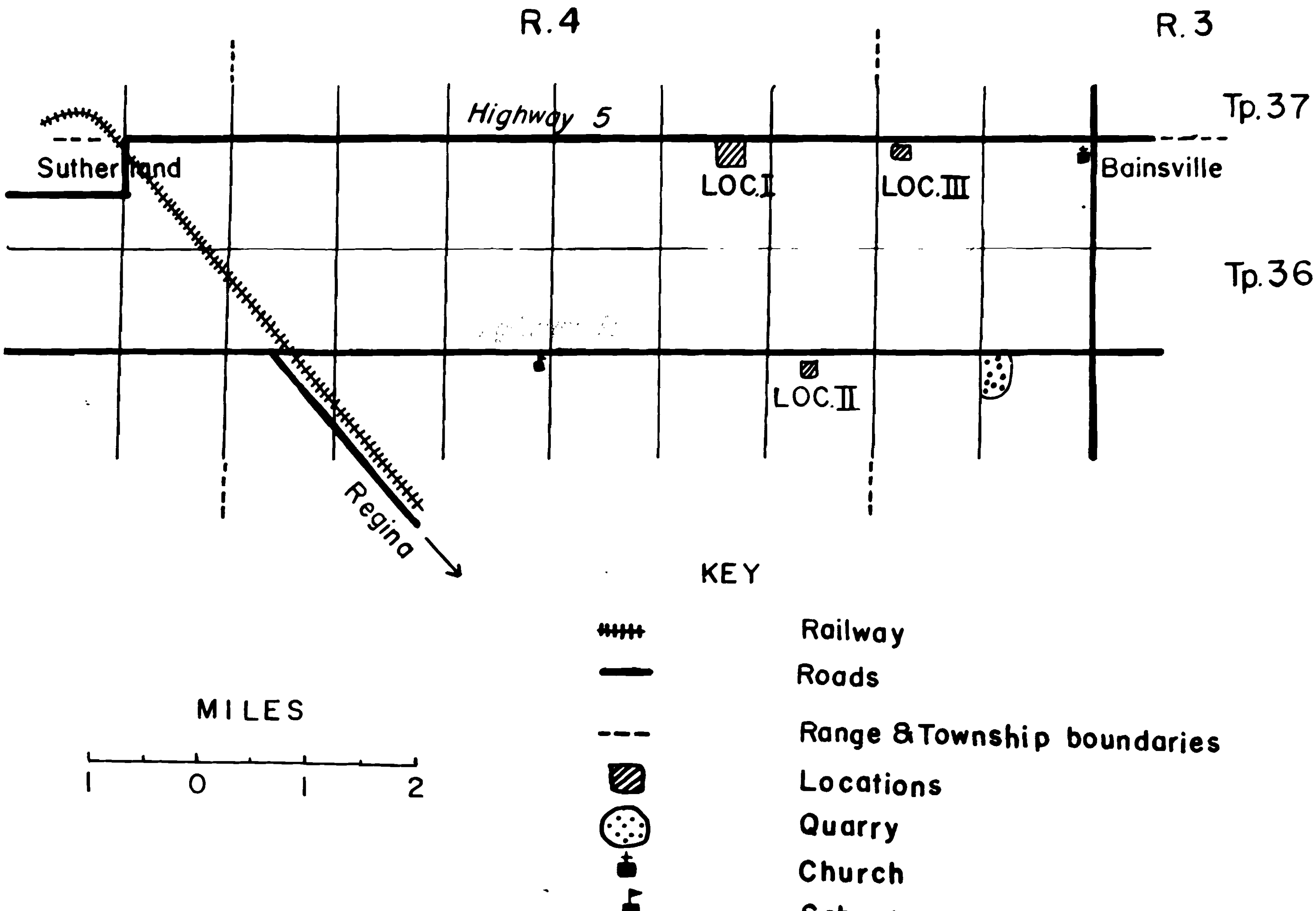

R.4
R.3
Tp.37
Tp.36
Highway 5
Sutherland
Bainsville
LOC.I
LOC.III
LOC.II
Regina
KEY
Railway
Roads
Range & Township boundaries
Locations
Quarry
Church
School
MILES
1
0
1
2

Fig.1

is the most extensive of the dark brown soil types. The area is mapped as gently to moderately rolling. Besides ensuring slopes of different orientation, the latter fact has resulted in the non-cultivation of certain portions of fields due to steepness. Such portions are not grazed during the growing season and support a good growth of relatively unmodified natural grassland. Three such portions were selected for study and were designated as Locations I, II and III. The position of the locations is shown in Fig. 1.

Location I was the main site. It is about 5 miles from Sutherland (the northeast boundary of Saskatoon) along Highway 5, and is in the northern half of Sec. 35, Tp. 36, R. 4. Vegetation data was obtained from four slopes at this site (Slopes B, C, E and F). Temperature readings and soil moisture data were obtained at this site also, Slopes B, C, D and E being sampled. No vegetation data was collected from Slope D since it was immediately adjacent to the plowed land and proved to be much disturbed by blowing soil and by movement of farm machinery. Location II was two miles south of I in Sec. 23, Tp. 36, R. 4. Here there was only one small, north-facing slope (Slope G). Location III was in Sec. 31, Tp. 36, R. 3, that is just over one mile further east than Location I and sampling was from a small east-west ridge. Only vegetation data was obtained from Locations II and III. The orientation of the slopes at the three locations are given in Table I. The directions are related to true north.

Saskatoon lies in the southern part of climatic Region 4 of Central Canada (Kendrew and Currie, 1955). This region stretches eastward from the Rocky Mountain Foothills to the Saskatchewan - Manitoba boundary, the northern limit coinciding with the 60°N. parallel. In Saskatchewan the southern

Table I. Orientation of the slopes sampled.
The compass directions have been corrected to refer to true north, the declination being 23°E.

	Slope	Orientation	
Loc. I	Slope B	199°	S.S.W.
	Slope C	203°	S.S.W.
	Slope F	189°	S.
	Slope D	23°	N.N.E.
	Slope E	8°	N.
Loc. II	Slope G	65°	E.N.E.
Loc. III	Slope H	351°	N.
	Slope J	169°	S.

boundary runs diagonally from the 50°N. parallel in the east to roughly 52° 30' N. in the west. Climatic Region 4 is described by Kendrew and Currie as including "The Forest and Parkland Regions of Alberta and Saskatchewan". It is distinguished from the other regions by topographic and vegetational characteristics, as well as by those of climate.

Weather data used in this discussion were obtained at Saskatoon, and were the closest to the Locations available. Although it is possible for considerable variation, especially in regard to precipitation, to occur within a few miles, the means obtained from Saskatoon probably give a good indication of the climate in the general area. Various climatic factors for the period October 1955 - September 1956 are given in Table II, the normals being included for comparison. The winter of 1955 - 56 will long be remembered for the large amount of snow which accumulated. The accumulation was due to the above normal precipitation for December, February and March, coupled with below normal temperatures, very little thawing occurring. The mean daily maximum temperature followed the same trend as the mean daily temperature, both being below normal from November to April, and above normal in May and June. The mean daily minimum was above normal in January and February but was otherwise like the mean daily, and mean daily maximum temperatures.

Variations from the normals were particularly marked for April. In spite of above normal mean daily sunshine, the temperatures were below normal. If the sky was likewise clear at night there may have been a great loss of heat by lack of a check to outgoing radiation. Total precipitation for the month was much below normal. In part, at least, the abnormalities may be due to prevailing wind being N.W. instead of the normal S.E. Winds from the latter

Table II. Comparison of weather data for each month of the year Oct. 1955 - Sept. 1956 with the normal values.

Climatic Factor	Month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Mean daily temperature °F.												
Normal[1]	39	22	7	-1	3	17	37	51	60	65	62	51
Oct. 1955 - Sept. 1956	41.9	7.0	-1.4	-2.7	2.4	14.0	31.4	53.7	63.5	64.7	62.6	50.7
Mean daily maximum temperature °F.												
Normal[1]	51	31	16	9	13	27	49	64	71	77	75	63
Oct. 1955 - Sept. 1956	52.3	14.0	6.9	3.6	11.4	23.2	41.4	67.1	75.7	76.5	75.2	62.8
Mean daily minimum temperature °F.												
Normal[1]	27	12	-2	-11	-7	6	26	38	48	52	49	38
Oct. 1955 - Sept. 1956	31.4	0.2	-9.6	-8.9	-6.7	4.8	21.5	40.2	51.4	53.0	50.0	38.5
Monthly precipitation (all forms), inches												
Normal[1]	0.8	0.5	0.6	0.8	0.5	0.6	0.7	1.4	2.5	2.4	1.9	1.4
Oct. 1955 - Sept. 1956	0.47	0.50	1.22	0.46	0.77	1.48	0.18	0.36	2.27	2.44	3.13	0.61
Mean daily sunshine, hours												
Normal[2]	5.0	3.5	2.5	2.7	4.6	5.2	7.1	8.4	8.7	10.7	9.2	5.9
Oct. 1955 - Sept. 1956	5.8	3.1	2.7	3.5	4.6	5.3	9.5	9.9	9.4	10.0	10.1	7.0
Prevailing wind direction												
Normal[3]	S.	W & NW	S.	S & W	S	SE	SE	SE	SE	SE	W & NW	W & NW
Oct. 1955 - Sept. 1956	SE	NW	SE	E	W	SE	NW	SE	SW	SE	NW	SE

[1] 38-year mean from Kendrew and Currie (1955).

[2] 20-year mean from the University of Saskatchewan.

[3] 22-year mean from the University of Saskatchewan.

direction bring rain to central Canada from the Gulf of Mexico. Precipitation was also below normal for May and June, but temperatures were above normal. Comparison of the difference between the mean daily maxima and minima for April, May, and June with that between normals for the same months shows that this was less than normal for April and slightly greater in May and June. The values are as follows:

Month	Mean daily Max. - Mean daily Min.	
	Normal	1956
April	23°F	19.9°F
May	26°F	26.9°F
June	23°F	24.3°F

The weather data for the 1956 growing season indicate that it was late in starting, and was unusually dry, in the early months, although the lack of precipitation may have been alleviated to some extent by the previous heavy snowfall. It is interesting that the total precipitation for the period October 1955 - September 1956 (13.89 in.) was below the 38-year normal of 14.5 in. A fairly large proportion of the precipitation fell in August, late in the growing season.

METHODS AND PROCEDURE

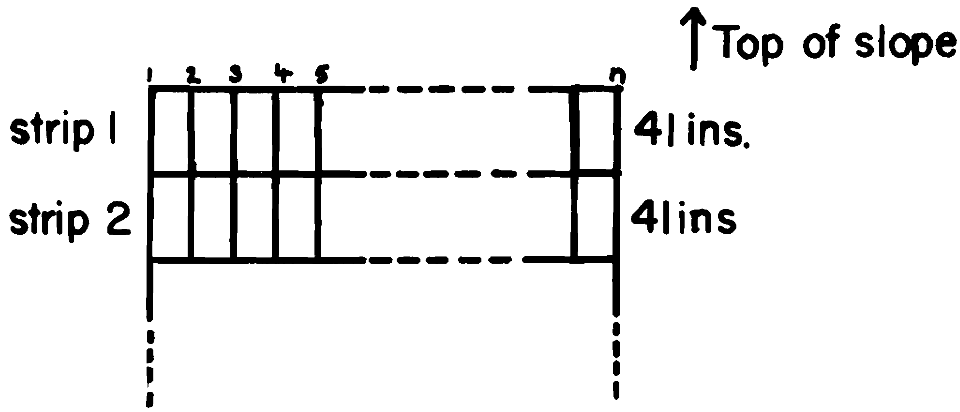
Vegetation Sampling

Two methods were employed to sample the vegetation. The first involved the use of a point frame. This instrument was 41 inches long and included 10 needles at 10 cm. intervals. A detailed description of the point frame and its use is given by Coupland (1950).

To sample the slope the point frame was placed parallel with the slope at regular intervals across a number of adjacent strips. The arrangement of these strips is shown in Fig. 2. On Slopes B and E the frame was set down every 18 in. and 200 points were taken per strip. On the other slopes 100 points only were taken. The number of strips used depended on the length of the slope - thus for Slope B 34 strips were necessary, whilst 10 were sufficient for Slope J. By the use of the above plan of strips, the basal cover of each species per strip could be easily determined, and represented an average of a fairly large portion of the slope at the same elevation. The point method gives good results for grasses and grass-like species and also for mat-forming plants such as Artemisia frigida and mosses. However, due to the low basal area of forbs in general in comparison with their tops, they are generally underestimated by the method (Coupland, 1950). Therefore a quadrat method was used to obtain forb data. For convenience of transport and accuracy in sampling a rigid alloy frame was constructed, measuring 50 x 25 cm. A cross wire divided this into two 25 x 25 cm. areas. The frame was placed on the vegetation and fixed in position by means of metal skewers in the four corners. The number of plants or rooted shoots of each forb species was counted, and the grass and sedge species present were recorded. This is a good method for plants which are clearly separated, but the results become somewhat arbitrary for species such as Antennaria parvifolia and Erigeron glabellus where the shoots form a continuous mat, and the relation of underground parts to shoots is obscure. To relocate the frame two of the pins were removed, the other two serving to fix the new position in the transect. In general two transects were made within the area sampled by the point method on each slope.

Fig. 2. The arrangement of the strips constituting a sampling-area.

a). Bird's-eye view of a Sampling-Area.



(1-n indicate the point-frame positions)

b). Vertical section of a slope.

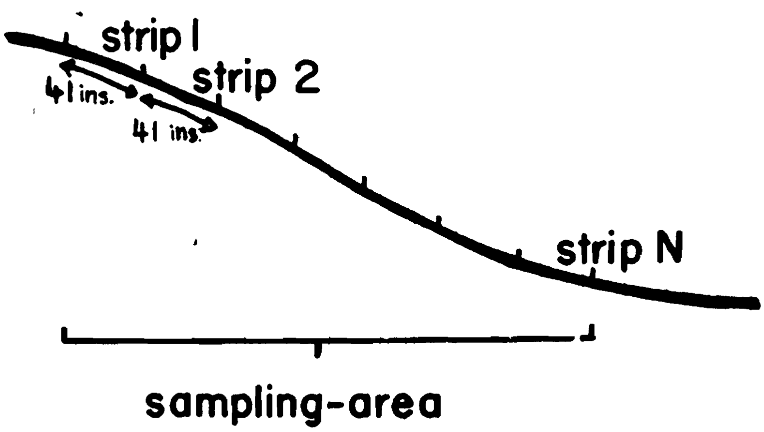


Fig.2

Hitchcock and Chase (1950) has been used as the authority for the names of the grasses, whilst Fernald (1950) was the main reference for the sedges, forbs and shrubs. Rydberg (1932) was used when the latter did not include the species of the area. In one or two cases it was necessary to use the nomenclature of Budd (1952).

Temperature Readings

A Fisher Dial-Type thermometer was used to obtain temperatures. The shaft of the instrument was 8 in. long, the distal 1.75 in. being the sensitive portion. Thus when completely inserted into the ground a reading for the temperature from the 6.25 - 8 in. depth was obtained. This was designated as an average and called the temperature at 7 in. Similar temperature-averages were obtained from the 2 - 4 in. depth (3 in.) and the 0 - 2 in. depth (1 in.). A reading of the air temperature at 3 in. above the ground surface was also taken. A reading was made only after the thermometer had been in position for at least 60 seconds, this being the minimum period of adjustment. In sampling, areas devoid of vegetation were avoided. Three positions were selected for sampling on each of Slopes B, C, D, and E. These were at the top, the middle, and near the base. Readings were made at approximate weekly intervals throughout the period of study, and were, with one or two exceptions, all made before 12 noon Mountain Standard time. The slopes were always sampled in the following order E, B, C, and D, the top position being taken first on each.

Soil Moisture

Soil was collected on Slopes B, C, D and E from the same general areas as were used for temperature readings. Sampling on May 3rd was by means of a soil tube. This was found to be very unsatisfactory due both to the stoniness of the soil and to its dryness. Frequently the soil from the lower depths fell out of the tube before the latter could be drawn to the surface. The hole made by the tube was too small to permit extraction of soil or stones by hand.

Thereafter a post hole borer was used. This had a diameter of about 5 - 6 in. and therefore the hole made was large enough to allow the sample to be obtained by hand if necessary. The main disadvantage of the post hole borer was the large amount of soil obtained. This was far in excess of that needed, and therefore to obtain an average sample of soil it was necessary to mix it in a pan before placing some in an airtight jar. On dry days there was probably considerable evaporation before the complete depth had been sampled.

Soil was obtained from the following depths at each position: 0-6 in. (with the vegetation mat being discarded) 6-12 in., and 12-24 in. These were designated 1, 2 and 3, respectively. Originally it was planned to sample the 24-36 in. depth also, but frequently the sample was either impossible to obtain, or was only from the 24-30 in. depth, since this was the maximum depth at which soil could be obtained by hand. The few results obtained at this depth have therefore been discarded. Samples were taken at approximate fourteen-day intervals and in general all the slopes were sampled within 3 to 4 hours of each other.

The percentage moisture in the soil was determined by a weight method. Two 50 gram samples from each jar were weighed as soon as possible, most of the stones, and decaying organic matter having been removed. The weighed samples were then oven dried at 110° C. for 24 hours. Increased length of drying time after this did not lead to further loss of weight.

The samples were cooled (this generally took about one hour) and then reweighed. The amount of moisture contained by the soil was calculated as follows:

$$\frac{W_1 - W_2}{W_2} \times 100$$

Where W_1 is the weight of the soil before drying

W_2 is the weight of the soil after drying.

Determination of Slope

An Abney Level was used to obtain the percentage slope for each of the sampling areas. Since a single overall reading was considered to be too general for the purpose, the following method was used whereby the percentage slope for each strip (as occurring in the centre of the sampling area) could be obtained.

Two vertical stakes were marked so that when they were inserted into the ground an equal amount protruded. The above-ground part was 55 cm. The two stakes were placed on each side of a strip (that is 41 in. apart). The objective end of the Abney Level was placed on the lower stake and it was then a simple matter to adjust the instrument so that the bubble coincided with the top of the other stake. The small amount of error introduced by the thickness of the Level was ignored. The manoever was repeated until a reading for each strip, plus part of the slope beyond the sampling area had been obtained. To plot the vertical sections of the slopes it was necessary to obtain the angle equivalent to the percent slope for each strip. This was done by calculation of the tangent as follows:

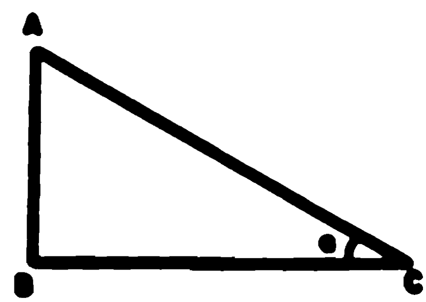


Fig. 3. The triangle ABC used to illustrate the calculation of angle from percent slope.

In Fig. 3.

$$\tan a = \frac{AB}{BC}$$

Now a slope of x percent means that for an increase of 100 units horizontally there is an increase of x units vertically.

Thus $\tan a = \frac{x}{100}$

Therefore each reading was divided by 100 and the angle obtained by the use of Tables of Natural Tangents. The angles were used to plot vertical sections of the slopes. These are illustrated in Figs. 4 and 5, with the zones and the principal grass species in these indicated.

RESULTS

Vegetation

The point sampling results for the grasses have been used to divide each slope into zones. A zone consists of a number of strips in which one or more species is characteristically either more or less abundant than in adjacent strips. Distribution of the grass species was chosen as the basis of the zonation for the following reasons. In the first place the vegetation is part of the grassland complex, and therefore one in which grasses and sedges are conventionally considered to be the dominant life form (Weaver and Clements, 1938). Due to difficulties encountered in the identification of the sedges in this investigation, the group has been considered as a total, and differences in distribution of the species is therefore masked. Also the percentage total sedge cover was generally less than that of the percentage total grass cover (Table III), notable exceptions being the a Zones of Slopes G and J. Grass cover was usually at least one-

Fig. 4. Vertical sections of the north-facing slopes, showing the zones and the major grass species present in these.

Fig. 5. Vertical sections of the south-facing slopes showing the zones and the major grass species present in these.

(The same scale is used in both diagrams.)

Ada = Agropyron dasystachyum; Bgr = Bouteloua gracilis; Fsc = Festuca scabrella; Kcr = Koeleria cristata; Mcu = Muhlenbergia cuspidata; Sco = Stipa comata; Sspv. cu = Stipa spartea var. curtiseta.

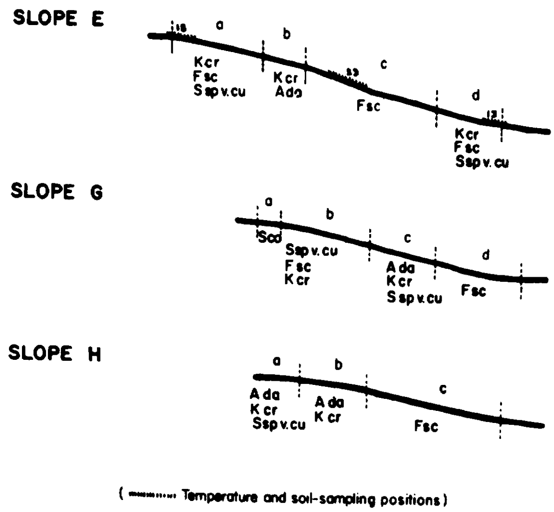

SLOPE E
SLOPE G
SLOPE H
Kcr
Fsc
Sspv.cu
Ada
Sco
(Temperature and soil-sampling positions)

Fig.4

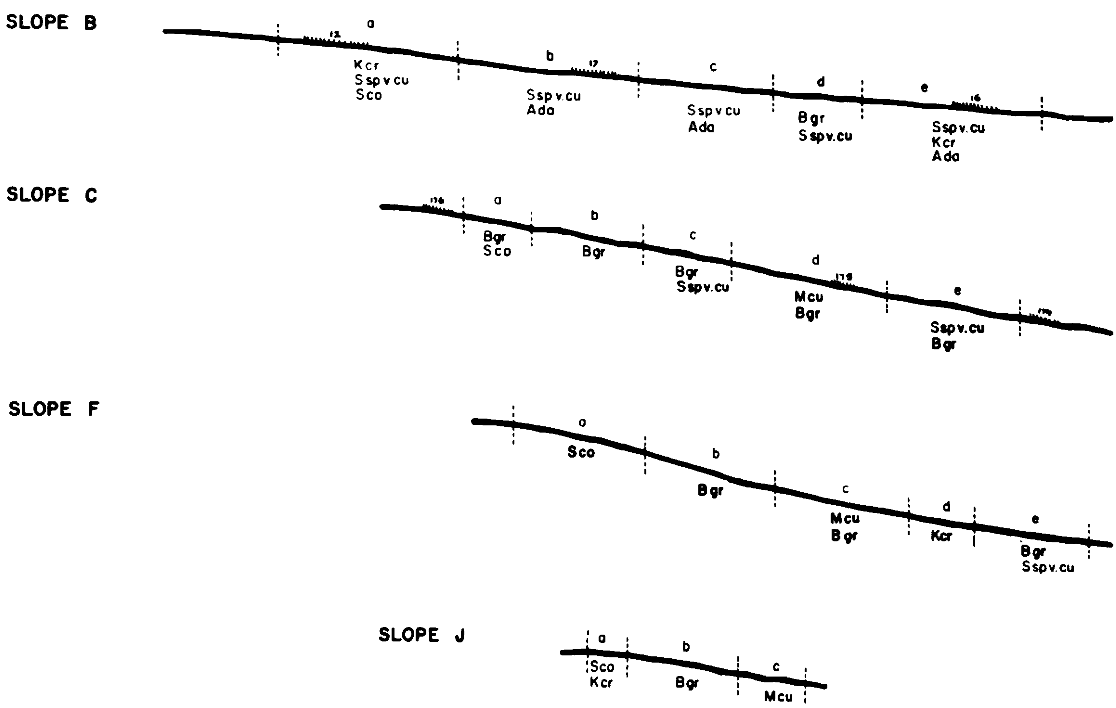
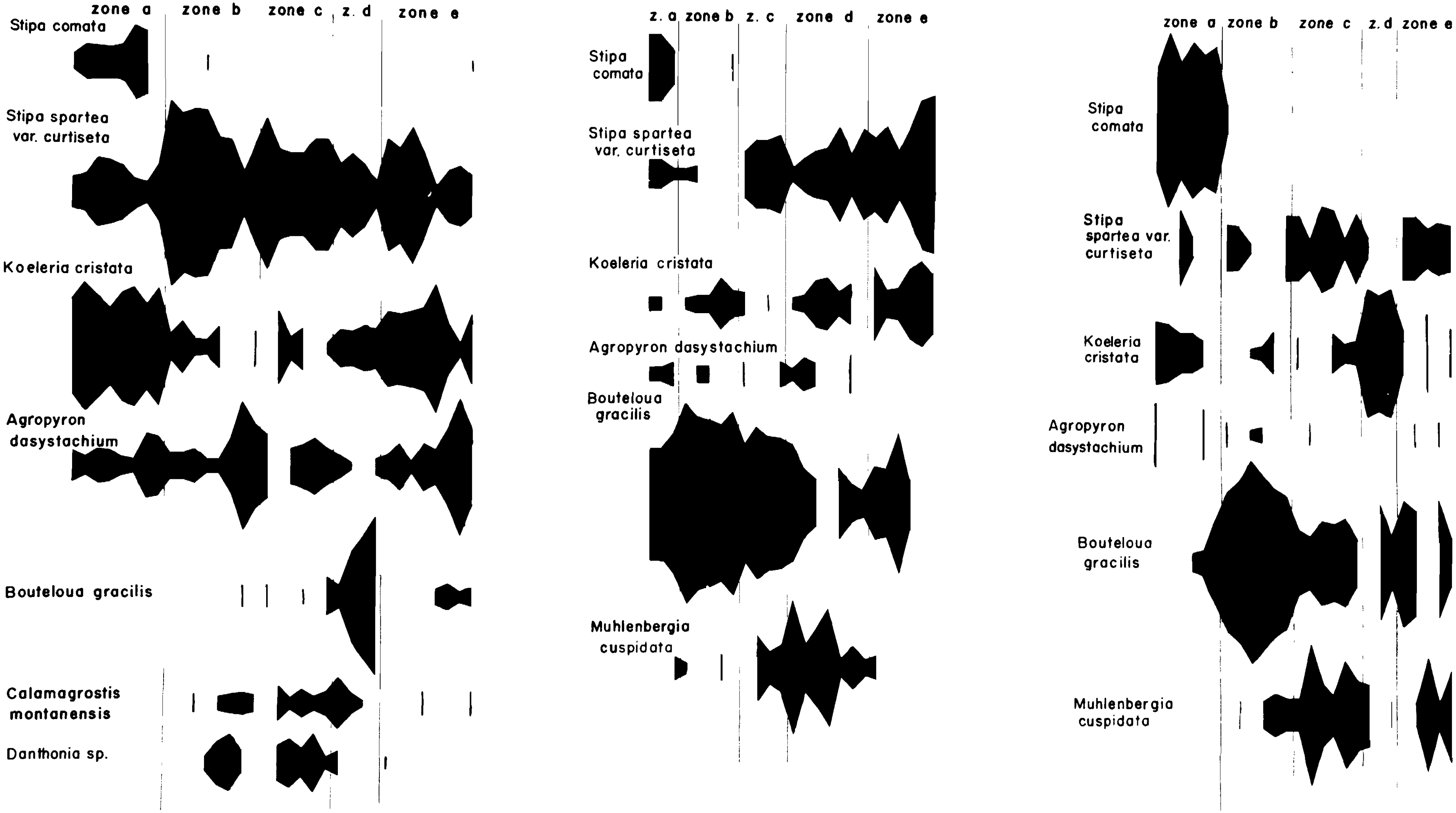

SLOPE B
SLOPE C
SLOPE F
SLOPE J
Kcr
Sspv.cu
Sco
Ada
Bgr
Mcu

Fig.5

Table III. Percentage composition of grasses and sedges in each zone. The mean basal cover for grasses and grasses plus sedges in each zone, expressed as a percentage of the total plant cover (ignoring mosses, lichens and Selaginella densa).

		Zone					Mean for
		a	b	c	d	e	the slope
Slope B.	Grasses	34.76	27.64	37.72	48.29	42.85	38.25
	Grasses and sedges	49.31	50.25	60.84	65.65	66.42	58.49
Slope C.	Grasses	68.39	65.05	64.10	65.92	50.00	62.69
	Grasses and sedges	75.98	72.81	75.64	77.55	73.38	75.07
Slope F.	Grasses	45.29	75.65	59.93	41.28	46.56	53.74
	Grasses and sedges	64.84	84.66	63.93	52.38	70.45	67.25
Slope J.	Grasses	28.20	69.51	38.29			45.33
	Grasses and sedges	71.79	83.54	43.67			66.33
Slope H.	Grasses	34.84	30.67	38.29			34.60
	Grasses and sedges	66.29	49.34	45.22			53.61
Slope E.	Grasses	40.56	45.34	63.29	58.23		51.85
	Grasses and sedges	55.97	65.48	78.87	77.64		69.49
Slope G.	Grasses	25.81	29.59	54.97	62.32		43.17
	Grasses and sedges	64.52	61.22	78.52	76.81		70.26

Fig. 7. Relative distribution of the major grass species on Slopes B, C, and F. The basal cover of the respective species is plotted as a percentage of the total grass cover in each strip. The zones are delimited by the narrow vertical lines, and the topmost strip on each slope is at the extreme left of the diagrams.



Slope B　　Slope C　　Slope F

Fig. 7

third, and sometimes greater than two-thirds that of the higher plants present.

Secondly, the relatively few species of grass compared to the forbs made them more convenient to work with. Another drawback to the use of forb and shrub species as a basis for zonation is that the point data for these groups is not very reliable, and the transect data covers a much smaller horizontal width of the slope. In any case transects were not made on all slopes. Thirdly, when the zones delimited on the basis of grass species distribution were applied to the results for forbs and shrubs, mosses, and lichens, many coincidences of distribution could be seen.

The differences in the distribution of the grass species are shown clearly in Figs. 7 and 10. In order to accent these differences the basal cover of the respective species has been plotted as a percentage of the total grass cover in each strip. (These values are tabulated in the Appendix.)

To facilitate comparison between zones, the mean percentage basal cover for each species was calculated by summation of the values in the component strips of the zone, and division of this figure by the number of strips. The average number of plants or rooted shoots of forbs and shrubs per quadrat, the average percent slope and average angle for each zone were obtained by analagous procedures.

The distribution of species on the various slopes and the division of the latter into zones will now be considered slope by slope.

Slope B.

Slope B is a long gently sloping area, facing S. S. W. It is protected by aspen groves on the west (Fig. 6).

The slope was sampled intensively by the point method. Two hundred

Fig. 6. Slope B from the bottom of the slope. The person is in the mid region of the sampling-area. April, 1957.

points per strip were taken, the frame being set down at 18 in. intervals. As mentioned above, 34 strips were necessary owing to the length of the slope, making a total of 6,800 points. Only one transect was made with the quadrat frame, a total of 136 quadrats being counted in the sampling area. The transect ran from top to bottom of the slope in the center of this area. The distribution of the grass species is shown diagramatically in Fig. 7.

In Table IV the mean percentage basal covers are listed for the species in the zones and Table V gives the average number of rooted shoots per quadrat for each. Comparison of the two tables shows discrepancies in the relative importance of the forb species in the zones. This is probably a result of the difference in width (and thus of habitat conditions sampled) of the transect compared to the sampling area. (Minor irregularities on the slope cause variation in the vegetation at an elevation.) Another source for discrepancy results from the difference in sampling dates - the point data being obtained during early June and the quadrat data during the last week in July.

Zone a.

Koeleria cristata is the most important grass with a mean percentage basal cover of 2.88. However, this zone was remarkable in the occurrence of Stipa comata in spite of its much lower mean (1.06 percent). The most important forbs were Artemisia frigida and Phlox hoodii. The former is the major forb over the whole slope according to both the point and quadrat data (Tables IV and V). Phlox hoodii decreases in importance on the lower part of the slope and is absent from Zone c. According to the quadrat results Linum lewisii was the third important species in Zone a. It was recorded in this zone by the point method also. Carex spp. were less abundant in Zone a than on other parts of the slope, and Selaginella densa

Table IV. Point sampling data from Slope B.
Comparison of the mean percentage basal cover in each zone. The values are based on 200 points per strip. The average percent slope, and average angle for each zone are also given, the zones being ordered a - e from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone				
	a	b	c	d	e
Grasses					
Stipa comata	1.06	0.06			0.06
Stipa spartea var. curtiseta	1.25	3.56	3.50	3.50	2.81
Koeleria cristata	2.88	0.63	0.84	2.38	2.56
Agropyron dasystachyum	0.88	1.25	1.34	0.63	2.25
Bouteloua gracilis		0.06	0.42	6.38	0.38
Muhlenbergia cuspidata	0.06	0.06	0.09	0.13	0.13
Calamagrostis montanensis		0.31	0.67	1.00	0.25
Danthonia sp.		0.50	1.17	0.25	0.06
Festuca scabrella	0.38	0.06	0.13		0.25
Poa secunda					0.06
Other grasses	0.06				0.06
Carex spp.	2.75	5.31	5.00	5.13	4.88
Forbs and shrubs					
Artemisia frigida	5.50	10.38	6.50	8.00	5.31
Phlox hoodii	1.69	0.92	0.25	0.63	
Gutierrezia diversifolia	0.44		0.39		
Solidago missouriensis var. fasciculata	0.31	0.06	0.39		
Chrysopsis villosa	0.31		0.34		0.13
Anemone patens var. wolfgangiana	0.25	0.06	0.25	0.13	0.38
Comandra pallida	0.19		0.09	0.13	0.06
Artemisia camporum	0.19		0.17		
Gaillardia aristata	0.13				
Linum lewisii	0.13				
Senecio purshianus	0.13				
Elaeagnus commutata	0.06				0.44
Geum triflorum	0.06			0.38	0.06
Astragalus flexuosus	0.06	0.13			
Rosa sp.			0.09	0.25	0.31
Astragalus goniatus				0.38	
Artemisia ludoviciana var. gnaphalodes					0.13
Agoseris scorzoneraefolia					0.13
Unidentifiable forbs - seedlings etc.	0.13	0.13		0.25	
Selaginella densa	3.56	1.75	3.17	0.88	0.13
Total grasses	6.57	6.49	8.16	14.27	8.87
Total grasses and sedges	9.32	11.80	13.16	19.40	13.75
Total forbs and shrubs	9.58	11.68	8.47	10.15	6.95
Total mosses	1.93	9.69	9.00	3.19	7.44
Total lichens	11.12	2.25	2.00	0.50	0.19

Table IV continued.

Species	Zone a	b	c	d	e
Total plant cover	35.51	37.17	35.80	34.12	28.46
Cover of grasses, sedges, forbs, and shrubs	18.90	23.48	21.63	29.55	20.70
Number of strips	8	8	6	4	8
Average percent slope	10.43	9.98	9.70	7.55	6.26
Average angle in degrees	5.93	5.75	5.50	4.25	3.43

Table V. Quadrat data from Slope B.
The average number of plants or rooted shoots of each forb and shrub species in a 25 centimeter-square quadrat in each zone.

Species	Zone a	b	c	d	e
Artemisia frigida	6.56	9.53	5.58	11.19	7.37
Phlox hoodii	5.15	1.56			
Linum lewisii	2.50				
Gutierrezia diversifolia	1.31	0.06	0.17		
Anemone patens var. wolfgangiana	0.63	0.22	0.54		0.28
Comandra pallida	0.19	0.22	0.67	0.69	0.81
Rosa sp.	0.06	0.03	1.21	0.50	0.62
Solidago missouriensis var. fasciculata	1.25	0.78	2.79	1.31	1.84
Liatris punctata	0.09	0.16		0.31	0.13
Erigeron glabellus	0.47		2.41		
Artemisia camporum	0.03		0.42		0.03
Lygodesmia juncea	0.03		0.29	0.19	0.03
Astragalus goniatus	0.03	0.34		5.81	
Chrysopsis villosa	0.44				
Geum triflorum		0.03	0.08	0.06	0.03
Androsace sp.		0.06			
Potentilla pensylvanica			0.04	0.19	0.09
Aster commutatus			0.24	1.19	1.47
Thermopsis rhombifolia			0.04		0.06
Gaura coccinea				0.50	0.72
Agoseris scorzoneraefolia				0.06	
Artemisia ludoviciana var. gnaphalodes					1.22
Galium boreale					0.06
Elaeagnus commutata					0.13
Erigeron caespitosus					0.22
Unidentifiable plants and seedlings	1.06	0.22	0.46	1.00	0.22
Total	19.80	13.21	14.94	23.00	15.33
Number of quadrats	32	32	24	16	32

was more abundant. (Moss and lichen distribution is considered below for all slopes together.)

Zone b.

Stipa spartea var. curtiseta was the chief grass. Koeleria cristata was much less abundant than in Zone a, whilst Agropyron dasystachyum had increased in importance - being the main secondary species. Artemisia frigida was very important, and there were few other forbs recorded.

Zone c.

The composition of the grass cover here was very similar to that in Zone b, Stipa spartea var. curtiseta and Agropyron dasystachyum having almost identical basal cover values as in the latter. However, there were increases in less important grasses, such as Bouteloua gracilis, Danthonia sp., and Calamagrostis montanensis. The value for Danthonia sp. was higher in Zone c than elsewhere on the slope. Also, many more forb species were recorded than in Zone b, and according to the quadrat data Solidago missouriensis var. fasciculata and Erigeron glabellus were more important in Zone c than b, (in fact the latter species was not present in Zone b). Erigeron glabellus was not recorded by the point method in Zone c. This may have been due to difference in time of sampling as mentioned above. The total for Carex spp. was very similar in both Zones b and c (and indeed for all the zones except a). Selaginella densa had a greater cover in Zone c than in Zone b.

Zone d.

Bouteloua gracilis was the dominant grass in this zone, with Stipa spartea var. curtiseta the second most abundant species. Koeleria cristata also increased in importance. The basal cover of Muhlenbergia cuspidata showed a slight increase as compared with the values obtained for this species further up the slope. Festuca scabrella did not occur in Zone d. In the point data Phlox hoodii was the second most important forb. However, this species was not recorded in the quadrat data - Astragalus goniatus being important instead.

Zone e.

Stipa spartea var. curtiseta, Koeleria cristata and Agropyron dasystachyum were present in almost equal proportions (respectively, 2.81, 2.56 and 2.25 percent). Stipa comata occurred with a value of 0.06 percent - this is interesting (if it is not due to an error in identification), since Stipa comata was only found on the upper part of the other slopes. As in Zone c, Solidago missouriensis var. fasciculata was, according to the quadrat data, the most important forb after Artemisia frigida, but it was not recorded by the point method. By the former method the following species were peculiar to Zone e: Galium boreale, Artemisia ludoviciana var. gnaphalodes, Elaeagnus commutata and Erigeron caespitosus.

When the average angle, and the average percent slope for each zone were calculated, the zones fell into the following order of steepness from the steepest (a), to the least steep (e): a, b, c, d, e (Table IV). Therefore the zone in which Bouteloua gracilis is maximum (that is Zone b) is the next to least steep.

Slope C.

Slope C is a moderately steep slope facing, like Slope B, S. S. W. It is protected on the north by an aspen grove and terminates in a depression of which Slope D forms the north-facing side. It is low-lying compared to Slope B - as the lower part of the latter slope is on the same level as the top of the former. As can be seen in Fig. 8, taken on April 19th, snow was

Fig. 8. Slope C as seen from the top of Slope D. Snow is lying at the base of Slope C and in the aspen groves. April, 1956.

still lying at the base of the slope. Snow was present in the aspen groves at that date, but was absent from other parts of the Location. The sampling area comprised 25 strips, each strip having 100 points and the frame being 36 in. apart. No quadrat transects were made on Slope C.

The mean basal cover for each species in the zones is tabulated in Table VI, and the distribution of the grass species is shown in Fig. 7.

Zone a.

Bouteloua gracilis and *Stipa comata* were the two most important grasses. There were very few forbs, of which *Artemisia frigida* and *Phlox hoodii* were the chief species.

Zone b.

Stipa comata was very sparse in this zone (and was found no further down the slope), *Bouteloua gracilis* being the sole dominant. *Stipa spartea* var. *curtiseta* had decreased and *Koeleria cristata* increased slightly as compared to Zone a. Zone b is interesting because of the occurrence of *Andropogon scoparius*. This species is characteristic of parts of the True Prairie (where the annual precipitation is higher than in the Mixed Prairie) and is rarely abundant in western Saskatchewan. Moss and Campbell (1947) report that it occurs on denuded slopes with poor soil in southern Alberta, and has probably recently increased by spreading from localized areas onto those previously occupied by fescue, but which have been grazed heavily.

Surprisingly *Artemisia frigida* was very sparse and *Phlox hoodii* was the most important forb. *Selaginella densa* was also very abundant, but *Carex* spp. reached their least cover for the slope.

Zone c.

Although still the species with the highest basal cover, *Bouteloua*

Table VI. Point sampling data from Slope C.
Comparison of the percentage basal cover in each zone. The values are based on 100 points per strip. The average percent slope, and average angle for each zone are also given, the zones being ordered a - e from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone a	Zone b	Zone c	Zone d	Zone e
Grasses					
Stipa comata	4.33	0.20			
Bouteloua gracilis	9.33	10.20	7.25	3.00	3.33
Stipa spartea var. curtiseta	1.67	0.40	3.50	2.71	5.50
Koeleria cristata	0.67	1.20	0.50	1.14	3.00
Agropyron dasystachyum	1.33	0.40	0.50	0.71	
Muhlenbergia cuspidata	0.67	0.60	0.50	3.86	0.83
Andropogon scoparius		0.40			
Festuca scabrella			0.25		0.17
Muhlenbergia squarrosa				0.71	
Carex spp.	2.00	1.60	2.25	2.14	6.00
Forbs and shrubs					
Artemisia frigida	3.00	0.80	2.25	0.71	0.33
Phlox hoodii	2.33	2.60			
Potentilla pensylvanica	0.33				
Rosa sp.	0.33	0.60	0.25	1.57	2.00
Chrysopsis villosa		0.60			
Gaura coccinea		0.40	0.25		
Galium boreale		0.20	0.25	0.71	1.83
Solidago missouriensis var. fasciculata		0.20		0.14	
Elaeagnus commutata		0.20	0.25	0.30	1.00
Astragalus goniatus			0.50		
Antennaria howellii			0.25		
Aster commutatus				0.14	
Artemisia ludoviciana var. gnaphalodes				0.14	
Androsace sp.				0.14	
Cerastium arvense				0.14	0.33
Orthocarpus luteus					0.33
Antennaria parvifolia					0.17
Achillea millefolium					0.17
Symphoricarpos occidentalis					0.67
Unidentifiable forbs - seedlings etc.	0.33		0.75	0.14	
Selaginella densa	2.00	7.40	6.25	0.30	
Total grasses	18.00	13.40	12.50	12.13	12.83
Total grasses and sedges	20.00	15.00	14.75	14.27	18.83
Total forbs and shrubs	6.32	5.60	4.75	4.13	6.83
Total mosses	1.00	0.80	1.25	0.85	4.33
Total lichens	3.00	6.80	4.75	0.57	

Table VI continued.

Species	Zone a	b	c	d	e
Total plant cover	32.32	35.60	31.75	20.12	29.99
Cover of grasses, sedges, forbs and shrubs	26.32	20.60	19.50	18.40	25.66
Number of strips	3	5	4	7	6
Average percent slope	15.40	16.00	17.60	19.71	16.55
Average angle in degrees	8.83	9.10	9.87	11.30	9.50

gracilis was less important than in Zone b, whilst Stipa spartea var. curtiseta showed a marked increase in abundance. In contrast to Zone b, Artemisia frigida had increased in importance and Phlox hoodii was absent. Astragalus goniatus and Antennaria howellii occurred solely in this zone. Selaginella densa had a high cover and that for Carex spp. showed an increase as compared to Zone b.

Zone d.

This could ~~almost~~ be called the 'Muhlenbergia Zone', since Muhlenbergia cuspidata had its maximum basal cover for the slope in the component strips. Bouteloua gracilis and Stipa spartea var. curtiseta were the other important grasses. Selaginella densa was very sparse and did not occur below this zone. Artemisia frigida was, with Galium boreale, a secondary species, Rosa sp. having the highest basal cover.

Zone e.

Stipa spartea var. curtiseta was the most important grass, with Bouteloua gracilis and Koeleria cristata being the secondary species. The latter reached its maximum basal cover for the slope. Agropyron dasystachyum was absent. Artemisia frigida was even more sparse than in Zone d, and the main forb species was Galium boreale. It is interesting that small shrubs were important (Rosa sp. and Elaeagnus commutata; one specimen of Symphoricarpos occidentalis was also recorded from this zone). Carex spp. were abundant.

Table VI gives the average angle and percent slope for the zones. From this table it can be seen that the order of steepness is as follows: d, c, e, b, a. Bouteloua gracilis is most abundant, therefore, in the two least steep zones, although occurring in all of them.

Fig. 9. Slope F from the bottom of the slope. The persons are near the top of the sampling-area. Amelanchier alnifolia forms a small clump in the foreground. April, 1957.

Slope F.

Slope F was less protected than the other two south-facing slopes at Location I and it faced almost due S. instead of S. S. E. (Fig. 9). Twenty-six strips were necessary, and 100 points were taken per strip with the frame being set at 36 in. intervals. Two quadrat-transects were made, approximately 6 ft. and 12 ft. from the western side of the sampling area, there being 104 quadrats in each.

As described above, the data for grass species was used in the division of the slope into zones (Fig. 7). The mean basal cover for the species in the zones, and the mean number of plants or rooted shoots of forbs and shrubs are given in Tables VII and VIII, respectively. The distribution of the species corresponded fairly well with the zonation established. Discrepancies between the two Tables are probably due to difference in method and sampling date. (The point sampling was completed in the middle of July, and the transects during the first week of August.)

Zone a.

Stipa comata was dominant in this zone, the second most important grass being Koeleria cristata. Bouteloua gracilis was relatively sparse. Only four forb species were recorded, of which Artemisia frigida and Phlox hoodii were the most important. (The two other species being Gutierrezia diversifolia and Erigeron caespitosus). Table VIII shows that in the first transect the two secondary forb species differed, whilst in the second there were very many more species in this zone. Carex spp. were fairly abundant, but Selaginella densa was sparse.

Table VII. Point sampling data from Slope F.
Comparison of the basal cover in each zone. The values are based on 100 points per strip. The average percent slope, and average angle are also given, and the zones are ordered a - e from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone				
	a	b	c	d	e
Grasses					
Stipa comata	5.83	0.17			
Stipa spartea var. curtiseta	0.50	1.33	2.17	0.33	2.00
Koeleria cristata	1.67	0.67	0.67	4.67	1.00
Agropyron dasystachyum	0.83	0.50	0.17		0.40
Bouteloua gracilis	0.83	10.17	3.00	1.67	3.40
Muhlenbergia cuspidata		1.17	3.67	1.33	1.40
Poa canbyi			0.17		
Festuca scabrella				0.67	
Other grasses			0.17		
Carex spp.	4.17	1.67	0.67	2.33	4.20
Forbs and shrubs					
Artemisia frigida	5.83	1.50	3.00	7.67	3.40
Phlox hoodii	1.33	0.17			
Gutierrezia diversifolia	0.17		0.17	0.67	
Erigeron caespitosus	0.17	0.17	0.17		
Rosa sp.		0.50	0.17	1.33	0.80
Solidago missouriensis var. fasciculata		0.50	0.33		
Comandra pallida			0.67		0.40
Cerastium arvense			0.67		
Antennaria parvifolia			0.17		
Elaeagnus commutata			0.17		
Artemisia ludoviciana var. gnaphalodes			0.17		
Artemisia camporum			0.17		
Achillea millefolium			0.17		
Galium boreale				0.33	0.60
Selaginella densa	0.67	3.67	2.86	0.67	0.60
Total grasses	9.66	14.01	10.02	8.67	8.20
Total grasses and sedges	13.83	15.68	10.69	11.00	12.40
Total forbs and shrubs	7.50	2.84	6.03	10.00	5.20
Total mosses	1.50	6.17	11.83	5.33	11.20
Total lichens	3.67	2.50	1.50	1.00	0.80
Total plant cover	27.17	30.86	32.91	28.00	30.20
Cover of grasses, sedges, forbs and shrubs	21.33	18.52	16.72	21.00	17.60
Number of strips	6	6	6	3	5
Average percent slope	19.70	26.20	19.30	14.80	13.70
Average angle in degrees	11.08	14.83	10.83	8.50	7.90

Table VIII. Quadrat data from Slope F.

The average number of plants or rooted shoots of each forb and shrub species in a 25 centimeter-quadrat in each zone. a_1 - e_1 represent results from the first transect, and a_2 - e_2 those from the second.

Species	Zone a_1	b_1	c_1	d_1	e_1	a_2	b_2	c_2	d_2	e_2
Artemisia frigida	4.00	1.62	3.46	3.75	7.52	4.41	0.71	3.42	7.50	7.13
Phlox hoodii	1.83	0.54				2.00	0.50			
Solidago missouriensis var. fasciculata	0.17	1.67	2.25	1.25	2.00		0.42	4.04	2.33	1.00
Anemone patens var. wolfgangiana	0.04	0.25				0.24	0.24			
Comandra pallida		0.54	2.66	0.17	0.74	0.17	1.17	1.37	0.67	1.04
Gutierrezia diversifolia			0.29	0.58	0.35	0.33			0.33	0.17
Liatris punctata		3.33	0.13			0.25	0.50	0.08	0.25	
Thermopsis rhombifolia					0.08	0.04				0.13
Petalostemon purpureus		0.08	0.08	0.17		0.04		0.04		
Solidago nemoralis var. decemflora		0.17						0.50		
Rosa sp.		0.54	100	0.66	2.30		0.38	0.42	1.58	1.91
Erigeron caespitosus		2.16	1.46	1.50			2.92			
Antennaria parvifolia		0.13								
Artemisia camporum		0.04	0.67	0.67	0.17		0.04	0.42	0.25	0.04
Galium boreale		0.04	10.70	9.92	4.73		0.04	8.33	1.50	1.91
Cerastium arvense			4.74	8.00	4.56		0.24	5.38	0.83	2.26
Agoseris scorzoneraefolia			0.04	0.08			0.67	0.24		
Achillea millefolium			2.54						0.17	0.04
Chrysopsis villosa			0.25							
Artemisia ludoviciana var. gnaphalodes			0.92	0.75	2.40			1.00		0.87
Campanula rotundifolia					0.13			0.04		
Elaeagnus commutata				0.17						
Potentilla pensylvanica				0.04						
Aster commutatus									1.67	1.09
Erigeron glabellus									0.08	
Unidentifiable plants and seedlings		0.21	1.03	0.59	0.26	0.32	0.17	0.53	0.66	0.60
Total	6.04	11.32	32.22	28.30	25.24	7.80	8.00	25.81	17.82	18.19
Number of quadrats	24	24	24	12	20	24	24	24	12	20

Zone b.

As on Slope C, *Bouteloua gracilis* was the most abundant species in Zone b. *Stipa comata* was extremely rare, whilst *Stipa spartea* var. *curtiseta* had increased as compared to Zone a, and *Muhlenbergia cuspidata* was recorded. *Artemisia frigida* was much less abundant than in Zone a - both according to the point and transect data. In the latter *Erigeron caespitosus* was important in both transects, with *Liatris punctata* important in the first transect and *Comandra pallida* in the second. *Phlox hoodii* was not present below this zone. *Carex* spp. became more sparse than in Zone a, whilst *Selaginella densa* reached its maximum cover for the slope.

Zone c.

Muhlenbergia cuspidata was the principal grass, although *Bouteloua gracilis* was a close second. *Stipa spartea* var. *curtiseta* had a greater basal cover than in Zone b. By the point method many more species were recorded from this zone than from the zones farther up the slope. *Galium boreale* and *Cerastium arvense* were more important than *Artemisia frigida* in both the transects. *Carex* spp. were at their lowest mean basal cover for the slope.

Zone d.

This zone was distinguished by the high basal cover of *Koeleria cristata*, the low values of *Bouteloua gracilis*, and *Stipa spartea* var. *curtiseta*, and by the absence of *Agropyron dasystachyum*. In the point data *Festuca scabrella* was recorded solely in this zone, but according to the transects it did not occur here although it was present on other parts of the slope. *Artemisia frigida* was important according to the point data and in the second transect. The two transects differed in regard to the importance of this species, and also to that of *Solidago missouriensis* var. *fasciculata*, *Galium boreale* and *Cerastium arvense* (Table VIII). *Carex* spp. were more abundant and *Selaginella densa* less abundant in this zone than in Zone c.

Zone e.

Bouteloua gracilis was the most abundant grass, with *Stipa spartea* var. *curtiseta*, and *Muhlenbergia cuspidata* as the secondary species. *Agropyron dasystachyum* was present but was sparse. The number of forb species recorded by the point method was but four - of which *Artemisia frigida* was the most important. In the first transect, *Galium boreale* and *Cerastium arvense* were the chief secondary species. In the second transect the forbs were much more sparse (apart from *Artemisia frigida*) and the secondary species were *Cerastium arvense* and *Rosa* sp. (although these had lower values than in the first transect). *Selaginella* was less important than in Zone d, whilst *Carex* spp. made up a larger part of the cover.

The average angle and average percentage slope are given in Table VII. In order of steepness the zones were as follows: b, a, c, d, e. Thus *Bouteloua gracilis* was most abundant on the steepest part of the slope.

Slope J.

Slope J was the only south-facing slope sampled which was not at Location I. It is one side of a small east-west ridge (Location III). The ridge was protected by a hill to the west and by an aspen grove to the south-west. Like Slope F, Slope J faced almost due S., but it terminated in a slough. This contained water when the site was visited in September, and appeared to have been wet during the whole summer.

No quadrat data was obtained from Slope J, one reason being that most of the forbs were dead by that late date and difficult to identify. (This same fact presumably accounts for the sparsity of forb species at the

Table IX. Point sampling data from Slope J.
Comparison of the mean percentage basal cover in each zone. The values are based on 100 points per strip. The average percent slope and average angle for each zone are also given, the zones being ordered a - c from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone a	Zone b	Zone c
Grasses			
Stipa comata	2.00	0.60	
Stipa spartea var. curtiseta	0.50	0.40	
Koeleria cristata	1.50	0.20	2.00
Agropyron dasystachyum	1.00	1.00	0.33
Bouteloua gracilis		19.60	2.67
Muhlenbergia cuspidata		0.60	6.00
Agropyron smithii	0.50		0.33
Festuca scabrella		0.40	0.33
Poa canbyi			0.33
Carex spp.	8.50	4.60	0.67
Forbs and shrubs			
Artemisia frigida	5.00	3.40	
Gutierrezia diversifolia	0.50		
Antennaria parvifolia		1.80	16.33
Unidentifiable forbs - seedlings etc.		0.20	
Total grasses	5.50	22.80	11.99
Total grasses and sedges	14.00	27.40	12.66
Total forbs and shrubs	5.50	5.40	16.33
Cover of grasses, sedges, forbs and shrubs	19.50	32.80	28.99
Number of strips	2	5	3
Average percent slope	4.75	16.72	13.53
Average angle in degrees	2.75	9.50	8.67

location (Table IX).) The sampling area was continuous with that on the north side of the ridge, which is considered below as Slope H. One hundred points were taken per strip, the frame being set at 18 in. intervals. The mean percentage basal cover for the species in the three zones delimited are given in Table IX, and the grass species in these are shown diagramatically in Fig. 10.

Zone a.

Stipa comata had the highest mean basal cover in this zone, Koeleria cristata being the secondary species. Only two forbs were recorded, these being Artemisia frigida and Gutierrezia diversifolia. The community had similarities to Zone a Slope F, except that Bouteloua gracilis and Phlox hoodii did not occur. Another difference was the remarkably high mean basal cover of Carex spp. (chiefly Carex stenophylla var. enervis) on Slope J. Indeed the mean basal cover of Carex spp. (8.50 percent) was greater than that of the grasses (5.50 percent).

Zone b.

Bouteloua gracilis had a very high value (19.60 percent) in this zone, and all other species were relatively unimportant. Artemisia frigida and Carex spp. had become more sparse than in Zone a, and Antennaria parvifolia was present.

Zone c.

Muhlenbergia cuspidata was the most important grass species - with Bouteloua gracilis and Koeleria cristata being secondary. Artemisia frigida did not occur, and Antennaria parvifolia was the only forb recorded, this being very abundant. Carex spp. were very sparse. The division between the Bouteloua and Muhlenbergia Zones was readily discernable by eye as both

Fig. 10. Relative distribution of the major grass species on Slopes E, G, H, and J. The basal cover of the respective species is plotted as a percentage of the total grass cover in each strip. The zones are delimited by the narrow vertical lines, and the topmost strip on each Slope is at the extreme left of the diagrams.

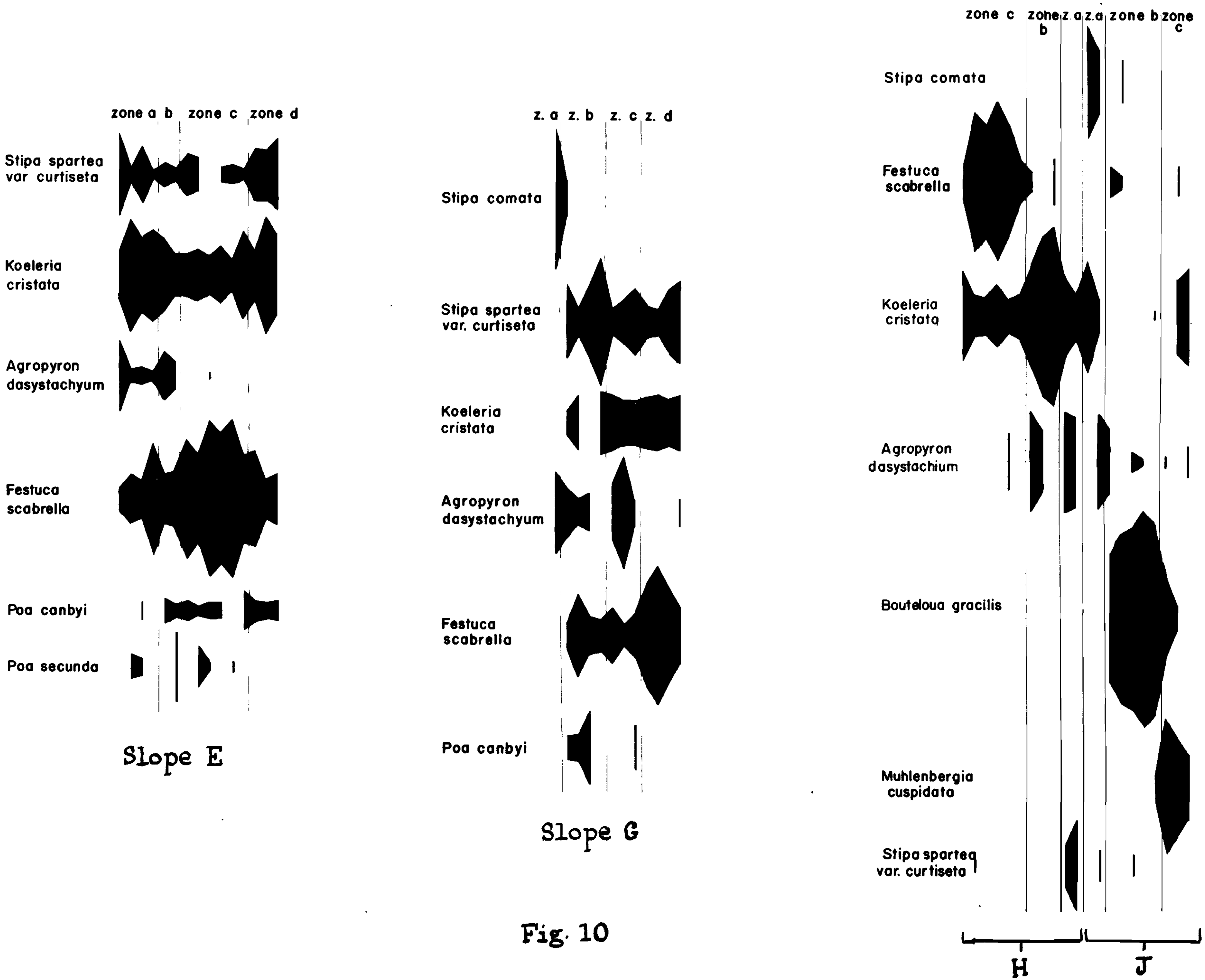

zone a
b
zone c
zone d
Stipa spartea var curtiseta
Koeleria cristata
Agropyron dasystachyum
Festuca scabrella
Poa canbyi
Poa secunda
Slope E
z. a
z. b
z. c
z. d
Stipa comata
Stipa spartea var. curtiseta
Koeleria cristata
Agropyron dasystachyum
Festuca scabrella
Poa canbyi
Slope G
zone c
zone b
z. a
z. a
zone b
zone c
Stipa comata
Festuca scabrella
Koeleria cristata
Agropyron dasystachium
Bouteloua gracilis
Muhlenbergia cuspidata
Stipa spartea var. curtiseta
H
J

Fig. 10

species had produced many infloresences. Table IX shows that Zone b was the steepest of the three - the least percent slope being in Zone a.

Slope H.

Slope H was on the north-facing side of the ridge described above. It is small, moderately steep, faces almost due N., and is unprotected except by the hill to the west. The series of photographs in Fig. 11 are continuous for Slopes H and J, and were taken from the west side of the sampling area. Table X lists the mean percentage basal cover for the species in each zone. It can be seen that the zones are clearly distinguishable.

Zone a.

Here Agropyron dasystachyum was the main grass, although Stipa spartea var. curtiseta and Koeleria cristata were also important. Only two forb species were present, of which Artemisia frigida was the most abundant. Geum triflorum, the second species in Zone a on the south slope was not recorded until Zone b. Carex spp. were important - Carex stenophylla var. enervis being the main species, as in Zone a on the south-facing side of the ridge.

Zone b.

Stipa spartea var. curtiseta was not recorded in this zone. Koeleria cristata had increased in abundance to become the dominant species, whilst Agropyron dasystachyum had decreased as compared to Zone a. Festuca scabrella appeared in this zone. Antennaria parvifolia was the chief forb; Artemisia frigida and Carex spp. being less abundant than in Zone a.

Zone c.

The number of grass and forb species recorded was much greater than further up the slope. Festuca scabrella was the most important grass with

Fig. 11a

Fig. 11b

Fig. 11c

Fig. 11d

Fig. 11. Location III. A series of photographs taken from the west side of the sampling area, September 1956. (The tape is lying in the center of the area.)

a. The Festuca scabrella community at the base of Slope H, the white line marking its upper edge.
b. The Koeleria cristata - Agropyron dasystachyum community, Slope H.
c. The top of the ridge. The white line indicates the junction of Slopes H and J.
d. Slope J. The white line demarcates the Stipa comata (to the left) and Bouteloua gracilis communities.

Table X. Point sampling data from Slope H.
Comparison of the mean percentage basal cover in each zone. The values are based on 100 points per strip. The average percent slope, and average angle for each zone are also given, the zones being ordered a - c from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone a	Zone b	Zone c
Grasses			
Stipa spartea var. curtiseta	2.00		0.17
Koeleria cristata	2.25	4.67	2.67
Agropyron dasystachyum	3.50	2.33	0.17
Festuca scabrella		0.67	4.50
Muhlenbergia cuspidata			1.83
Poa canbyi			0.50
Agropyron smithii			0.33
Agropyron repens			0.33
Carex spp.	7.00	4.67	1.73
Juncus sp.			0.17
Forbs and shrubs			
Artemisia frigida	6.50	3.67	0.33
Antennaria parvifolia	1.00	8.67	13.17
Geum triflorum		0.33	0.17
Solidago missouriensis var. fasciculata			0.50
Erigeron glabellus			0.17
Aster laevis			0.17
Antennaria howellii			0.17
Campanula rotundifolia			0.17
Anemone patens var. wolfgangiana			0.17
Selaginella densa	0.50		
Total grasses	7.75	7.67	10.50
Total grasses, sedges, and rushes	14.75	12.34	12.40
Total forbs and shrubs	7.50	12.67	15.02
Cover of grasses, sedges, rushes, forbs and shrubs	22.25	25.01	27.42
Number of strips	2	3	6
Average percent slope	2.95	12.03	18.87
Average angle in degrees	1.75	6.83	10.67

Koeleria cristata and Muhlenbergia cuspidata as the main secondary species. Antennaria parvifolia was again the most abundant forb. Carex spp. were rare. In this zone Carex stenophylla var. enervis was very sparse - Carex pensylvanica var. digyna being the main sedge. The latter was not recorded on the slope above Zone c. As shown in Table X, Zone c had the greatest average percent slope. Zone a has an average of 2.95 percent - which is less than that for Zone a of Slope J. Fig. 10 indicates the differences between Slopes H and J for the grass species. As far as the forbs are concerned, it can be seen from Tables IX and X that there are many more species on the north than on the south face of the ridge, and that Antennaria parvifolia extends further up the slope on the former. The Carex spp. show, however, similarities of distribution on both aspects. C. stenophylla var. enervis is the sole sedge in the a Zones - that is on top of the ridge. It is very important in this area, but decreases as the slopes steepen and is not found near the base of either aspect. Carex pensylvanica var. digyna appears in Zones Hc and Jc. It is recorded further up the slope on the northern than on the southern side of the ridge. The main difference between the two aspects as regards distribution is the occurrence of an unidentified species (with shaggy scale-leaves) on the mid part of Slope H. One interesting point about Location III was the virtual absence of Selaginella densa. This species was recorded once only, in Zone a, Slope H.

Location III illustrates very well the differences and similarities between slopes of different aspect even when they are situated in close proximity to one another.

Slope E.

Fig. 12 shows the general appearance of Slope E. It is taken looking

Fig. 12

Fig. 13

Fig. 12. Slope E from the west. The sampling-area is indicated by the white lines. April 1957.

Fig. 13. The plant cover in the Festuca Zone (c) on Slope E. The shrub in the right hand corner is Elaeagnus commutata. The rule, only part of which is showing, is 6 in. long. September 1956.

east. The slope is steep, faces N. and is unprotected. The sampling area comprised 15 strips, in each of which 200 points were taken, the frame being set at 18 in. intervals. Two transects were made with the quadrat frame, and were 6 ft. and 12 ft., respectively, from the west side of the sampling area. Sixty quadrats were counted in each.

Tables XI and XII present the results of the two methods of sampling for each of the zones. The diagrams of the grass data used to establish these zones are shown in Fig. 10.

The quadrat data fitted fairly well to Zones a-d, but there were discrepancies between the forb data obtained by the point and quadrat methods. This is particularly obvious in Zones c and d. The point data (Table XI) indicates that the forbs had very low basal covers - thus making up a very small part of the community. Elaeagnus commutata and Anemone patens var. wolfgangiana have the highest value of the various species recorded in Zones c and d, respectively. In Table XII both transects show very low values for Elaeagnus commutata in these zones although Anemone patens var. wolfgangiana is fairly common in the second transect. The most important species are, however, Solidago missouriensis var. fasciculata, Galium boreale and Cerastium arvense. The two latter are species that are liable to be missed by the point-sampling method. Time may be responsible for part of the discrepancy, the slope being point sampled during the last two weeks of June, whilst the transects were made in the middle of August.

Zone a.

Koeleria cristata and Festuca scabella had the highest mean basal covers in this zone. The zone was notable in that Stipa comata was recorded. This species was not found further down the slope. The chief forbs were

Table XI. Point sampling data from Slope E.
Comparison of the mean percentage basal cover in each zone. The values are based on 200 points per strip. The average percent slope and average angle for each zone are also given, and the zones are ordered a - d from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone			
	a	b	c	d
Grasses				
Stipa spartea var. curtiseta	1.50	0.50	1.09	3.50
Koeleria cristata	3.25	3.00	2.67	5.00
Agropyron dasystachyum	1.13	2.00	0.09	
Festuca scabrella	2.38	1.25	6.67	4.17
Poa canbyi	0.13	0.50	0.84	1.17
Poa secunda	0.38	0.63	0.50	
Stipa comata	0.13			
Other grasses				0.17
Carex spp.	3.38	3.50	2.92	4.67
Forbs and shrubs				
Artemisia frigida	3.50	1.00		0.34
Phlox hoodii	2.25	0.25		
Elaeagnus commutata	1.38	1.00	0.92	0.17
Solidago missouriensis var. fasciculata	0.63	0.50	0.17	0.67
Chrysopsis villosa	1.13	0.75	0.25	
Gutierrezia diversifolia	0.38	0.50		0.17
Comandra pallida	0.13			
Gaillardia aristata	0.13			
Geum triflorum		0.50	0.25	0.34
Anemone patens var. wolfgangiana		0.50	0.34	0.84
Senecio purshianus		0.50	0.17	
Artemisia camporum		0.25	0.17	
Cerastium arvense		0.25		
Galium boreale			0.34	0.50
Oxytropis macounii			0.17	
Antennaria howellii			0.25	0.34
Linum lewisii			0.09	
Antennaria parvifolia			0.25	0.50
Astragalus flexuosus				0.33
Achillea millefolium				0.17
Sisyrinchium mucronatum				0.17
Unidentifiable forbs - seedlings etc.	0.13		0.59	0.84
Selaginella densa	1.63	0.25		0.17
Total grasses	8.90	7.88	11.86	14.01
Total grasses and sedges	12.28	11.38	14.78	18.68
Total forbs and shrubs	9.66	6.00	3.96	5.38
Total mosses	3.45	24.00	42.95	48.17

Table XI continued.

Species	Zone a	b	c	d
Total lichins	20.00	5.15	2.33	0.17
Total plant cover	47.02	46.78	64.02	72.57
Cover of grasses, sedges, forbs and shrubs	21.94	17.38	18.74	24.06
Number of strips	4	2	6	3
Average percent slope	18.45	25.15	30.98	19.53
Average angle in degrees	9.25	14.25	17.08	11.00

Table XII. Quadrat data from Slope E.

The average number of plants or rooted shoots of each forb and shrub species in a 25 centimeter-square quadrat in each zone. a_1 - d_1 represent results from the first transect, and a_2 - d_2 those from the second.

Species	Zone a_1	b_1	c_1	d_1	a_2	b_2	c_2	d_2
Artemisia frigida	7.12	5.00	1.00	4.25	5.37	3.87	0.21	2.92
Phlox hoodii	5.75	1.25	0.08		0.44			
Gutierrezia diversifolia	1.94	2.87	0.42		0.94	0.75		1.25
Erigeron caespitosus	2.68	6.50	5.00		11.81	2.25	0.75	
Geum triflorum	0.56	0.50	0.62	0.08	0.06	1.00	1.71	0.67
Commandra pallida	1.00		0.08	0.17	1.06		0.62	
Anemone patens var. wolfgangiana	0.44	1.12	1.46	0.25	0.31	0.75	1.75	2.33
Linum lewisii	0.62	1.00	0.29		0.50	0.25	1.43	0.25
Artemisia camporum	0.06	1.87	2.46	0.08	0.62	0.37	0.71	
Chrysopsis villosa	0.25	1.25	0.62	0.83	2.32	0.75	0.54	0.25
Elaeagnus commutata	0.13	0.13	0.17	0.25	0.19	0.25	0.38	0.17
Solidago missouriensis var. fasciculata	2.00	3.12	3.84	1.75	3.31	9.37	6.28	6.25
Campanula rotundifolia	0.62	0.13	0.58	0.92	0.13	1.62	0.67	
Astragalus flexuosus	0.25							
Cerastium arvense		2.50	3.58	8.00	1.62	2.27	4.04	4.67
Oxytropis macounii		0.50	0.67	0.08	0.50	0.75	0.33	
Achillea millefolium			0.54	1.17		0.13	0.62	1.58
Galium boreale			2.49	4.07		2.27	7.45	5.75
Solidagorigida var. canescens			0.58	0.92			1.35	0.50
Thermopsis rhombifolia			0.25	0.67			0.46	0.58
Aster laevis			0.04	0.17			0.33	0.08
Astragalus goniatus			0.17	0.08			0.25	0.08
Erigeron glabellus			0.04	0.50			0.04	5.00
Sisyrinchium mucronatum			0.13	0.08			0.21	0.58
Solidago nemoralis var. decemflora			1.21	0.17	2.18	1.37		
Senecio purshianus			0.17		0.25		0.04	
Potentilla arguta			0.04	3.84				
Antennaria howellii			1.46				3.00	7.50
Potentilla pensylvanica					1.37	0.62	0.13	

Table XII continued.

Species	Zone							
	a_1	b_1	c_1	d_1	a_2	b_2	c_2	d_2
Androsace sp.					0.25			
Antennaria parvifolia							0.21	
Artemisia ludoviciana var. gnaphalodes								0.21
Unidentifiable forbs, seedlings etc.	0.38	7.50	1.96	1.33	0.50	0.75	0.75	1.08
Total	23.80	35.24	29.95	29.66	33.73	29.39	34.26	41.70
Number of quadrats	16	8	24	12	16	8	24	12

Artemisia frigida and Phlox hoodii. In the point data, a shrub - Elaeagnus commutata, was important, whilst Erigeron caespitosus ranked high in importance in the transects. (In fact it was the most abundant species in this zone in the second transect.) Carex spp. were fairly constant in mean percentage basal cover for all the zones, whilst Selaginella densa was most abundant in Zone a.

Zone b.

Koeleria cristata was again the most abundant grass, but the secondary species in this zone was Agropyron dasystachyum. Stipa spartea var. curtiseta reached its lowest value for the slope. In the point data for forbs a number of species not present in Zone a were recorded. These included Geum triflorum, Cerastium arvense, Anemone patens var. wolfgangiana and Artemisia camporum. Artemisia frigida had become more sparse and was equal in basal cover to Elaeagnus commutata. In the quadrat-transect data the most important species were Solidago missouriensis var. fasciculata, Artemisia frigida, and Erigeron caespitosus.

Zone c.

Festuca scabrella was the dominant grass in this zone. As mentioned above, the forbs had very low values as recorded by the point method. Selaginella densa was absent, but an almost complete cover was formed between the higher plants by a species of Brachythecium. Fig. 13 shows the comparatively lush appearance of the vegetation here - the grasses having much longer leaves than on the other slopes investigated.

Zone d.

Koeleria cristata returned to being the chief grass species. Festuca scabrella was still important and Stipa spartea var. curtiseta increased to become the third most abundant grass. Agropyron dasystachyum was not

Fig. 14. Slope G from the cultivated land to the east. The sampling area is indicated by the white lines. April, 1957.

recorded, whilst Poa canbyi reached its maximum value for the slope. In both sampling methods, Artemisia frigida increased again in Zone d, having been very sparse in Zone c. Distribution of the forbs - comparing Tables XI and XII - has been considered above. Selaginella densa reappeared in this zone. When the average angle and average percent slope had been calculated (Table XI) it was found that Zone c was the steepest, whilst the other zones were, in order of decreasing steepness, as follows - b, d, and a. Thus Festuca scabrella, as on Slope H, is dominant on the steepest part of the slope.

Slope G.

Slope G was short, fairly steep and faced E. N. E. (Fig. 14). It was apparently not protected although there were some bushes about 20 meters to the east. It differed from the other north-facing slopes in that Bouteloua gracilis occurred on the upper parts, although not recorded in the point sampling. Only twelve sampling strips were necessary, each having 100 points and the frame being set at 18 in. intervals. Two quadrat-transects were made. The second of these took one less quadrat (equivalent to 25 cm.) to reach the bottom of the area than the first. Possible this was due to a difference in the curve of the slope in the respective regions. Fig. 10 shows the four zones delimited. The distribution of forbs, both from the point method and quadrat data coincided well with these divisions. Comparison of Tables XIII and XIV shows the similarities and differences between the results for forbs as obtained by the two methods. Error due to time must be negligible since the transects were made immediately after the area was point sampled. The sampling was completed during the last week in August.

Table XIII. Point sampling data from Slope G.
Comparison of the mean percentage basal cover in each zone. The values are based on 100 points per strip. The average percent slope and average angle for each zone are also given, the zones being ordered a - d from the top to the bottom of the slope. The important species in each zone are underlined.

Species	Zone a	Zone b	Zone c	Zone d
Grasses				
Stipa comata	5.00	0.25		
Agropyron dasystachyum	3.00	1.00	2.67	0.25
Stipa spartea var. curtiseta		2.50	2.00	2.50
Koeleria cristata		1.25	2.00	2.50
Festuca scabrella		1.25	1.67	4.75
Poa canbyi		1.00	0.67	
Muhlenbergia cuspidata			0.33	0.25
Poa cusickii				0.25
Danthonia sp.				0.25
Carex spp.	12.00	8.25	4.00	2.50
Forbs and shrubs				
Artemisia frigida	10.00	3.50	1.33	0.50
Phlox hoodii	1.00	2.75	0.33	
Gutierrezia diversifolia		1.50		
Anemone patens var. wolfgangiana		0.75		
Solidago missouriensis var. fasciculata		0.25	0.33	
Vicia sp.		0.25		
Geum triflorum			1.33	0.25
Rosa sp.			0.33	0.25
Cerastium arvense				1.25
Antennaria parvifolia				1.00
Erigeron glabellus				0.25
Achillea millefolium				0.25
Aster laevis				0.25
Selaginella densa	1.00			
Total grasses	8.00	7.25	9.34	10.75
Total grasses and sedges	20.00	15.00	13.34	13.25
Total forbs and shrubs	11.00	9.00	3.65	4.00
Cover of grasses, sedges, forbs and shrubs	31.00	24.50	16.99	17.25
Number of strips	1	4	3	4
Average percent slope	8.50	19.06	24.30	15.50
Average angle in degrees	5.00	10.75	13.50	8.75

Table XIV. Quadrat data from Slope G.

The average number of plants or rooted shoots of each forb and shrub species in a 25 centimeter-square quadrat in each zone. $a_1 - d_1$ represent the results from the first transect, and $a_2 - d_2$ those from the second.

Species	Zone a_1	b_1	c_1	d_1	a_2	b_2	c_2	d_2
Artemisia frigida	7.75	4.94	4.92	2.44	5.25	5.50	1.67	1.13
Anemone patens var. wolfgangiana	1.25	2.62	2.00	0.62	2.50	4.06	1.50	0.73
Phlox hoodii	2.25	2.25	0.17		15.5	6.75		
Arabis sp.	1.00	1.19	0.17		1.25	0.37	0.08	
Gutierrezia diversifolia	0.50	0.62			2.75	1.56		
Vicia sp.	0.25	0.19				0.56		
Solidago missouriensis var. fasciculata		3.50	0.33	0.62		3.69	0.75	0.73
Aster commutatus		0.25	1.50	0.19		0.25	1.75	0.53
Achillea millefolium		0.69	0.25	1.37		0.19	0.83	6.93
Cerastium arvense		0.06	0.08	8.56			0.13	9.80
Comandra pallida		0.50	1.92	0.31			0.33	0.07
Antennaria parvifolia		0.69	0.25			2.12	3.84	4.73
Solidago rigida var. canescens		0.06		1.31			0.13	3.13
Erigeron glabellus		0.69		1.44				1.47
Astragalus goniatus		0.06			0.25	0.44		
Artemisia camporum		1.00		0.06				
Geum triflorum			0.50	0.19	2.00	1.37	3.50	0.07
Rosa sp.			0.17	0.06				
Potentilla pensylvanica		0.19	0.17			0.06	0.08	
Thermopsis rhombifolia		0.06						
Chrysopsis villosa		0.06						
Campanula rotundifolia								0.33
Galium boreale								0.40
Unidentifiable plants and seedlings			0.91	1.00			0.17	0.47
Total	13.00	19.62	13.34	18.17	29.50	26.92	14.76	30.62
Number of quadrats	4	16	12	16	4	16	12	15

Zone a.

In Zone a only two species of grass were recorded: Stipa comata and Agropyron dasystachyum, of which the former was the more abundant. Artemisia frigida was very important as were Carex spp. (In this case C. stenophylla var. enervis was the sole sedge.) In the quadrat sampling, Phlox hoodii was relatively more important than Artemisia frigida, and more forb species were recorded.

Zone b.

Stipa spartea var. curtiseta was the most important of the grass species. The main secondary species were Koeleria cristata and Festuca scabrella. Agropyron dasystachyum was more sparse than in Zone a. The number of forb species recorded from Zone b was much greater than from Zone a. This is true both of the point-sampling and quadrat data (Tables XIII and XIV). According to the latter Solidago missouriensis var. fasciculata was important besides Artemisia frigida and Phlox hoodii. Carex stenophylla var. enervis again contributed substantially to the value for Carex spp. However, two unidentified species were also important in this zone.

Zone c.

Agropyron dasystachyum, Stipa spartea var. curtiseta and Koeleria cristata were more or less equally abundant. Muhlenbergia cuspidata occurred, and Festuca scabrella was slightly more frequent than in Zone b. Few forb species were recorded by the point method, and of these Artemisia frigida and Geum triflorum were the most important. (The latter largely occurred as a seedling stage.) In the second transect Geum triflorum, and Antennaria parvifolia were the major species, whilst in the first transect these were Artemisia frigida, Comandra pallida and Anemone patens var. wolfgangiana.

Carex stenophylla var. *enervis* became scant below Zone b, the main species in Zones c and d being *C. pensylvanica* var. *digyna*.

Zone d.

The dominant grass was *Festuca scabrella*; *Koeleria cristata*, and *Stipa spartea* var. *curtiseta* being the major secondary species. *Agropyron dasystachyum* was very infrequent. *Artemisia frigida* reached its lowest basal cover for the slope, in both the two transects and according to the point-sampling data. *Cerastium arvense* was recorded as the most important forb in all three sets of data. *Antennaria parvifolia* was of significance in the point data and in the second transect, but was not present in the first transect (Tables XIII and XIV). *Carex* spp. reached their minimum value for the slope. Table XIII gives the average angle and percent slope for the four zones. However, these may be in error as the sampling area had not been staked and therefore forthe measurements of percent slope its position had to be determined by memory. It can be seen that the zones in order of steepness are as follows: c, b, d, a. Therefore, unlike the other two north-facing slopes, *Festuca scabrella* is not dominant on the steepest part of the slope.

Cyperaceae.

It will have been observed in the foregoing paragraphs that the sedges present have been mainly considered as a total rather than as separate species. This was due to the errors made (especially at the beginning of the study) in the identification of the different species, most of which did not seem to produce inflorescences. However, it was noted that of the three species which were probably most often correctly recognized - that is, *Carex filifolia*, *C. stenophylla* var. *enervis* and *C. pensylvanica* var. *digyna*, the two former occurred on the upper, and the latter on the lower, parts of the slopes.

This was true of both north- and south- facing slopes.

Mosses and Lichens

Although the data obtained was of a very preliminary nature, it did indicate that the distribution of the mosses and lichens is interesting and would repay further study. Very little, if any, work on the occurrence of mosses and lichens has been done in Saskatchewan.

The results obtained in the point-sampling method are given in the Appendix, moss and lichen species being recorded on Slopes B, C, F and E. The distribution of each species will now be considered.

Bryum sp. The exact species could not be determined from the specimen collected. This moss was, however, the most abundant one on the three south-facing slopes (B, C and F), occurring mainly on the lower parts, that is in Zones b, c, and e on Slope B, Zone e on Slope C, and Zones c and e on Slope F. This moss was also recorded from Slope E, where it occurred at the top of the slope (in Zone a) which is probably the area most like the south slopes with regard to microenvironment.

Weissia controversa. This species was recorded from all four slopes investigated, although only very occasionally from Slope C. On Slope B it was most abundant in Zone c, but was recorded in Zones a and b also. On Slope F it occurred in Zones b, c, d, and e - mainly in the first of these. Thus, on the south slopes *Weissia controversa* seemed to be distributed in much the same way as *Bryum* sp. On the north slope (E), however, *Weissia controversa* was most abundant in Zone b and thus occurred lower down the slope than *Bryum* sp.

Brachythecium sp. As mentioned in the results for Slope E, *Brachythecium* sp. covered very nearly all the available ground surface in

Zone c. It was not recorded from the other slopes. However, additional north-facing slopes would have to be investigated before conclusions regarding its distribution can be drawn. It might, or might not be generally associated with the Festuca scabrella Zone.

Ceratodon purpureus and Amblystegium juratzkanum were also only recorded on Slope E - the former in Zones b, c and d, and the latter in c and d. The values for the two species increased towards the bottom of the slope.

Two very small mosses - Mnium cuspidatum and Campylium hispidulum also occurred on the lower parts of Slope E. They may have been more widespread but could easily have been overlooked due to their small size.

Tortula ruralis was recorded from the mid parts of Slopes F and E.

Tortula mucronifolia was recorded in Zones d and e on Slope F.

Grimmia sp. This species was recorded solely from Slope F: from Zones a, b, c, and d. In b and c it had a very similar distribution to Weissia controversa. Apparently this Grimmia sp. is very unusual and nothing quite like it had been seen by Dr. Crum (personal communication) before.

Bryum argenteum. This species occurred at the top of Slope B, and although not recorded, must also have been present on Slope E as it was identified among a sample of Weissia controversa from the latter. Similarly, another species, Didymodon recurvirostris was found among a sample of Brachythecium from Slope E. These two incidents serve as good examples of the possible occurrence of species which were not recorded as present, and indicates that a very much more thorough and widespread investigation should be made before conclusions are more than very tentatively drawn. The same criticism applies to the results obtained for the lichens. In general lichens were absent on the lower parts of the slopes with their maximum cover values recorded for the strips near the summits.

An unidentifiable Cladonia sp. was the most widespread over the slope-surface. (See the results for Slopes E and F.)

Cladonia pyxidata also occurred on much of each of the slopes investigated, and was the most abundant lichen on Slopes C and E, with maxima in Zones b and a, respectively. It was not recorded from Slope F.

Physcia muscigena was present on each of the four slopes, being most abundant in the a Zones (except on Slope C).

The above were the most widely distributed species, but several others were recorded from various parts of the different slopes (see Appendix). These included (slopes in brackets) Diplochistes scruposus (C); Dermatocarpon hepaticum (C, F, and B); Peltigera canina var. rufescens (B, C, and E); Parmelia chlorochroa (B and F); Lecidea luridella (B and F); Lecidea decipiens (B); Ochrolechia frigida (F); and Candelariella dispersa (F).

In contrast to the distribution of the mosses, very few lichen species were recorded from the north slope (E) and the number was much larger on Slopes B and F. It should be mentioned that the lichens and mosses recorded were growing on the surface of the ground to a very large extent. (There were possibly one or two occasions in which a lichen was found on a stone or on a piece of decaying vegetation.)

Temperature

The three sampling positions on each slope were numbered as follows for convenient identification:-

Position on Slope	Slope B	Slope C	Slope E	Slope D.
Top	12	176	18	171
Mid	17	175	23	172
Base	16	174	13	173

The average temperatures throughout the period of study for each position are given in Table XV. The data from which these values were calculated is tabulated in the Appendix. It can be seen that the average temperatures differ according to depth of sampling, position, and the slope concerned. However, the differences were not constant, and in some cases were reversed. (This is shown by the data in the Appendix.) In order therefore, to determine whether the differences were significant, the data was treated statistically. For this the paired t-test method was used. Use of this method was considered valid since the temperatures obtained on the same day could be paired. The results of the t-tests are given in Table XVI. In certain cases, as for instance on most of Slope C, the differences between the three positions were sufficiently large and constant as to make t-tests unnecessary. Where this is so the symbol t* has been used. In the Tables the asterisk indicates a significant result.

Slope B.

At the 1 in. and 3 in. depths, the mid (17) and base (16) positions were warmer than the top (12), whilst at 7 in. and 3 in., 17 was the warmest position on the slope. In summary it may be said that 12 is the coolest position and 17 the warmest. This relationship supports the theory that due to its angle to the rays of the sun, the steeper parts of a south-facing slope may be warmer than the less steep top and bottom parts. (This was discussed in the literature review.) The temperature of the soil may also be influenced by the nature of the plant cover, by wind, and by moisture content (since water has a greater specific heat than air, a damp soil will be cooler than a dry one). The plant cover affects the temperature of the soil through reflection and through the trapping of heat (of both in-coming and out-going radiation) between the leaves (Geiger, 1950). Comparison of

Table XV. Average temperature (°F.) throughout the period of investigation.

Depth of Sampling	Slope B			Slope C			Slope E			Slope D		
	12	17	16	176	175	174	18	23	13	171	172	173
+3"	66.6	67.6	69.3	69.1	69.6	70.1	66.3	65.7	65.7	69.2	68.2	69.6
1"	64.5	66.3	66.6	71.9	64.3	62.2	62.6	58.9	60.5	69.2	67.1	68.7
3"	56.7	58.5	58.2	61.3	57.1	54.8	55.0	52.9	52.8	58.1	56.9	58.0
7"	55.1	56.5	55.7	57.6	54.9	53.4	52.6	51.0	51.4	54.6	53.6	55.5

Table XVI. Comparison of the temperatures at the various positions on the respective slopes. The values of **t** obtained by paired t-tests are given. (In each comparison, the apparently warmer position is listed on the left.

Depth of Sampling	Slope B		t	Slope C		t	Slope E		t	Slope D		t
1"	17	12	2.945*	176	175	t *	18	23	4.944*			
	17	16	0.594	176	174	t *	18	13	2.611*			
	16	12	2.278*	175	174	t *	13	23	2.515*			
3"	17	12	8.525*	176	175	4.944*	18	23	4.216*			
	17	16	2.709*	176	174	t *	18	13	4.628*			
	16	12	2.424*	175	174	t *	23	13	0.247			
7"	17	12	7.205*	176	175	3.776*	18	23	3.778*	171	172	1.668
	17	16	11.514*	176	174	8.247*	18	13	3.470*	173	171	0.3684
	12	16	0.5767	175	174	12.258*	13	23	0.196	173	172	1.320

* Indicates a significant result.

t* Indicates that the difference was sufficiently obvious to render a t-test unecessary.

Figs. 15 and 16 show that the type of vegetative cover was different at the top of the slope from the mid and base regions. In the former, the tufts of grass are seen to be scattered, with comparatively little top growth. The vertical height of the vegetation is less than further down the slope. Artemisia frigida, Phlox hoodii, Selaginella densa and lichens form a cover between the grasses. Possibly a sparse cover with low vertical height allows a greater loss of heat at night through radiation, than does a denser one.

Mäde (1940, as cited by Geiger, 1950) states that a fresh wind lowers temperature by removing excess heat through increasing convection. Although no measurements were made it does seem plausible that wind is greatest at the top of a slope. Vegetation height is important since it is well known that plant cover reduces wind velocity very markedly. This reduction would be less in a low vegetation such as found at the top of, than in the denser growth further down, the slope.

Slope E.

Theoretically, the greater the steepness of a north-facing slope, the lower the insolation and therefore the lower the temperature. Byram and Jemison's (1943) results give experimental support for this, and the results given in Table XVI indicate that the relation holds true for Slope E. The top position (18) is significantly warmer than the mid (23) and base(13) positions at all three depths. At 1 in. 13 is warmer than 23, but at 3 in. and 7 in. the difference between the two positions is not significant. In this connection, the averages for Slope D indicate that the mid position (172) is the coolest, although this is not significant at the 7 in. depth. Further t-tests were not made on Slope D, since (as explained above) no data on vegetation was obtained from it.

Fig. 15. The plant cover at the top (Zone a) of Slope B. September 1956.

Fig. 16. The plant cover at the bottom (Zone e) of Slope B. Note the much denser top growth of the grass here as compared to Zone a in Fig. 15.

Fig. 15

Fig. 16

Slope C.

The top position (176) was clearly the warmest at all depths as regards soil temperatures, and the t-tests showed that 174 was the coolest position. This is contrary to the results obtained for the other south-facing slope (B). Slope C was also interesting for the fact that whereas the average air temperature increased from positions 176 to 174, the average temperature in the first 2 in. of soil decreased (Table XV). This situation may be due to the trapping of hot air amongst the dense plant cover at positions 175 and 174, and also to the probable decrease in wind velocity, 174 in particular being very sheltered. The low temperature of the soil on the other hand probably results from its high moisture content (see below under Soil Moisture). Position 176 was the only one in the area investigated in which the average temperature of the first 2 in. of soil was greater than that of the air. The vegetation was very sparse in the region investigated and thus hot air could easily be removed. Also the ground was very stony and it was frequently noted from several positions that the temperature of the soil immediately above a stone was higher than that of soil at the same depth not underlain by stones.

Table XVII gives the results of t-tests comparing data from Slope B with that from Slope E. Paired t-tests were again used, although due to the 30 minutes or so difference in sampling time it may not be valid to pair the readings for the same date, since Slope B always had an extra 30 min. insolation. The temperatures at the 1 in. and 7 in. depths were compared for similar positions on each of the slopes. The results indicate that Slope B was significantly warmer than Slope E at every position at the 7 in. depth and at all but the top positions (12 and 18) at the 1 in. depth. This may indicate that the amount of insolation received at positions 12 and 18 is

Table XVII. Comparison of temperatures on Slopes B and E, using paired t-tests.

Depth	Position	$\bar{X}$	t
1"	12	64.5	1.895
	18	62.6	
1"	17	66.3	t *
	23	58.9	
1"	16	66.6	5.141*
	13	60.5	
7"	12	55.1	6.217*
	18	52.6	
7"	17	56.5	t *
	23	51.0	
7"	16	55.7	t *
	13	51.44	

Table XVIII. Standard deviations (s) for soil moisture results.

Position	Depth	s	Position	Depth	s	Position	Depth	s
121	1	4.03	17	1	4.08	16	1	4.28
176	1	4.004	175	1	4.27	174	1	8.101
18	1	3.74	23	1	2.05	13	1	6.28
171	1	4.79	172	1	5.75	173	1	4.87
12	2	2.49	17	2	3.03	16	2	2.04
176	2	3.53	175	2	2.77	174	2	6.04
18	2	3.28	23	2	2.42	13	2	3.43
171	2	3.86	172	2	2.82	173	2	3.08
12	3	1.53	17	3	1.24	16	3	1.47
176	3	3.14	175	3	1.85	174	3	3.55
18	3	1.37	23	3	2.27	13	3	2.27
171	3	2.81	172	3	1.16	173	3	1.76

very similar up to the time of reading. The difference at the 7 in. depth may therefore result from difference in soil characteristics, and the affect of the vegetation on out-going radiation. On the other hand, position 12 may receive a greater amount of insolation during the rest of the day than does 18, and this would result in a greater temperature at 7 in.

No t-tests have been made on the data for the air temperatures. The main reason for this is that the air temperatures were very variable and were even affected by the sun becoming clouded over for a few minutes (in spite of the thermometer being shaded whilst the reading was being made). Also they were considered as probably less important than the soil temperatures in comparing vegetation.

Soil Moisture

Soil samples were collected as described above on the following dates: May 3rd and 23rd, June 12th, July 9th and 23rd, August 6th and 21st, and Oct. 2nd. The results, as percentage moisture in the soil are given in the Appendix. The same positions on the slopes as coded under Temperature were used.

The results indicate the great variation that occurred not only from date to date but from place to place. Due to the infrequency of sampling, these variations cannot be seen to follow any sequence. They were probably in part due to difference in wind direction during various rainstorms, to variation in the time elapsing between rainstorms and sampling (so that the extent of runoff would have varied) and the drying effect of the prevailing wind between the times of sampling. Another source of variation may be due to drying varying with the moisture level of the soil as found by Carlson, Reinhart and Horton (1956) in Mississippi. They state that drying has a characteristic curve for each season, and that both accretion and depletion are affected by differences in soil, topography and vegetation.

Table XVIII is a summary of the variation at each position. Standard Deviation is a good statistic for representing variation as (unlike Range) it considers all values. It can be seen that in general the variation decreased with increasing depth from the surface. This is to be expected since evaporation is of little importance in reducing soil moisture below a depth of 20-30 cm from the surface (i.e. below 8 in. - 12 in.) according to Veihmeyer (1938) (in Daubenmire, 1947). Carlson, Reinhart and Horton (1956) found that the 0-6 in. layer was wetted more frequently than the 6-12 in. layer (since the lighter showers did not penetrate that deeply into the soil). In connection with the Standard Deviations the high values at 174 should be noted even though this was the position which generally had the highest moisture content. Position 23 on the other hand, was one of the driest, and yet had comparatively low values, especially at the 0-6 in. (1) depth.

In order to compare the various positions on the slopes and also one slope with another the data were analysed by the t-test method. In general the paired t-test method was used but owing to there being two samples missing at the 12 - 24 in. depth at 18, the unpaired method was used where this position was involved. The results of t-tests for Slopes B and E are given in Tables XIX and XX. In comparing the two slopes (Table XX) the data for the 0-6 in. and 6-12 in. depths were treated together as 0-12 in. It is interesting that neither at this depth, nor at 12-24 in. were the two slopes significantly different.

(The 0-6 in. depth was not considered alone when comparisons were made between the different positions on the same slope (Table XIX) due to the possibilities for variation at this depth discussed above.)

Table XIX. Results of t-tests used to compare soil moisture. In each case the position which was apparently the wettest was written on the left.

Sampling Depth	Slope B		t	Slope E		t
6 - 12" (2)	17	12	0.7529	18	23	0.965
	17	16	1.559	13	23	1.661
	12	16	0.615	13	18	0.439
12 - 24" (3)	17	12	2.331	23	18+	1.519
	17	16	4.074*	23	13	4.365*
	12	16	3.814*	18	13+	0.129

* Indicates a significant result.
\+ The unpaired t-test method was used.

Table XX. Results of t-test comparing soil moisture on Slopes B and E.

Depth compared	Position compared		t
0 - 12"	12	18+	0.738
	17	23	1.5709
	13	16	1.9533
12 - 24"	12	18+	1.607
	17	23	1.045
	13	16	0.687

* The unpaired t-test method was used.

The differences at the 0-12 in. depth were not significant for either slope although at the 12-24 in. depths position 16 (at the base of Slope B) was found to be significantly drier than either the mid or top positions, whilst the two latter were not significantly different. At this depth on Slope E, 23 (the mid position) was significantly wetter than 13 (at the base of the slope). One drawback to these comparisons is that the rooting depth of the various species in each of the areas was not determined. The depth of root absorption could be expected to vary with the different parts of the slope due to effects of topography on soil depth and distribution of species. Thus, one depth at a particular position could seem abnormally dry when compared to similar depths on the same or other slopes.

However, the results do indicate that there was no significant accretion of moisture at the base of either Slope B or Slope E due to runoff from regions further up the slope at the depths sampled. It is perhaps worth pointing out, that even though the differences were not significant, there is an indication that Slope B, which faces south, has more total moisture than the north-facing Slope E (Table XX). Possibly this arises from the fact that the primary rain carrying wind is from the S.E. However, much of the rain during the growing season comes from thunder showers in which the rain comes down more or less vertically. On the other hand, this situation may have resulted from the difference in angle of the two slopes. Slope B was a very gentle slope on which runoff would be slight compared to that on Slope E.

DISCUSSION

1. Zonation patterns, and the relation of the zone-communities to other grasslands described in Western Canada.

A comparison of the zonation of species on the seven slopes investigated reveals similarities and differences between them, both in regard to the community composition, and the relation of one community to another. The north-facing and south-facing slopes are clearly distinguishable, the former being characterised by a zone in which Festuca scabrella is dominant, and by the absence of zones in which either Bouteloua gracilis or Muhlenbergia cuspidata is important.

On the south-facing slopes, which will be considered first, the a Zones were either dominated by Stipa comata (Slope F and Slope J) or this species was a very important part of the community. The a Zone on each slope was generally in the region in which the slope began to level off towards the top of the knoll, and Stipa comata was rarely found on lower parts of the slope. On Slope C Bouteloua gracilis had a mean basal cover in Zone a of about twice that of Stipa comata. However, Coupland (1950) counted Stipa comata as a codominant when its basal cover was one-third that of Bouteloua gracilis, owing to its greater stature. In the community in Zone a Slope C Artemisia frigida and Phlox hoodii were the most important forbs. Their basal cover was greater than the values recorded in the Bouteloua-Stipa faciation by Coupland (1950), but the two communities are otherwise very similar. Coupland states that the Bouteloua-Stipa faciation is characteristic of undifferentiated glacial till in the drier part of the Brown Soil Zone, and mentions that it occurs on the tops of knolls in the moister parts of this zone. The temperature and moisture data obtained from the top of Slope C (Position 176) indicate that it is very hot and dry. Koeleria cristata was the secondary species in Zone a on Slope J, but was more important than Stipa comata in this zone on Slope B. Bouteloua gracilis was not present in the a Zones of these two slopes.

Slope B was rather different from the other three south-facing slopes and therefore discussion of its zone-communities will be deferred.

The b Zones of Slopes C, F, and J supported communities in which Bouteloua gracilis was the sole dominant. Very low basal cover values were recorded for secondary grasses and for forbs. It is interesting that in spite of the low basal cover values the actual number of forb species was greater than in the a Zones. Artemisia frigida was the most important of the forbs except on Slope C. Coupland (1950) and Moss (1955) mention respectively, that in dry situations in the Bouteloua-Stipa faciation in Saskatchewan, and the Stipa comata-Bouteloua gracilis association in Alberta, a consocies of Bouteloua gracilis may result from overgrazing. It seems rather unlikely that overgrazing is a cause of the Bouteloua Zones in the areas investigated in this study, since grazing is slight, and since Stipa comata is abundant a little further up the slope.

On Slopes J and F Muhlenbergia cuspidata dominated the community of the zones immediately below the Bouteloua Zone. On Slope C a community in which Bouteloua gracilis and Stipa spartea var. curtiseta were the major species occurred between the Bouteloua and Muhlenbergia Zones. The main secondary species in the Muhlenbergia Zones was Bouteloua gracilis. Stipa spartea var. curtiseta was third in importance on Slopes C and F, and Koeleria cristata on Slope J. Comparison of Tables VI, VII and IX shows that the most important forbs varied from one to the other. Coupland (1950) states that Muhlenbergia cuspidata is relatively unimportant except as part of the Agropyron - Muhlenbergia facies on eroded hill slopes. Agropyron spp. were not important in the Muhlenbergia Zones in the three locations studied.

However Coupland admits that only general conclusions can be drawn as to the Agropyron - Muhlenbergia facies since only one such site was sampled in his study. Erosion was not apparent in the Muhlenbergia Zones. However, if erosion is not too rapid the A Horizon is replenished by constant incorporation of material from the B Horizon, and thus a good supply of nutrient materials is ensured. An eroded area may therefore sometimes support a surprisingly rich flora. Good supplies of nutrients may also result from flushing (or washing down) of materials from the above slopes. Possibly Muhlenbergia cuspidata has a high nutrient requirement which is satisfied in one or both of these ways. It could be, on the other hand, that M. cuspidata grows in the areas of deposition of eroded material where other species are prevented from growing. These are no more than very tentative suggestions and may lie far from the truth. The Muhlenbergia Zone was at the base of the sampling area on Slope J, immediately above the vegetation fringing the slough. Slope F had two zones below the Muhlenbergia Zone. These were Zone d in which Koeleria cristata was dominant, and Zone e in which Bouteloua gracilis and Stipa spartea var. curtiseta were the principal species. Only one zone occurred in this position on Slope C and was occupied by a very similar community as that in Zone e on Slope F, except that Stipa spartea var. curtiseta had a greater mean basal cover than Bouteloua gracilis.

Slope B differed from the other south-facing slopes in that it lacked Bouteloua and Muhlenbergia Zones. The latter was not very important on the slope although it did increase slightly in Zones d and e that is, towards the bottom of the slope. Bouteloua gracilis was the most important species in Zone d, but in so far as Stipa spartea var. curtiseta had a mean basal cover of about half that of Bouteloua, the zone was more like the Bouteloua - Stipa community of Zone c Slope C, than the typical Bouteloua dominated b Zones. Stipa spartea var. curtiseta was the most important species in Zones b, c, and e on Slope B. Bouteloua gracilis was relatively unimportant in any of these, and therefore the communities were not like those of the e Zones of Slopes C and F. It can be seen from Table VI that Zones b and c are very similar in regard to grass cover, although Danthonia sp. is relatively more important in Zone c. However, the forb distribution distinguishes the two zones quite clearly as there are comparatively few species in Zone b. In Zone e, Stipa spartea var. curtiseta, Koeleria cristata and Agropyron dasystachyum had approximately the same average basal cover values. A similar trend, that is to an increase in Agropyron and Koeleria is indicated by the values for these species in the e Zones of Slopes C and F. Coupland (1950) describes a Stipa-Agropyron faciation in which Stipa spartea var. curtiseta and Agropyron dasystachyum are the most important species, whilst Bouteloua gracilis, Koeleria cristata and Stipa comata are secondary. Artemisia frigida is the main forb. The community is said to occur on the intermediate slopes in the Dark Brown Soil Zone "as a post climax community to the Stipa-Bouteloua type.". The various Stipa spartea var. curtiseta dominated communities on the south slopes, in which Bouteloua gracilis is relatively unimportant, may be variants of this faciation. An Agropyron - Stipa "association" was described from the Parkland Area of the Peace River region of Alberta by Moss (1952). In the drier sites, Stipa spartea var. curtiseta and S. columbiana are said to become more important than Agropyron dasystachyum which has taken the place of A. trachycaulum and A. subsecundum. Apart from the presence of Stipa columbiana the community seems to be comparable with Stipa spartea var. curtiseta - Agropyron dasystachyum communities described in Saskatchewan.

Among the zones on the three north-facing slopes in only one (namely Zone b Slope G) was Stipa spartea var. curtiseta the most important grass species. However, the community differed from those of the Stipa Zones on the south slopes in that Festuca scabrella was the main secondary species, Agropyron dasystachyum being unimportant. It is interesting to note that Bouteloua gracilis was present in this zone. This species was not recorded from the areas sampled on the other north-facing slopes. The fairly regular arrangement of zones found on the south slopes seemed to be absent from the north slopes to a very large extent. The one characteristic zone was that in which Festuca scabrella was dominant. This zone occurred in general on the steepest part of the slope, and theoretically the coolest. The temperature data for Slope E indicate that position 23, which was in the Festuca zone, was cooler than the positions at the top and base of the slope. The secondary species were Koeleria cristata and Stipa spartea var. curtiseta (although the latter was replaced by Muhlenbergia cuspidata on Slope H). Considering all three slopes, the chief forbs in the Festuca Zones were Cerastium arvense, Antennaria parvifolia, Achillea millefolium, Galium boreale and Solidago missouriensis var. fasciculata (Tables X, XI, XII, XIII and XIV.). Thus the composition of the community agrees reasonably well with that of the fesuce grassland in the Black Soil Zone of north central Saskatchewan described by Coupland and Brayshaw (1953). However, in their results Stipa spartea var. curtiseta was more important than Koeleria cristata. On Slopes E and H the community immediately above the Festuca Zone was one in which Koeleria cristata and Agropyron dasystachyum were the main species. The community on Slope G was very similar except that the Stipa spartea var. curtiseta was important. The latter community very like that in Zone e Slope B, and was immediately below the Stipa spartea var. curtiseta Zone (b) described above. The community in Zone a on Slope H was also very similar as is shown by comparing species and proportions of the principal grasses. Two species of forb occurred in this zone on Slope H: Artemisia frigida and Antennaria parvifolia, both of which were found in Zone c on Slope G. The difference in the position of the community on the respective slopes should be noted. However, it does not necessarily mean that the conditions in the three are identical. The unreliability of species as indicators has been demonstrated by McMillan (1956 a, 1956 b). His results, from uniform garden studies on the flowering behaviour and growth of various grass species in Nebraska, indicate the presence of a remarkable amount of ecotypic variation. In the case of Andropogon scoparius there seemed to be inherited differences in flowering behaviour of plants from different parts of the same slope.

The a Zone of Slope G supported a Stipa comata - Agropyron dasystachyum community and thus resembled a south rather than a north slope. On Slope E Zones a and d, respectively above the Koeleria - Agropyron, and below the Festuca Zones, had stands with very similar grass composition, In each Koeleria cristata, Festuca scabrella and Stipa spartea var. curtiseta were the most abundant species and in much the same proportion. The forb, moss, and lichen constituents of the community were very different, however (Tables XI and XII). In Zone d the important forbs were similar to those in the neighboring Festuca community (Zone c) whilst Artemisia frigida, Phlox hoodii and Erigeron caespitosus were the main species in Zone a. It is interesting that Festuca scabrella was more important in Zones a and c on Slope E than in Zone b. The latter was, however, on the most convex part of the slope. Thorp, Williams and Watkins (1948) suggest that convexity increases the dryness of a slope. The Koeleria - Festuca - Stipa (Slope E Zones a and d), and Koeleria - Agropyron (Slope E Zone b and Slope H Zone b) communities do not seem to be related to any occurring on the south slopes. The Koeleria Zone (Slope F Zone d) in that Bouteloua gracilis and Muhlenbergia cuspidata are the secondary species, is clearly distinct from the north slope Koeleria communities.

Koeleria dominated communities do not seem to have been described in Saskatchewan, although this species is ranked as a codominant in the Agropyron - Koeleria faciation (Coupland, 1950). This faciation is said to occur on uniform clay deposits formed in the beds of glacial lakes. Clay soils have a high water retaining capacity and are frequently physiologically dry. As mentioned above, the Koeleria - Agropyron communities occur on convex, and therefore possibly the driest, parts of the slope. Thus drought resistance may be the connecting link between the communities in the very different environments. Doubtless there are many other important factors, and it would also be interesting to know the clay fraction in the soil of the zones concerned.

2. Microclimatic factors with relation to the zone-communities.

The zonation of the communities on the slopes described above, indicates the critical nature of the microenvironment. A community can extend over only a few meters of slope-surface and yet be distinct from those above and below it. One of the most important contributary factors to this zonation will be insolation as affected by variations in the steepness of slope. However, there must be many other factors involved, for an examination of Table XXI, in which the average percent slope is given for each community, reveals that the same type of community (e.g. the Bouteloua community) occurs on areas of very different steepness from one slope to another. (It should be noted that communities are being equated mainly by the most abundant grass species). In any case, equivalence of solar climate between a slope and a level area distant from it (Alter, 1912), does not necessarily result in equivalence of community. There are firstly problems connected with migration, and secondly differing tolerance ranges for the species involved. For instance, Aamodt (1941) postulated that grass species adapted to dry regions are less influenced by varying temperature than those adapted to

Table XXI. The percent slope for each zone-community.
The communities are denoted by the principal grass species present in each. The zones are bracketed.

Community	Percent slope for the zones						
	Slope C	Slope F	Slope J	Slope B	Slope E	Slope G	Slope H
Stipa comata	15.40(a)	19.70(a)	4.75(a)			8.50(a)	
Koeleria cristata) Stipa comata)				10.43(a)			
Bouteloua gracilis	16.00(b)	26.20(b)	16.72(b)				
Muhlenbergia cuspidata	19.70(d)	19.30(c)	13.53(c)				
Bouteloua gracilis) Stipa spartea var. curtiseta)	17.60(c)		7.55(d)				
Stipa spartea var. curtiseta) Bouteloua gracilis)	16.55(e)	13.70(e)					
Koeleria cristata) Bouteloua gracilis) Muhlenbergia cuspidata)		14.80(d)					
Stipa spartea var. curtiseta) Agropyron dasystachyum)				9.98(b) 9.70(c)			
Stipa spartea var. curtiseta) Koeleria cristata) Agropyron dasystachyum)				6.26(e)		24.30(c)	2.95(a)
Festuca scabrella					30.98(c)	15.50(d)	18.70(c)
Koeleria cristata) Agropyron dasystachyum)					25.15(b)		12.03(b)

Table XXI continued.

Community	Percent slope for the zones						
	Slope C	Slope F	Slope J	Slope B	Slope E	Slope G	Slope H
Koeleria cristata)					18.45(a)		
Festuca scabrella)					19.53(d)		
Stipa spartea var. curtiseta)							
Stipa spartea var. curtiseta)							
Festuca scabrella)						19.05(b)	
Koeleria cristata)							

humid regions, and credited Bouteloua gracilis as being able to grow within a range of air temperature from 60° to 110°F. (Caution is necessary in making and using such generalisations owing to the increasing awareness of ecotypic differentiation, Olmstead, (1952); McMillan (1956 a, 1956 b).)

Insolation differences due to topographical variation would most probably result in difference in the thermoperiod on different parts of the slope. In the first place the maximum temperature would be influenced by slope orientation and inclination, and by exposure to wind. The minimum temperature would vary according to the possibilities for cold air drainage, and the position of the "warm belt" (Geiger, 1950). The greater amount of moisture in depressions would presumably modify the thermoperiod by decreasing the maximum, and increasing the minimum temperatures of the soil. McMillan (1956 b), as mentioned above, found that considerable differences in flowering time were shown by clones of the same species from different parts of a slope when grown in a uniform garden. Since there should have been no difference in photoperiod in the original situation, he attributed the behaviour to differences in thermoperiod. Thus thermoperiod might be important in the zonation of species on a slope. It might also be causal in the failure of some species to flower in certain years. For example, in 1956, which was abnormally hot and dry at the beginning of the growing season (Table II), Bouteloua gracilis and Muhlenbergia cuspidata were the only species which flowered to any extent in the areas studied. Valuable information on thermoperiodic phenomena could be obtained by the establishment of thermographs at various elevations on slopes of different aspect.

Soil moisture is generally considered to be one of the important environmental factors controlling the distribution of vegetation. However, as Daubenmire (1947) points out, the plant is most sensitive to factors where these are at minimum levels. Thus moisture will be most critical at the dry edge of a species' range. The results obtained for soil moisture indicate that two of the slopes sampled (B and E)did not differ significantly with regard to total moisture (Table XX), and yet they supported very different zone-communities. Differences in humidity and moisture could arise from differences in dew formation, and would not have been detected in this investigation. The higher soil temperatures on a south-facing slope may help to maintain soil moisture (Duvdevani, 1952).(It should be noted that available moisture was not determined, and that the number of samples were probably too few to be reliable). However, the results may indicate that soil moisture is not a critical factor for at least some species in this area. For instance, Bouteloua gracilis is at its cold edge in central Saskatchewan and is therefore probably influenced to a greater extent by temperature variations than by those of moisture. On the other hand, more northerly species could be at their dry edge, and this may apply to Festuca scabrella, especially since it decreases on the most convex part of Slope E. The Stipa comata, Bouteloua gracilis, Muhlenbergia cuspidata, and Festuca scabrella Zones seem to be more clearly defined in relation to one another and to their position on the slope than do the zones in which Koeleria cristata, Agropyron dasystachyum, or Stipa spartea var. curtiseta are the important species. Could this be due to the former group being near the edge of their respective ranges?

In the virtual absence of microclimatic data, it is in general not possible to draw more than tentative conclusions as to the relationship of a zone-community to its position on the slope. The following explanations are, however, offered for the anomalous Slopes: B and G. The latter was unlike the other two north slopes studied in that the upper two Zones (a and b) were dominated by Stipa comata and S. spartea var. curtiseta, respectively.

Presumably the upper parts at least receive solar radiation for a longer period each day than the more due- north-facing slopes. Other factors such as drainage and protection may also be important. Orientation was presumably not the critical factor in regard to Slope B since the aspect (S. S. E.) was the same as Slope C. Comparison of the average percentage slope of the zones given in Table XXI shows that Slope B was very much less steep than the other south-facing slopes. Thus the slope as a while would receive less insolation than the other slopes and could be expected to be cooler. It is especially strange that *Bouteloua gracilis* does not occur on the steeper parts of this slope. Possibly these are more exposed to the cooling effect of the wind due to their position on the upper part of the slope. Table XVI does show that the mid and basal positions (17 and 16) were significantly warmer than the top position (12). (However, the latter was situated where the slope began to level off towards the top of the knoll, and was not, therefore on the steepest part.) Among the differences between Slopes B and C was the scarcity of *Anemone patens* var. *wolfgangiana* on the latter, whilst it was frequent on Slope B, and was in fact flowering when the location was first visited (April 19th 1956), (Fig. 17). Thus conditions for growth early in the season cannot be particularly unfavorable on Slope B. From the very general notes that were made on the phenology of the species on Slopes B, C, D, and E, it does seem that many species flowered first at the mid position on Slope C. Aikman (1941) mentions that late frosts are more likely to cause damage on south slopes because these warm up earlier than north slopes. Presumably Slope C, due to its greater inclination, would warm up earlier than Slope B. Thus possibly the occurrence of species starting growth early in the season is prevented on Slope C by the damaging affects of late frosts. If this is so, then *Bouteloua gracilis*, which starts growth much later than other species, might be expected to be more abundant on Slope C than on Slope B.

3. <u>Possible uses of sloping areas in agriculture</u>.

Increase in the world population has necessitated increases in food production and thus of the utilization of more unfavorable areas for crops. Hilly areas are an example of the latter, and they pose special land use problems (Oosting, 1956). Crops must be carefully chosen to prevent erosion, and are best if of a fairly permanent nature since this reduces both the work, such as ploughing, and the amount of time the soil is bare. Mendell and Aikmen (1944, quoted by Oosting, 1956) recommend orchards, vineyards and pastures for hillsides.

The small scale of market gardening adapts it to hillculture. By planting early and late varieties at different elevations and on slopes of different exposures, growth of crops beyond their normal range is possible and also the period of flowering or fruiting can be extended. Daubenmire (1947) mentions that thermoperiod affects the production of heads or flowers on lettuce. Thus details of the microclimate are very necessary, so that suitable species and varieties can be planted, and crop failures averted. At the moment market gardening is relatively unimportant in Central Saskatchewan. However, with increase in the population it may become necessary to utilize those areas (which owing to rough topography and stoniness are unsuitable for grain production) for flowers, vegetables and fruit.

It is obvious that increased attention should be given to the microclimate and to the ways in which it may affect the plant. This can be achieved only by direct and detailed measurements in the field, coupled with growth experiments under controlled conditions.

SUMMARY AND CONCLUSIONS

1. The vegetation on four south-facing, and three north-facing slopes was sampled by methods yielding quantitative results (namely by point sampling and by quadrat counts). The seven slopes are in an area of Weyburn loam near Saskatoon.

2. The plant species on each slope were found to be combined into a number of distinct communities. The areas of the slope occupied by the respective communities were designated "zones", each zone, or community, being denoted by its dominant grass species present.

3. The vegetation of north-, and south-facing slopes was distinguished by the occurrence of characteristic communities. On the former there was a Festuca scabrella Zone, and Koeleria cristata and Agropyron dasystachyum were more important than on the south-facing slopes. Bouteloua gracilis and Muhlenbergia cuspidata were dominant in respective zones on the south-facing slopes, and Stipa comata was characteristically important on the upper parts of these slopes. Stipa spartea var. curtiseta was more abundant in the communities of the south-facing slopes.

4. There was some evidence for the existance of patterns in the zonation - that is of one particular community tending to occur in the same relationship to the other communities. On the south slopes there was first a Stipa comata Zone, then a Bouteloua gracilis Zone, a Muhlenbergia cuspidata Zone and finally a Stipa spartea var. curtiseta - Bouteloua gracilis Zone. The pattern on the north-facing slopes was less clear, but a Koeleria cristata - Agropyron dasystachyum community did seem to occur immediately above the Festuca scabrella Zone.

5. The results of the investigation seem to corroborate in part at least, the suggestions of other workers as to the vegetation of slopes in the area

concerned, but indicate that these suggestions have been of a too general nature.

6. The composition of the grass species in each zone was, with one or two exceptions, between 33 and 75 percent, whilst the forbs and shrubs contributed 12 to 50 percent, the balance being made up by sedges. In the relative calculations the cover of Selaginella densa, and of the mosses and lichens was ignored. (The distribution of these groups would repay further study.)

7. The data for soil temperature indicates that the steepest part of a north-facing slope is the coolest part of that slope, and as might also be expected, that the south-facing slopes are warmer than the north-facing ones.

8. The results for total soil moisture show that this was extremely variable throughout the summer, but that there was no significant difference between Slope B (south-facing) and Slope E (north-facing).

9. It is suggested that variation in temperature factors (as for example, resulting from differences in insolation) maybe of primary importance in the areas investigated. One of the most critical of the effects of temperature might be that involving thermoperiodism.

10. Other very important microenvironmental factors in hilly areas are drainage, soil type, depth and constituents, position of graoves of trees, and wind direction. Knowledge of their variation and interaction would be of value to crop production, especially in such branches as market gardening.

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Appendix 1. The strips comprising each Zone. In each case Zone a is at the top of the slope.

Slope	The strips in each zone				
	Zone a	Zone b	Zone c	Zone d	Zone e
Slope B	34 - 27	26 - 19	18 - 13	12 - 9	8 - 1
Slope C	1 - 3	4 - 8	9 - 12	13 - 19	20 - 25
Slope F	1 - 6	7 - 12	13 - 18	19 - 21	22 - 26
Slope J	12 and 13	14 - 18	19 - 21		
Slope H	11 and 10	9 - 7	6 - 1		
Slope E	1 - 4	5 and 6	7 - 12	13 - 15	
Slope G	1	2 - 5	6 - 8	9 - 12	

Appendix 2. Species recorded in the point-frame, and quadrat sampling in alphabetical order; with their respective authorities.

Grasses.

Agropyron dasystachyum (Hook) Scribn.
Agropyron repens (L.) Beauv.
Agropyron smithii Rydb.
Andropogon scoparius Michx.
Bouteloua gracilis (H.B.K.) Lag. ex. Steud.
Calamagrostis montanensis Scribn.
Danthonia Lam. and Dc. Sp.
Festuca scabrella Torr.
Koeleria cristata (L.) Pers.
Muhlenbergia cuspidata (Torr.) Rydb.
Muhlenbergia squarrosa (Trin.) Rydb.
Poa canbyi (Scribn.) Piper.
Poa cusickii Vasey.
Poa secunda Presl.
Stipa comata Trin. and Rupr.
Stipa spartea Trin. var. spartea Hitchc.

Sedges.
Carex filifolia Nutt.
Carex pensylvanica Lam. Var. digyna Boechl.
Carex stenophylla Wahlenb. var. enervis (C.A. Mey.) Kukunth
Carex

Rushes.
Juncus L. sp.

Forbs and Shrubs.
Achillea millefolium L.
Agoseris scorzoneraefolia (Schrad.) Greene
Amelanchier alnifolia Nutt.
Androsace L.
Anemone patens L. var. wolfgangiana (Bess.) Koch.
Antennaria howellii Greene
Antennaria parvifolia Nutt.
Arabis L.
Artemisia camporum Rydb.
Artemisia frigida Willd.
Artemisia ludoviciana Nutt. var. gnaphalodes (Nutt.) T. and G.
Aster commutatus T. and G.
Aster laevis L.
Astragalus goniatus Nutt.
Astragalus flexuosus Dougl.
Campanula rotundifolia L.
Cerastium arvense L.
Chrysopsis villosa (Pursh) Nutt.
Comandra pallida A. DC.
Elaeagnus commutata Bernh.

Appendix 2. Cont.

Forbs and Shrubs cont:

Erigeron caespitosus Nutt.
Erigeron glabellus Nutt.
Gaillardia aristata Pursh.
Galium boreale L.
Gaura coccinea Pursh.
Geum triflorum Pursh.
Gutierrezia diversifolia Greene.
Liatris punctata Hook.
Linum lewisii Pursh.
Lygodesmia juncea (Pursh) D. Don.
Orthocarpus luteus Nutt.
Oxytropis macounii (Greene) Rydb.
Petalostemum purpureum (Vent) Rydb.
Phlox hoodii Richardson.
Potentilla arguta Pursh.
Potentilla pensylvanica L.
Rosa L.
Senecio purshianus Nutt.
Sisyrinchium mucronatum Michx.
Solidago nemoralis Ait. var. decemflora (DC.) Fern.
Solidago missouriensis Nutt. var. fasiculata Holzinger.
Solidago rigida var. canescens (Rydb.) Breitung.
Symphoricarpos occidentalis Hook.
Thermopsis rhombifolia (Nutt.) Richards.
Vicia L.

Clubmoss

Selaginella densa Rydb.

Mosses

Amblystegium juratzkanum Schimp.
Brachythecium sp.
Bryum argenteum Hedw.
Bryum sp.
Campylium hispidulum (Brid.) Mitt.
Ceratodon purpureus (Dedw.) Brid.
Didymodon recurvirostris (Hedw.) Jenn.
Grimmia sp.
Mnium cuspidatum Hedw.
Tortula mucronifolia Schwaegr.
Tortula ruralis (Hedw.) Smith
Weissia controversa Hedw.

Lichens

Candelariella dispersa (Ras.) Hakul.
Cladonia pyxidata (L.) Fr.
Cladonia sp.
Dermatocarpon hepaticum (Ach.) T. Fr.

<u>Appendix 2</u>. Cont.

Lichens cont:

Diplochistes scruposus (Schreb.) Norm.
Lecidea (Psora) decipiens (Ehrh.) Zahlbr.
Lecidea (Psora) luridella (Tuck.) Fink.
Ochrolechia frigida (Sw.) Lynge
Parmelia chlorochroa Tuck.
Peltigera canina (L.) Willd. var. rufescens (Weis.) Mudd.
Physcia muscigena (Ach.) Nyl.

Appendix 3. Relative distribution of the grass species. The basal cover of the respective species is expressed as a percentage of the total grass cover in each strip. (Figs. 7 and 10 represent the values diagramatically). The strips are arranged in order from the top to the bottom of each sampling area.

Slope B

Species	Strip number											
	34	33	32	31	30	29	28	27	26	25	24	23
Stipa comata	6.7	15.4	14.3	13.3	15.4	31.2	27.3					5.9
Stipa spartea var. curtiseta	13.3	15.4	28.6	26.6	23.1	12.5	9.1	25.0	77.8	66.7	71.0	70.5
Koeleria cristata	40.0	53.8	42.9	33.3	46.2	50.0	36.4	50.0	11.1	22.2	7.1	5.9
Agropyron dasystachyum	13.3	7.7	14.3	13.3	7.7	6.2	27.3	25.0	11.1	11.1	14.2	5.9
Bouteloua gracilis												
Calamagrostis montanensis											7.1	
Danthonia												5.9
Muhlenbergia cuspidata		7.7										
Festuca scabrella	25.6			13.3								5.9
Poa secunda												
Other grasses					7.7							
	98.9	100.0	100.1	99.8	100.1	99.9	100.1	100.0	100.0	100.0	99.4	100.0

Strip number															
22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7
47.0	46.2	18.2	42.8	63.6	38.4	35.0	35.3	47.1	47.3	26.3	35.3	25.8	10.0	47.3	40.0
17.6			14.3		30.8	10.0	17.6		5.3	15.8	14.7	19.4	16.7	31.6	30.0
5.9	23.1	54.5	35.7	27.2		15.0	17.6	23.6	15.8	10.5	2.9		6.7	10.5	20.0
		9.1		9.1			5.9		15.8	10.5	38.2	51.6	66.7		
5.9	7.7	9.1	7.1		15.4	5.0	11.8	5.9	10.5	21.0	8.8	3.2			
17.6	23.1	9.1			15.4	20.0	11.8	23.6	5.3	10.5				5.3	
5.9						5.0				5.3					
						10.0									10.0
														5.3	
99.9	100.1	100.0	99.9	99.9	100.0	100.0	100.0	100.2	100.0	99.9	99.9	100.0	100.1	100.0	100.0

6	5	4	3	2	1
					4.2
57.8	35.0	7.7	22.2	25.3	16.7
31.6	35.0	53.8	22.2	5.3	29.2
5.3	20.0	15.4	33.3	57.8	33.3
		7.7	11.1	5.3	8.3
	10.0				8.3
			5.5	5.3	
		15.4	5.5		
5.3					
100.0	100.0	100.0	99.8	99.0	100.0

Appendix 3. Cont. Slope C

Species	Strip number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stipa comata	29.4	29.4	15					11.1						
Stipa spartea var. curtiseta	11.8	11.8	5.0	5.0	6.7				20.0	29.4	28.6	33.3	5.5	14.3
Koeleria cristata	5.9	5.9		5.0	6.7	7.1	22.2	11.1	10.0		7.1		5.5	7.1
Agropyron dasystachyum	5.9	5.9	10.0		6.7	7.1			10.0			11.1	5.5	14.3
Bouteloua gracilis	47.0	47.0	60.0	85.0	73.3	71.4	66.6	77.8	50.0	64.6	57.1	55.6	50.0	28.6
Muhlenbergia cuspidata			10.0	5.0		7.1	11.1			5.9	7.1		27.8	14.3
Festuca scabrella									10.0					
Andropogon scoparius					6.7	7.1								
Muhlenbergia squarrosa													5.5	21.4
	100.0	100.0	100.0	100.0	100.1	99.8	99.9	100.0	100.0	99.9	99.9	100.0	99.8	100.0

15	16	17	18	19	20	21	22	23	24	25
20.0	22.2	40.0	16.7	38.9	30.8	41.2	20.0	40.0	63.6	66.6
20.0	22.2	10.0	16.7		30.8	11.8	13.3	30.0	36.4	25.0
10.0			16.7							
20.0		30.0	16.7	11.1	30.8	29.4	60.0	20.0		
20.0	55.6	20.0	33.4	50.0	7.7	17.6	6.7	10.0		
										8.3
10.0										
100.0	100.0	100.0	100.2	100.0	100.1	100.0	100.0	100.0	100.0	99.9

Appendix 3. Cont. Slope E

Species	Strip number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stipa comata		5.6													
Stipa spartea var. curtiseta	36.8	5.6	25.0	4.5	11.1	6.3	19.1	15.4		7.4	9.5	5.5	22.8	22.2	31.8
Koeleria cristata	21.0	50.0	33.3	40.8	33.3	18.7	19.1	23.0	16.7	25.9	14.3	38.9	22.8	51.8	36.4
Agropyron dasystachyum	31.6	5.6	8.3	4.5	22.2	12.5			3.3						
Festuca scabrella	10.5	22.2	16.6	50.0	22.2	25.0	52.5	38.5	70.0	59.2	71.5	38.9	42.8	18.5	22.7
Poa canbyi			8.3		11.1	6.3	9.5	3.8	6.6	7.4		16.7	8.6	7.4	9.1
Poa secunda		11.2	8.3			31.2		19.3	3.3		4.8				
Other Grasses													2.8		
	99.9	100.2	99.8	99.8	99.9	100.0	97.7	100.0	99.9	98.9	100.1	100.0	99.8	99.9	100.0

Appendix 3. Cont. Slope F

Species	Strip number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stipa comata	45.4	75.0	50.0	66.7	55.5	62.5	10.0							
Stipa spartea var. curtiseta			33.3	8.3			20.0	18.8	4.3			28.5	28.5	7.7
Koeleria cristata	27.2	25.0	16.7	16.7	11.1				4.3	5.9	18.2		14.3	
Agropyron dasystachyum	27.2				22.2		10.0		4.3	5.9				7.7
Bouteloua gracilis				8.3	11.1	37.5	60.0	68.7	87.1	76.4	63.6	57.2	28.5	23.1
Muhlenbergia cuspidata								12.5		11.8	18.2	14.3	14.3	61.5
Festuca scabrella														
Poa canbyi														
Danthonia sp.													14.3	
	99.8	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0

Strip number											
15	16	17	18	19	20	21	22	23	24	25	26
36.4	33.3	7.7	30.0	9.1			27.3	27.3	16.7	22.2	20.0
	16.7	7.7	10.0	54.6	50.0	55.5	18.1		33.3		20.0
								9.1		11.1	
36.4	33.3	38.5	20.0		50.0	22.2	54.5	45.4		55.5	20.0
27.3	16.7	46.2	30.0	27.3		11.1		9.1	50.0	11.1	40.0
				9.1		11.1					
			10.0								
								9.1			
100.1	100.0	100.1	100.0	100.1	100.0	99.9	99.9	100.0	100.0	99.9	100.0

Appendix 3. Cont. Slope G

Species	Strip number											
	1	2	3	4	5	6	7	8	9	10	11	12
Stipa comata	62.5	11.1										
Stipa spartea var. curtiseta		33.3	12.5	33.3	57.1	12.5	20.0	30.0	15.4	12.5	28.6	37.5
Koeleria cristata		11.1	25.0		28.5	25.0	20.0	20.0	23.1	25.0	21.4	25.0
Agropyron dasystachyum	37.5	22.2	12.5	16.6		25.0	50.0	10.0				12.5
Festuca scabrella		11.1	37.5	16.6	14.3	25.0	10.0	20.0	46.2	62.5	42.8	25.0
Poa canbyi		11.1	12.5	33.3				20.0				
Muhlenbergia cuspidata						12.5			7.7			
Poa cusickii									7.7			
Danthonia											7.1	
	100.0	99.9	100.0	99.8	99.9	100.0	100.0	100.0	100.1	100.0	99.9	100.0

Appendix 3. Cont. Slope H (1-11) and Slope J (12-21)

Species	Strip number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stipa comata												50.0	28.5		17.7
Stipa spartea var. curtiseta		6.2								18.1	40.0		14.2		
Koeleria cristata	40.0	18.7	16.6	28.5	15.0	20.0	45.4	71.4	80.0	36.3	20.0	50.0	14.2		
Agropyron	15.0				25.0		45.4	28.5		45.4	40.0		42.8	28.5	
Festuca scabrella	15.0	62.2	50.0	71.4	50.0	20.0	9.1		20.0					14.2	5.9
Bouteloua gracilis														57.1	76.5
Muhlenbergia cuspidata	15.0	12.5	33.3		15.0	60.0									
Poa canbyi	15.0														
	100.0	99.6	99.9	99.9	100.0	100.0	99.9	99.9	100.0	99.8	100.0	100.0	99.7	99.8	100.1

16	17	18	19	20	21
9.5					
		3.3		33.3	42.6
9.5	2.6		5.0		14.2
				11.1	
80.9	97.4	86.7	35.0	11.1	
		10.0	60.0	44.5	28.4
					14.2
99.9	100.0	100.0	100.0	100.0	99.4

Appendix 4. Point sampling results for mosses. The results are based on 100 points per strip, and the strips are in sequence from the top to the bottom of the respective sampling areas.

Slope B — Sampling areas

Species	Strip number																				
	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14
Bryum sp.	1.5	1		1.5	1.5	2.5	1.5	1.5	2	7	6.5	15	14.5	10	7	9.5	15.5	9	8	13	6
Bryum argenteum	1	1																			
Weissia controversa	0.5				1.5	1			1	2				0.5	1	1.5	0.5	0.5	0.5	3	3.5

Slope C

Species	Strip number																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Bryum sp.	2			3		1				1	3	1	1			1	2		2	5	3	4	4	5	4
Weissia controversa	1									1											1				

Slope F

Species	Strip number																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Grimmia sp.	5	3	1					1	2	2	2	6	2	2	3	1	1				1					
Weissia controversa								2	2	2	3	7	4	2	1		3	3	2	1	1	2	2			1
Bryum sp.								1		1	2	1	6	1	7	6	9	12		5	5	9	9	17	6	7
Tortula ruralis											2	1	3	2		2								1		
Tortula mucronifolia																		1	1				2			

13	12	11	10	9	8	7	6	5	4	3	2	1
12	17	3.5	4	1	6	10.5	9	10.5	8		9.5	6
0.5												

Appendix 4. Cont.

Slope E

Species	Strip number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bryum sp.	3	3	2.5	3.5	0.5	1.0									
Weissia controversa		1	0.5	2	6.5	2	2	1.5	0.5	0.5			0.5		0.5
Brachythecium sp.				1	7	29	33	43	36	40	41.5	42	31.5	24	25
Amblystegium juratzkanum					0.5	1.5		1.5	2	1.5	4.5	1	2	5	6
Ceratodon purpureus								9	10.5	10.5	5	4	19	16.5	12.5
Campylium hispidulum											2.5	2.5	1	0.5	
Tortula ruralis								0.5			0.5				
Mnium cuspidatum													0.5		

Appendix 5. Point sampling results for lichens. The results are based on 100 points per strip, and the strips are in sequence from the top to the bottom of the respective sampling areas.

Slope B

Species	Strip number																					
	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13
Physcia muscigena	11.5	11	14.5	12	11	3		0.5			0.5	0.5		0.5	0.5							
Cladonia pyxidata		2.5		0.5	1	1.5	1.5	1.5	0.5		2.5		1	3	1	2.5	2	3	1.5	2.5	1	2
Cladonia sp.	1.5	2																				
Parmelia chlorochroa		0.5	1	1	1	3	1.5	2	3	0.5	0.5	0.5										
Lecidea luridella		0.5	1		1		0.5			0.5												
Dermatocarpon hepaticum)) Lecidea decipiens)				0.5												0.5						
Peltigera canina																						
Rufescens																						

12	11	10	9	8	7	6	5	4	3	2	1
1											
	0.5		0.5	0.5							
					0.5						0.5

Appendix 5. Cont.

Slope C

Species	Strip number																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Physcia muscigena	1				6		1		2	4		2													
Cladonia pyxidata		1	2	3	2	3	10	7	3	4	2	2		1	1		1								
Diplochistes scruposus		1	1					1					1												
Dernatocarpon hepaticum		2																							
Peltigera canina			1		1																				

Slope F

Species	Strip number																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Physcia muscigena	5		1	1			1		1																	
Cladonia sp.	1	4	3		1		1	1	1	1	1	1	1	2	1		1	3	1	1	1	1			2	1
Parmelia chlorochroa	3								1																	
Lecidea luridella																										
Ochrolechia frigida				2																						
Dermatocarpon hepaticum							1		1	1		2	1													
Candelariella dispersa										1																

Slope E

Species	Strip number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Physcia muscigena	13	6.5	2.5	1	2.5										
Cladonia pyxidata	6	9.5	16	16.5	7	3	2.5	2	1	0.5					
Cladonia sp.		1.5	3	3	0.5		2.5		0.5	1.5	1.5	1.5		0.5	
Peltigera canina		0.5	1							0.5					

<u>Appendix 6.</u> Soil and air temperatures.

The readings are arranged under position on each slope. Besides the date of sampling the number of days from the first (April 19th) are given. An asterisk denotes that the pointer of the thermometer dial jammed and that the instrument had to be tapped before the correct reading could be obtained. +3" refers to the air temperature 3" above the ground surface.
Ap = April; My = May; Jn = June; Jy = July; Au = August; S = September; O = October.

1. Slope B

Date		Ap 19	My 1	My 4	My 8	My 9	My 10	My 11	My 23	My 30	Jn 6	Jn 13	Jn 20	Jn 27	Jy 4	Jy 11	Jy 18	Jy 25	Au 1
No. of days from 1		1	13	16	20	21	22	23	35	42	49	56	63	70	77	84	91	98	105
12	+3"	-	41	58	61	61	63	43	72	56.5	63	66	84	71	67	78.5	72.5	77	79
	1"	-	51	57.5	57	55.5	61	49.5	66	60	57	73	74.5	68	67	76	69.5	84	70
	3"	-	42	43	49	48	50	46	55.5	54.5	52.5	63	67	61	61	69.5	63.5	70	65
	7"	-	38.5	39	46.5	46.5	48	45.5	54.5	54	53	60.5	64	58.5	58.5	66	60*	68	64
17	+3"	at 5": 66.5	57	58	61	57	64.5	43	74	58.5	62	64.5	85.5	74	66.5	78	72	83	74.5
	1"	65.5	51.5	64.5	56.5	57.5	58	50.5	64	62	58	69.5	75	75	70	75.5	74	83	71*
	3"	56	42	46	51.5	50	53.5	49	57	58	55	64	67.5	62.5	62	71	65.5	73	65*
	7"	45	39	42	49.5	50	51.5	49	57	58	56	63	65	60	61	68	62	68	64.5
16	+3"	-	-	58	64.5	61	64	42.5	72	64.5	62	68	83	76	68	79	75	90	74
	1"	-	-	55	54.5	58	55.5	51	67.5	59.5	58	70	80	69	70	81	71.5	81	74
	3"	-	-	41	47	47	49	47	57	56	55	63	68	60.5	62	71.5	65	70	66
	7"	-	-	37.5	45	45	47.5	46.5	54.5	54.5	55	61	64	58	59.5	65	61	67	64

Au 8	Au 15	Au 22	Au 29	S 18	S 25	O 4
112	119	126	133	153	160	169
74.5	77	78.5	69	66	68	53
74	73	71*	68	58	57	51
66	65	64	59	51	49.5	47
63.5	63	63	59	52	50	47
73.5	75	77	69	69.5	68	56.5
81	73	73	72	61	59	58.5
68	65	66	61	53	51	49.5
65	64	62.5*	60	53	50*	50
73	75	79	71	69.5	68	58
72	76.5	75	72	64	58.5	58
66	66	69	60.5	53	50	48.5
63*	63.5	62	59	52	50	47

Appendix 6. Cont.

2. Slope C

Date		Ap 19	My 1	My 4	My 8	My 9	My 10	My 11	My 23	My 30	Jn 6	Jn 13	Jn 20	Jn 27	Jy 4	Jy 11	Jy 18	Jy 25
No. of days from 1		1	13	16	20	21	22	23	35	42	49	56	63	70	77	84	91	98
176	+3"	-	52	58	66	62	64	42.5	73.5	63	64	69	86	74	68	81	75	82
	1"	-	51	57.5	61	64.5	69.5	51.5	75.5	60.5	61	80	83	79	73	85	84	91
	3"	-	42	43	52.5	51	56.5	49	61	60	55	69	74.5	67.5	65	78	74	73*
	7"	-	38	39	49.5	48	50	48	57	59	54.5	64	68	61	62	71	64	69.5
175	+3"	-	48	58	67	60	67	43	74	65.5	64	67	88	75	69	83	75	81
	1"	54	44	64.5	54.5	57.5	56.5	50	62	65.5	62	66.5	69.5	67	65	74	70	78.5
	3"	43	40.5	46	50.5	50.5	54	49.5	57	58	56	61.5	65	59	60	68	65	67.5
	7"	35.5	38	42	49	49	51	49.5	55.5	56	56	59.5	62.5	57	58	64	60.5	65.5
174	+3"	-	-	58	68	63.5	68	44	74	65	64.5	65.5	85	70.5	68	78	77	83
	1"	-	-	55	52.5	51	59	47	61	58	57	64.5	70.5	66	62	69	70.5	74*
	3"	-	-	41	46	46	49	46	53	54	55	56.5	61	57	56	63	60	65*
	7"	-	-	37.5	44.5	45.5	47.5	46	51	53	54.5	56	58	55	55	59	58	62*

Au 1	Au 8	Au 25	Au 22	Au 29	S 18	S 25	O 4
105	112	119	126	133	153	160	169
76	75	79	80	71	69.5	68	60.5*
76	77	81	97	72	69	65	62
67.5	70.5	69	69	61	55	53.5	55
65	66*	67*	66	60	54	53.5	49*
80	75	81	78	69	73	70.5	59*
75	74	75	70.5	71	65	57	59
66	66.5*	65.5	64	59	54.5	52	49.5*
63.5	64	63	61*	58*	53	52	49*
74.5	78	76.5	76	73	73.5	71	59*
71	69	69	64.5*	66	59	57	59
63	62.5	62	59*	58	51	49.5	46*
60.5	60.5	61	57.5*	57	50.5	49	49

Appendix 6. Cont.

4. Slope D

Date		Ap 19	My 1	My 4	My 8	My 9	My 10	My 11	My 23	My 30	Jn 6	Jn 13	Jn 20	Jn 27	Jy 4	Jy 11	Jy 18	Jy 25
No. of days from 1		1	13	16	20	21	22	23	35	42	49	56	63	70	77	84	91	98
171	+3"	-	52	58	63	60.5	63	43	76	58	64	73	86.5	79	67.5	81	70	81.[illegible]
	1"	-	51	57.5	61.5	62	61	50.5	70	62	60	81	84	83	70.5	86	78	85.[illegible]
	3"	-	42	43	49	49	50	45.5	57	54.5	54	65	67	66.5	63.5	73	68	71*
	7"	-	38	39	45.5	45.5	48	44.5	54	52.5	53	60	64	59	59	67	62	65*
172	+3"	-	48	58	69.5	57	64.5	44	75	62	67	70	87.5	73.5	69	78	69	78
	1"	59	44	64.5	60	58	58	50.5	61	57	60.5	75	88.5	81	68	82	77	87
	3"	41	40.5	46	48	49.5	53.5	45.5	55	53	54	63	67	63.5	61	72	67	73
	7"	36	38	42	45	45.5	51.5	44.5	52	51.5	53	59	63	57.5	58	66	61	65*
173	+3"	-	-	58	68	61	64	46.5	74	63	66	68	85.5	78	67	78	72	81
	1"	-	-	55	58	61	55.5	49.5	71	67	66	70.5	81	81.5	70	80	73	89
	3"	-	-	41	49.5	49	49	46	58	57	57	63	68	66	62*	71	66	71
	7"	-	-	37.5	46	46	47.5	45.5	54	55	56	61	64	58	59*	68.5 at 6"	61	66

Au 1 105	Au 8 112	Au 15 119	Au 22 126	Au 29 133	S 18 153	S 25 160	O 4 169
75	76.5	77	83	72.5	73	68	60.5*
75	71	76.5	79*	73	66	57	60
66.5	67.5*	66	65*	61	53	49	49.5*
62.5	63	62.5	61*	58*	51	49	47*
73	72.5	76	81	69.5	68	70	56*
76.5	73.5	69.5	78	71	65	59	55
66.5	66	64.5	64	60.5	53	48	47
63	62.5	61	60.5	57	50.5	47	46
77	74	76*	79	69	69	70.5*	56*
75.5	73	75*	80	71.5	65	61*	52*
65	66.5	66	64	60.5	53	49*	46.5*
63	63.5	63*	60	58	50	48	45.5*

Appendix 6. Cont.

3. Slope E

Date		Ap 19	My 1	My 4	My 8	My 9	My 10	My 11	My 23	My 30	Jn 6	Jn 13	Jn 20	Jn 27	Jy 4	Jy 11	Jy 18	Jy 25
No. of days from 1		1	13	16	20	21	22	23	35	42	49	56	63	70	77	84	91	98
18	+3"	-	40.5	56.5	61	54.4	66	47.5	71.5	59	63	65	87.5	73	69	79	70.5	84
	1"	58	44.5	43.5	54	54	59	51.5	65	59	58	66	73	73	73	80	69.5	78
	3"	50	37.5	35	47	47.5	50	48	53	53.5	52	61	66.5	59.5	62	69.5	62.5	68
	7"	39	32.5	33	46	46	48	47.5	52	53	52	58.5	62	56	57	64..	58.5*	65
23	+3"	-	39	55.5	59	55	66	48.5	74.5	56	63.5	64	84	72	65.5	77	70	85
	1"	65	37.5	39	50	46	51.5	47	61	57.5	56	62	75	68	66	76	65.5	76
	3"	57	33	31	43	42	45	43	51	52..	53.5	57	66	57	60	68	59.5	69
	7"	43.5	31	32	39.5	40	43	42.5	50	51	53.5	56	61	55.5	56	63.5	57.5	65
13	+3"	-	39	55.5	59	54.5	65.5	47	72.5	56	62	64.5	84.5	70.5	71	79	72	82
	1"	62.5	38	38	50.5	48	56.5	47	60	56.5	59.5	60.5	79	69	68	68.5	72	76
	3"	55	32	32	45	44	47	45	51	50.5	54	56	64	58.5	58	63	61.5	64
	7"	46	31	32	43	42.5	45	45	49	50	54	55	59.5	55.5	56	61	58.5	62.5

Au 1	Au 8	Au 15	Au 22	Au 29	S 18	S 25	O 4
105	112	119	126	133	153	160	169
70.5*	75*	75.5	76.5	67	64	64.5*	51
68	72.5	68	70*	65.5	59	56	46.5
63	65*	63	63*	58	50.5	47	44
61.5	61.5	61.5	60	57	49.5	47	46
74*	73	76	76.5*	66	62	64	51
70*	65	64.5	64.5	60.5	52	53	43
62*	62	60.5	59	56	58	44.5	43
60.5*	61	59.5	58	56	49	46	44
75*	72	75	75.5*	69	61	64.5	50.5
69*	73	70	66	67	55	54	48*
61.5*	62.5*	62	58	56.5	49	46	43.5*
59.5*	60*	60	57	56.5	48	46	43.5*

Appendix 7. Total soil moisture, represented as the % loss of weight or drying a given amount of soil.
The positions on each slope are as follows:-

Slope	Top	Mid	Base
B	12	17	16
C	176	175	174
E	18	23	13
D	171	172	173

Depth at each position:-
1 = 0-6"; 2 = 6" - 12"; 3 = 12" - 24"; 4 = 24" - 36"

Positions at the top of the Slopes.

Position and Depth		Date of Sampling							
		May 6	May 23	June 12	July 9	July 23	Aug. 6	Aug. 21	Oct. 2
12	1	11.98	8.46	8.46	15.65	7.81	17.38	8.98	6.02
176	1	12.80	6.11	7.41	13.80	4.67	13.69	6.30	4.94
18	1	12.96	5.54	11.09	11.39	5.71	16.18	7.63	7.89
171	1	15.40	6.99	8.35	16.79	6.76	17.34	8.50	7.03
12	2	10.71	11.63	8.18	7.26	7.04	12.72	9.47	5.52
176	2	15.67	8.36	8.53	7.66	4.89	12.37	8.93	5.47
18	2	11.00	4.01	12.13	5.53	5.11	11.04	11.25	7.27
171	2	14.75	5.30	11.74	8.41	5.08	9.85	3.93	4.98
12	3	10.33	10.22	8.60	6.25	7.39	8.10	8.29	6.41
176	3	12.00	10.86	5.28	5.49	3.75	4.82	6.20	3.82
18	3	7.12	-	9.51	-	6.15	6.59	5.50	6.72
171	3	8.69	3.29	9.53	9.02	3.92	11.56	6.96	8.25

Appendix 7. Cont.

Position in the mid part of the Slopes.

Position and Depth		Date of Sampling							
		May 3	May 23	June 12	July 9	July 23	Aug. 6	Aug.23	Oct. 2
17	1	13.45	8.38	10.02	14.51	7.43	19.22	9.81	7.87
175	1	18.76	10.93	11.94	17.26	8.80	19.48	9.80	8.01
23	1	-	11.44	10.40	11.92	10.99	14.47	10.50	7.68
172	1	16.73	7.64	10.15	17.44	7.53	23.37	10.51	8.71
17	2	12.06	8.52	7.25	7.40	7.60	15.89	10.12	7.81
175	2	14.80	10.78	10.96	9.08	7.94	15.19	10.70	8.05
23	2	9.80	10.53	6.71	5.12	4.01	9.46	7.67	5.39
172	2	14.24	8.60	10.53	8.23	6.57	13.54	7.72	7.43
17	3	11.11	10.63	8.05	8.01	7.98	9.85	9.67	8.71
175	3	14.10	12.41	12.89	9.61	14.49	11.68	14.28	10.19
23	3	12.36	11.35	7.71	6.04	7.06	8.30	9.04	6.47
172	3	8.03	9.48	9.27	6.80	7.40	10.00	8.71	-

Appendix 7. Cont.

Positions at the base of the Slopes.

Position and Depth		Date of Sampling							
		May 3	May 23	June 12	July 9	July 23	Aug. 6	Aug. 23	Oct. 2
16	1	16.54	8.44	11.99	14.11	8.28	19.78	10.54	8.13
174	1	23.94	32.49	15.82	21.67	15.08	28.95	11.46	10.49
13	1	18.14	12.79	9.37	18.27	7.80	27.05	13.39	10.50
173	1	18.83	12.33	13.92	17.62	8.70	22.37	10.34	10.00
16	2	12.15	8.11	7.96	7.91	6.63	11.50	8.50	6.77
174	2	17.63	24.28	14.96	8.76	7.53	17.19	9.17	8.01
13	2	15.13	9.38	7.13	5.46	5.09	12.49	9.02	7.75
173	2	13.95	8.86	10.29	7.80	6.74	15.13	8.70	7.52
16	3	7.29	8.13	7.50	6.14	7.20	6.59	4.41	4.05
174	3	11.86	15.85	14.01	9.60	7.62	6.93	8.28	5.92
13	3	8.73	10.38	6.50	4.85	6.18	5.34	6.72	5.87
173	3	11.29	8.57	7.54	5.79	7.15	5.78	7.02	8.01