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PLANT PATTERN, MICRORELIEF
AND *BOUTELOUA GRACILIS* CULM DENSITY
STUDIES ON THE PAWNEE SITE: 1970-1971

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ABSTRACT

Plant distribution, microrelief, and *Bouteloua gracilis* culm density were intensively measured in a 30-year exclosure and in the pastures with light, medium, and heavy rates of utilization at the IBP Pawnee Site on the Pawnee National Grasslands. Measurements were made using a .5 × 1 m microplotter with horizontal X and Y axes and a vertical Z axis. *Bouteloua gracilis* was the dominant species with composition of 55.6% on medium, 44.4% on light, and 32.5% on the heavy grazed pasture. The degree of roughness was found to be similar for the 30-year exclosure as well as the light and medium grazed pastures, but showed a definite decrease on the heavy grazed site. Culm density within clumps of *Bouteloua gracilis* showed a definite increase from 3.5 per 5 cm² surface area on the light grazed to a net 7.3 on the heavy grazed site.

INTRODUCTION

This report describes the methods used for sampling $.5 \times 1$ m permanent plots for plant distribution, blue grama (*Bouteloua gracilis*) density, and microrelief. Instrumentation developed for the measurement of plant locations and microrelief was described in Fisser (1969). The primary objectives of this project were to determine spatial arrangement of plant individuals, plant structure, and blue grama density and to evaluate the influence of grazing intensity and microrelief on plant individuals.

METHODS AND PROCEDURES

Field Sites

During the summer of 1970, sites were established on light, medium, and heavy grazed treatments located on sections 23W, 15E, and 23E. Within each pasture, typical upland (Ascalon soil) and lowland (47-AB undifferentiated soil) sites were selected. Permanent $.5 \times 5$ m transects were established at each location for intensive measurement of plant distribution and microrelief. The transects were established on sites with minimal slopes and oriented with the 5-m length parallel to the existing slope. In addition to sites on the three grazing treatments, a transect was established on the irrigated and fertilized portion of section 21, using the same procedures that were followed on other treatments.

Field sampling during the summer of 1971 consisted of locating a $.5 \times 5$ m transect in the 30-year enclosure located in section 23W for additional plant distribution and microrelief data. A study of blue grama density (culms per clump) was conducted in 1971 utilizing the same permanent plots established for plant distribution measurement.

Methods

Transects (.5 × 5 m) were established on the selected sites using a transit and chain. Along one side of each transect, at 1-m intervals, 3/8-inch plastic stakes were driven flush with the soil surface marking five contiguous .5 × 1 m plots. These stakes were used to establish the 0- and 1-m points of each plot along the long X axis of the microplotter.

The field microplotter records location along three axes; X and Y are the horizontal axes, and Z is the vertical axis. For a complete description and illustration of the microplotter, the reader is referred to Fisser (1969). Readings from the digital meters on the X, Y, and Z axes are in inches at .1-inch intervals. The microplotter setup was accomplished by placing the frame about .6 m above the soil surface and leveling and positioning the frame over the corner markers. With the X and Y axes meters set at zero, the vertical Z axis was centered over the marker identifying the beginning of the plot and then moved along the X axis to the center of the 1-m corner marker. The Z axis meter was set at a random three-digit number on the first plot, with adjustments on subsequent adjacent plots such that all relief readings within the transect were relative to each other.

Plant Locations

Determination of plant locations for the individual plants was done by recording the X and Y axes readings of the plant. Single-stemmed plants were located by an X and Y coordinate taken at their bases. Plants forming mats or clumps, including blue grama, were located by X and Y coordinates taken at the periphery of their bases (similar to that done by pantographing). Plains prickly pear (*Opuntia polyacantha*), a rhizomatous species, was located by X and Y coordinates taken from the periphery of the pads, with seedlings smaller than .5 cm² treated as single-stemmed plants.

Microrelief

Microrelief readings were taken on 20 parallel lines spaced at 2.5-cm intervals along the Y axis and run the 1-m length of the X axis. The horizontal X and Y readings plus the elevation reading from the vertical Z axis pin were recorded as either organic (living and dead plant material) or mineral (bare soil or rock).

Blue Grama (*Bouteloua gracilis*) Culm Density

Sampling for blue grama culm density within clumps was conducted in 1971 on the permanent plots established for plant location and microrelief sampling in sections 15E, 23E, and 23W, including the 30-year enclosure in 23W. Equipment used for these measurements consisted of the microplotter and a 5-cm² frame.

The microplotter was set up following the procedures used for plant location measurement. The .5-m² area of the plot was divided into 50 subplots, each 1-dm² (Fig. 1), giving a possible sampling number of 50 per plot. When blue grama occupied at least 1/3 of the 1-dm² subplot, the 5-cm² frame was placed with the base-line midpoint located at the center of the subplot. The base line of the 5-cm² frame was oriented parallel to the Y axis and the sides parallel to the X axis, with the base line representing the smallest digital number. If the entire 5-cm² frame was not within a blue grama clump, then the frame was moved to the location nearest the center of the subplot where the entire frame would be within a clump. The X and Y coordinate was then recorded for the base-line midpoint, and a numbered flag was placed to mark the location. After repeating the procedure for all 1-dm² subplots, the microplotter was removed and the 5-cm² frame was placed into position with base-line midpoint, identified by a plot numbered flag, for counting and recording of numbers of clumps per frame.

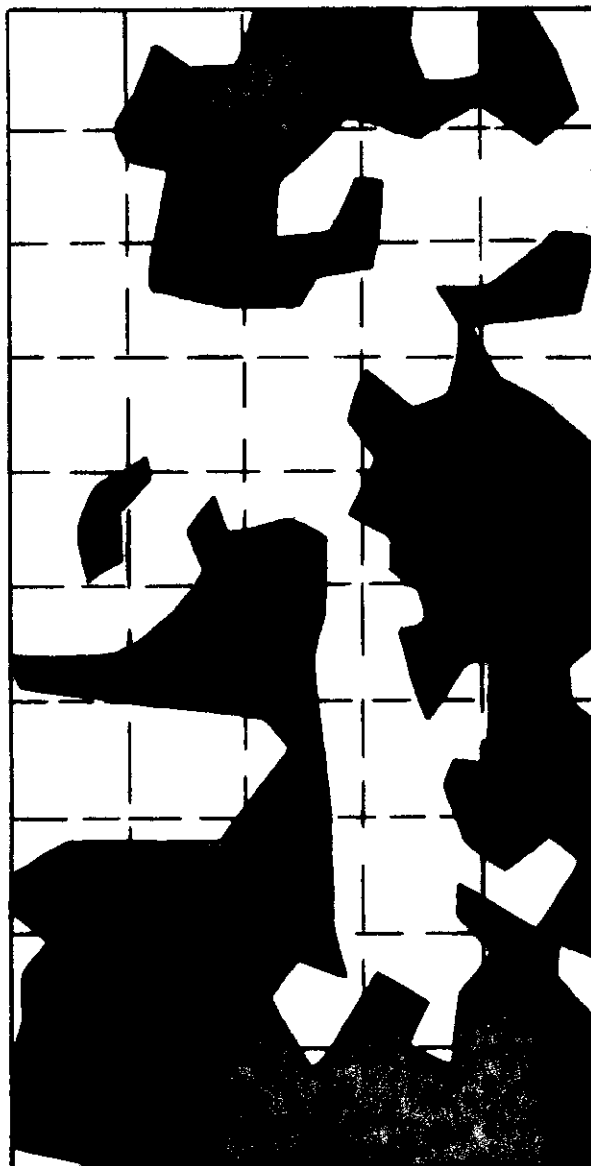


Fig. 1. A computer printout map outlining clumps of blue grama for plot 3 in the 30-year enclosure. The dashed lines show how the plot is divided into 50, 1-dm² subplots for culm density measurements.

DISCUSSION

Plant Composition

The area of the plot occupied by each species (composition) was expressed as a percent of the total area within the .5-m² plots. Blue grama was the dominant species on all transects sampled except the heavy grazed lowland site where buffalo grass (*Buchloe dactyloides*) was more abundant than blue grama. Differences in blue grama composition ranged from a high of 55.6% on the medium grazed to 44.4% on the light and 32.5% on the heavy grazed treatment. The low value for blue grama on the heavy grazed was due at least in part to the abundance (17.9%) of buffalo grass. The remainder of the composition consisted of about 15 different species and bare soil which ranged from a low of 43.1% on the medium grazed to 49.3% on the heavy and 54.0% on the light grazed treatment.

Upland (Ascalon soil) sites included a transect on the 30-year enclosure (section 23W), in addition to the transects on the pastures. Blue grama was the dominate species in all treatments, with composition ranging from 38.2% on the enclosure to 40.0% on heavy, 50.2% on light, and 55.7% on the medium grazed treatment. Species which appeared to be limited primarily to one treatment were buffalo grass (3.5% on the heavy grazed), red three-awn (*Aristida longiseta*) (2.0% on the 30-year enclosure), and thread-leaf sedge (*Carex filifolia*) (3.2% also on the 30-year enclosure). The additional 10 to 15 species reported on each site occupied less than 2% of the plot area. Bare soil composed the remainder of the area with a range from 43.4% on the medium grazed to 48.6% on the light, 54.0% on the enclosure, and 56.3% on the heavy grazed pasture.

Lowland (47-AB soil) sites were sampled in each of the three utilization areas. Two vegetation types were found among the three pastures with

blue grama dominant on the medium (55.6%) and light (38.6%) treatments. Buffalo grass was the most abundant on the heavy grazed, with 32.3% compared to 25.0% for blue grama. In addition, there were 10 other species present on the light, 15 other species on the medium, and 7 other species on the heavy grazed treatment, which comprised less than 2% of the composition. Bare soil represented the remainder of the area with 41.8% on medium, 42.0% on heavy, and 60.0% on the light grazed treatment.

Microrelief

Microrelief measurements were made on all transects in the light, medium, and heavy grazed pastures as well as the 30-year enclosure by taking approximately 600 soil elevation points, from which data a horizontal plane was fitted to each set of plot data. Deviations from this plane represent an index of the average height of rises and the average depth of the depressions.

On upland Ascalon soil sites (Table 1) the means for the 30-year enclosure and light and medium grazed pastures are similar in roughness. In contrast, the heavy grazed pasture shows a definite decrease in roughness. A similar roughness pattern is found on the lowland 47-AB undifferentiated soil sites only to a lesser degree. On the lowland soils the heavy grazed pasture showed a definite decrease in roughness similar to the upland site, especially when compared to the medium grazed pasture.

The decrease in roughness found on both the upland and lowland sites in the heavy grazed pasture must be due to grazing pressure, since other factors such as soil development, soil type, and precipitation are the same for all rates of utilization.

Culm Density

Density of blue grama culms was measured by counting the number of live culms per 5-cm² frame. The summary of this data indicates there are

Table 1. Summary of microrelief data for the upland sites (Ascalon) and lowland sites (47-AB undifferentiated) on sections 23W, 15E, and 23E.

Treatment	Depression Mean (inches)	Rises Mean (inches)
<i>Upland Sites</i>		
30-year exclosure	.34	.33
Light grazed	.34	.35
Medium grazed	.36	.35
Heavy grazed	.29	.25
<i>Lowland Sites</i>		
Light grazed	.23	.21
Medium grazed	.25	.26
Heavy grazed	.19	.17

differences due to utilization rates. Culm density ranged from an average of 3.4 on the light grazed to 4.3 on the medium and 7.3 on the heavy grazed pasture.

When upland sites are considered at all rates of utilization, including the 30-year exclosure, an average of 3.6 on the 30-year exclosure, 3.4 on the light, 4.4 on the medium, and 7.2 on the heavy grazed pasture were reported. Similar differences were found on the lowland sites with 4.3 on light, 4.9 on medium, and 8.0 on the heavy grazed pasture.

Differences in density were similar on both the upland and lowland sites, with the heavy grazed pasture appearing to be significantly higher than the light or medium grazed areas.

The data also indicate that on upland sites the size of individual clumps are smaller on the heavy grazed than on the light grazed treatment. In addition, it appears from the data that culm density declines rapidly as location of sampling extended from the edge of the clump toward the center.

SUMMARY

The dominant species at all three utilization areas on the IBP Pawnee Site was blue grama, with clump and surface area composition values ranging from 55.6% on the medium to 44.4% on the light and 32.5% on the heavy grazed. The one location where another species was more abundant was the heavy grazed lowland site with 32.3% buffalo grass, compared to only 25% blue grama.

The degree of roughness was found to be similar in the 30-year exclosure and light and medium grazed treatments, but showed a definite decrease on the heavy grazed pasture. Roughness patterns on the Ascalon and 47-AB

undifferentiated soils were similar, but a lesser degree of relief variation was noted on the 47-AB soil.

The culm density of blue grama taken at all sites showed definite differences among rates of utilization, ranging from 3.4 per 5-cm² surface area on the light to 4.3 on the medium and 7.3 on the heavy grazed pasture.

LITERATURE CITED

- Fisser, H. G. 1969. Preliminary report of methodology and results for analysis of plant pattern subproject research on the Pawnee Site. U.S. IBP Grassland Biome Tech. Rep. No. 9. Colorado State Univ., Fort Collins. 65 p.

APPENDIX I
SAMPLES OF RAW DATA COLLECTED

The plant pattern data collected in 1970 and 1971 is Grassland Biome data set A2U007B. Samples of the data follow.

Appendix Table 1. Sample of plant location data from light grazed, section 23W, upland site.

1	2	3	4	5	6	7	8 ^{a/}	1	2	3	4	5	6	7	8
061870	LG02	PLC	CIRC	BOGRX	092Y	196		061870	LG02	PLC	CIRC	BOGRX	221Y	059	
							BOGRX106Y196								BOGRX231Y052
							BOGRX144Y196								BOGRX242Y060
							BOGRX158Y184								BOGRX242Y075
							BOGRX160Y174								BOGRX225Y080
							BOGRX154Y167								BOGRX210Y072
							BOGRX144Y165								BOGRX195Y070
							BOGRX144Y147								BOGRX187Y058
							BOGRX158Y138								BOGRX179Y057
							BOGRX158Y125								BOGRX174Y064
							BOGRX168Y124								BOGRX164Y069
							BOGRX180Y142								BOGRX152Y070
							BOGRX187Y167								BOGRX146Y062
							BOGRX202Y175								BOGRX156Y057
							BOGRX226Y182								BOGRX169Y053
							BOGRX252Y184								BOGRX165Y047
							BOGRX266Y162								BOGRX150Y043
							BOGRX275Y142								BOGRX137Y037
							BOGRX285Y120								BOGRX134Y028
							BOGRX289Y102								BOGRX139Y012
							BOGRX300Y090								BOGRX144Y002
							BOGRX299Y083								BOGRX125Y000
							BOGRX278Y091								BOGRX103Y000
							BOGRX268Y087								BOGRX103Y005
							BOGRX250Y084								BOGRX126Y007
							BOGRX251Y067								BOGRX117Y027
							BOGRX247Y054								BOGRX101Y032
							BOGRX231Y046								BOGRX094Y046
							BOGRX242Y029								BOGRX088Y059
							BOGRX253Y010								BOGRX089Y080
							BOGRX265Y000								BOGRX121Y086
							BOGRX231Y000								BOGRX143Y071
							BOGRX223Y015								BOGRX150Y082
							BOGRX210Y007								BOGRX138Y109
							BOGRX202Y007								BOGRX132Y129
							BOGRX206Y025								BOGRX129Y148
							BOGRX190Y037								BOGRX113Y143
							BOGRX199Y059								BOGRX103Y123
							BOGRX212Y065								BOGRX079Y103

^{a/} 1. Columns 1-6: Collection date. 2. Columns 7-8: Location. 3. Columns 9-10: Plot number. 4. Columns 11-12: PL = Plant location data. 5. Columns 13-16: CIRC = Plot data; Point = Single point location. 6. Columns 17-20: Plant names. 7. Columns 21-24: Location on X axis. 8. Columns 25-28: Location on Y axis.

Appendix Table 2. Sample of microrelief data from light grazed, section 23W, upland site.

1	2	3	4	5	6	7	8 ^{a/}	1	2	3	4	5	6	7	8
062470	LG	05	MT	OX	000Y	000Z	767	062470	LG	05	MT	OX	366Y	010Z	749
							OX067Y000Z772								OX379Y010Z762
							OX101Y000Z765								OX394Y010Z759
							OX123Y000Z757								OX000Y020Z774
							MX129Y000Z755								OX032Y020Z773
							MX146Y000Z758								OX055Y020Z770
							OX151Y000Z757								OX082Y020Z771
							OX162Y000Z757								OX113Y020Z769
							OX173Y000Z763								OX124Y020Z756
							OX201Y000Z764								MX128Y020Z757
							OX218Y000Z762								MX143Y020Z753
							OX232Y000Z756								MX169Y020Z757
							MX235Y000Z755								MX179Y020Z760
							MX251Y000Z753								OX185Y020Z762
							MX275Y000Z749								OX200Y020Z761
							MX294Y000Z748								OX214Y020Z763
							MX315Y000Z748								OX231Y020Z760
							MX340Y000Z751								OX247Y020Z759
							MX350Y000Z750								MX256Y020Z753
							OX354Y000Z752								MX284Y020Z748
							OX373Y000Z765								MX316Y020Z746
							OX385Y000Z750								MX354Y020Z752
							OX394Y000Z765								OX356Y020Z753
							OX000Y010Z765								OX368Y020Z760
							OX018Y010Z776								OX394Y020Z756
							OX054Y010Z776								OX000Y030Z771
							OX070Y010Z771								OX034Y030Z769
							OX094Y010Z764								OX055Y030Z771
							OX116Y010Z760								MX057Y030Z771
							OX120Y010Z760								MX069Y030Z768
							MX122Y010Z756								MX076Y030Z769
							MX145Y010Z754								OX079Y030Z771
							MX170Y010Z757								OX087Y030Z768
							OX173Y010Z760								OX100Y030Z767
							OX186Y010Z761								OX111Y030Z764
							OX206Y010Z761								OX127Y030Z762
							OX225Y010Z763								OX133Y030Z761
							OX236Y010Z759								OX150Y030Z758
							OX243Y010Z762								OX168Y030Z759
							OX248Y010Z752								OX190Y030Z769
							MX252Y010Z751								OX215Y030Z764
							MX281Y010Z747								OX246Y030Z763
							MX315Y010Z747								OX270Y030Z755
							MX342Y010Z750								OX286Y030Z752
							OX351Y010Z753								MX290Y030Z750

^{a/} 1. Columns 1-6: Collection date. 2. Columns 7-8: Location. 3. Columns 9-10: Plot number. 4. Columns 11-12: MT = Microrelief data. 5. Column 13: 0 = Organic; M = Mineral. 6. Columns 14-17: Location on X axis. 7. Columns 18-21: Location on Y axis. 8. Columns 22-25: Elevation measurement on Z axis.

Appendix Table 3. Blue grama (*Bouteloua gracilis*) culm density field data from light grazed pasture, section 23W, upland site.^{a/}

Date of Collection	Location	No. of Culms per 5-cm ² Frame
080371	X129 Y010	4
	220 020	2
	300 020	2
	348 024	5
	380 023	3
	093 060	4
	133 060	5
	180 072	2
	215 059	3
	340 060	3
	375 060	10
	059 095	1
	100 100	0
	180 109	3
	220 095	2
	260 105	3
	290 097	3
	347 105	3
	178 147	1
	220 140	3
	263 142	2
	305 146	6
	337 145	3
	151 181	3
	222 182	0
	255 175	1
	380 180	3

^{a/} U.S. IBP Grassland Biome data set reference no. A2U00SB.

APPENDIX II
SUMMARY OF DATA

Appendix Table 4. Vegetation and surface area composition percent of the .5-m² plots located in sections 23W, (30 year enclosure and light grazed), 15E (medium grazed), and 23E (heavy grazed).

Species	Plot					Mean
	1	2	3	4	5	
<i>30-Year Enclosure Upland</i>						
ARLO	0.53	0.29	2.52	6.43		1.96
BOGR	59.84	35.22	51.22	31.92	13.64	38.17
CAEL	0.01	0.03	0.01	0.02	0.01	0.02
CAFI					16.02	3.20
LEDE	0.01	0.01	0.00	0.02	0.01	0.01
OPPO	0.73	1.87	0.19	0.10	1.80	0.94
PSTE		0.74			0.00	0.15
SIHY		2.71		0.61		0.66
SPCO	0.25	0.67		0.01	0.00	0.19
STCO	0.00		0.74	0.81	0.91	0.49
THME	0.01	0.01	0.01	0.01	0.02	0.01
Remaining bare ground	38.61	58.44	45.31	60.07	67.59	54.00
<i>Light Grazed Upland</i>						
ARFR	0.01	0.49				0.10
ARLO	1.31	0.03	0.19		0.00	0.31
BOGR	45.46	42.16	41.51	54.42	64.53	50.22

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Light Grazed Upland (Continued)</i>						
BRSL ^{a/}	7.81	3.50			4.05	3.07
CHNA				0.64		0.13
FEOC		0.00		0.02	0.01	0.01
GACO			0.01			0.00
LARE	0.00					0.00
LEDE	0.01	0.01	0.01	0.01	0.02	0.11
LIIN				0.00		0.00
OECO					0.00	0.00
OPPO	0.21	1.90	0.66	2.32	0.45	1.11
PLPU			0.00			0.00
PSTE					0.00	0.00
SAKA					0.00	0.00
SIHY	0.14					0.03
SPCO	0.01	0.01	0.01	0.01	0.01	0.11
SPCR					0.10	0.02
STCO			0.03			0.01
THME	0.00	0.00				0.00
TROC	0.00	0.00	0.01	0.00	0.00	0.00
Remaining bare ground	45.03	51.89	57.58	42.58	30.81	45.58

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Light Grazed Lowland</i>						
ARLO				0.02		0.00
BAOP		0.00	0.00	0.00	0.00	0.00
BOGR	36.54	39.61	44.52	30.82	42.50	38.60
BRSL		1.01	2.55		11.57	3.03
BUDA	3.28					0.66
CAEL	0.18	0.05	0.02	0.06	0.09	0.81
FEOC		0.00	0.00	0.00	0.01	0.00
LARE	0.00			0.00	0.01	0.00
LEDE				0.00		0.00
PLPU	0.01	0.00	0.00	0.00	0.00	0.00
SAKA		0.00	0.00	0.00	0.00	0.00
SPCO	0.01	0.01	0.00			0.00
Remaining bare ground	59.99	59.32	52.90	69.09	45.82	57.42
<i>Medium Grazed Upland</i>						
ALDR		0.00				0.00
ARLO		0.33				0.07
ASTA			0.00	0.00		0.00
BOGR	51.53	48.11	65.25	46.02	67.71	55.73
BRSL		1.28	1.94		2.76	1.12
CAEL	0.04	0.00	0.04	0.07	0.10	0.05

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Medium Grazed Upland (Continued)</i>						
CHLE					0.00	0.00
EULA	0.01					0.00
FEOC	0.00	0.00	0.01	0.00	0.00	0.00
GILA					0.00	0.00
LARE				0.00	0.00	0.00
LEDE		0.00				0.00
MUTO	0.45	0.24				0.14
OPPO		0.61		0.00	0.47	0.22
ORHY		1.21				0.24
PLPU	0.00	0.00	0.01	0.00	0.00	0.00
SPCO				0.00	0.01	0.00
THME	0.01	0.01	0.00	0.01		0.00
Remaining bare ground	47.97	48.21	32.74	53.89	28.94	42.35
<i>Medium Grazed Lowland</i>						
ARFR	0.10	0.12	0.00	0.22		0.09
ARLO		1.70	0.15			0.37
ASVI	0.01	0.00	0.00	0.00	0.00	0.00
BOGR	38.15	47.52	47.20	68.44	76.89	55.64
BRSL		2.94			2.18	1.02
BUDA			2.14		0.05	0.44

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Medium Grazed Lowland (Continued)</i>						
CAEL	0.43	0.53	0.51	0.33	0.23	0.41
CHNA	0.36			0.05	0.19	0.12
FEOC	0.02	0.00	0.00	0.03	0.01	0.01
GACO		0.00		0.00		0.00
HYLU			0.00			0.00
LEDE			0.00			0.00
MUTO		0.19				0.04
OECO		0.00		0.00	0.00	0.00
SPCO	0.06	0.03	0.01	0.03	0.01	0.03
STCO			0.00			0.00
THME	0.00					0.00
TOSE			0.00			0.00
Remaining bare ground	60.86	46.97	49.98	30.89	20.44	41.82
<i>Heavy Grazed Upland</i>						
ALDR			0.00			0.00
ASMO				0.00		0.00
ASTA		0.00				0.00
ASVI	0.00			0.00		0.00
BAOP	0.00					0.00
BOGR	46.17	61.60	26.45	31.29	29.48	39.00

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Heavy Grazed Upland (Continued)</i>						
BRSL		2.69		11.15		2.77
BUDA		3.89	6.63	4.52	2.55	3.52
CAEL	0.09	0.01	0.01	0.02	0.02	0.03
CAFI		0.00				0.00
FEOC	0.01	0.01	0.00	0.01	0.02	0.01
LARE				0.00	0.00	0.00
LEDE	0.01	0.01	0.00	0.01	0.03	0.01
OPPO	0.07	0.37	0.00	3.27	2.17	1.18
PLPU		0.00		0.00	0.00	0.00
SPCO	0.00	0.00	0.00	0.01	0.01	0.00
TOSE		0.00			0.00	0.00
Remaining bare ground	53.65	31.40	66.90	49.73	65.72	53.48
<i>Heavy Grazed Lowland</i>						
BOGR	20.37	32.86	54.53	14.53	2.51	24.96
BRSL	2.52	9.63	3.80	1.39	3.78	4.22
BUDA	8.49	17.12	14.21	64.16	57.76	32.35
CAEL	0.23	0.18	0.09	0.15	0.26	0.18
CHNA		0.00	0.01	0.00	0.01	0.00
FEOC		0.00	0.00			0.00
LARE			0.00		0.00	0.00

Appendix Table 4. (Continued).

Species	Plot					Mean
	1	2	3	4	5	
<i>Heavy Grazed Lowland (Continued)</i>						
LEDE			0.00	0.00		0.00
OPPO	0.05		0.90	0.73		0.34
Remaining bare ground	68.34	40.22	26.45	19.03	36.68	38.14

^{a/} This represents bare soil units which were recorded since they were completely enclosed by a species clump.

Appendix Table 5. Microrelief data for the upland Ascalon soil sites located in sections 23W light grazed, 15E medium grazed, and the 23E heavy grazed.

Treatment	Plot Number	Depressions		Rises	
		Number of Observations	Mean (inches)	Number of Observations	Mean (inches)
30-year ex-closure	1	147	.366	175	.308
	2	166	.386	155	.413
	3	136	.320	158	.275
	4	157	.316	136	.365
	5	139	.309	152	.283
Mean		149	.339	155	.329
Light grazed	1	315	.342	288	.374
	2	259	.294	267	.285
	3	291	.303	264	.334
	4	194	.372	212	.341
	5	277	.372	241	.427
Mean		267	.337	254	.352
Medium grazed	1	529	.324	468	.366
	2	491	.427	498	.421
	3	394	.369	403	.361
	4	314	.443	387	.360
	5	358	.248	335	.265
Mean		417	.362	418	.354
Heavy grazed	1	294	.266	342	.229
	2	284	.374	409	.260
	3	357	.219	377	.208
	4	346	.239	334	.248
	5	300	.365	343	.319
Mean		316	.293	361	.253
Ascalon soil mean		287	.333	297	.322

Appendix Table 6. Microrelief data for the lowland 47-AB undifferentiated soil sites located in sections 23W light grazed, 15E medium grazed, and 23E heavy grazed.

Treatment	Plot Number	Depressions		Rises	
		Number of Observations	Mean (inches)	Number of Observations	Mean (inches)
Light grazed	1	365	.245	385	.232
	2	357	.237	405	.209
	3	361	.201	415	.174
	4	328	.242	365	.217
	5	388	.242	396	.237
Mean		360	.233	393	.214
Medium grazed	1	189	.219	173	.239
	2	189	.207	183	.214
	3	166	.222	155	.238
	4	189	.257	209	.232
	5	228	.321	205	.357
Mean		192	.245	185	.256
Heavy grazed	1	293	.192	303	.186
	2	240	.226	280	.193
	3	238	.227	293	.184
	4	127	.205	139	.187
	5	233	.117	275	.099
Mean		226	.193	258	.170
47-AB mean		259	.224	278	.213

Appendix Table 7. A comparison of the density of live blue grama (*Bouteloua gracilis*) culms on sections 23W light grazed, 15E medium grazed, and 23E heavy grazed.

Treatment	Plot Number	Number of Observations	Number of Culms per 5-cm ² Frame ^{a/}	Mean
30-year ex-closure upland	1	33	126	3.8
	2	16	47	2.8
	3	38	151	4.0
	4	28	119	4.3
	5	17	55	3.2
Mean		26		3.6
Light grazed upland	1	21	76	3.6
	2	25	80	3.2
	3	35	126	3.6
	4	25	87	3.5
	5	39	126	3.2
Mean		29		3.4
Light grazed lowland	1	33	117	3.5
	2	26	118	4.5
	3	27	113	4.2
	4	27	136	5.0
	5	29	121	4.2
Mean		28		4.3
Medium grazed upland	1	27	144	5.3
	2	24	114	4.8

Appendix Table 7. (Continued)

Treatment	Plot Number	Number of Observations	Number of Culms per 5-cm ² Frame ^{a/}	Mean
	3	31	117	3.8
	4	15	59	3.9
	5	26	110	4.2
Mean		25		4.4
Medium grazed lowland	1	22	130	5.9
	2	27	159	5.9
	3	28	152	5.4
	4	35	136	3.9
	5	33	109	3.3
Mean		29		4.9
Heavy grazed upland	1	24	184	7.7
	2	27	172	6.4
	3	24	172	7.2
	4	23	166	7.2
	5	24	174	7.3
Mean		24		7.2
Heavy grazed lowland	1	26	206	7.9
	2	26	219	8.4
	3	16	99	6.2
	4	11	71	6.5
	5	5	56	11.2
Mean		17		8.0

^{a/} Excluding zero readings within blue grama clumps.

APPENDIX III
SPECIES AND CODES

This appendix contains a list of all plant species present on sampled sites for which four-letter computer codes appear in preceding tables.

ALDR	<i>Allium drummondii</i> Regel
ARLO	<i>Aristida longiseta</i> Steud.
ARFR	<i>Artemisia frigida</i> Willd.
ASVI	<i>Asclepias viridiflora</i> Raf.
ASTA	<i>Aster tanacetifolius</i> H.B.K.
ASMO	<i>Astragalus mollissimus</i> Torr.
BAOP	<i>Bahia oppositifolia</i> (Nutt.) DC.
BOGR	<i>Bouteloua gracilis</i> (H.B.K.) Lag.
BUDA	<i>Buchloe dactyloides</i> (Nutt.) Engelm.
CAEL	<i>Carex eleocharis</i> Bailey
CAFI	<i>Carex filifolia</i> Nutt.
CHLE	<i>Chenopodium leptophyllum</i> Nutt.
CHNA	<i>Chrysothamnus nauseosus</i> (Pall.) Britt.
EULA	<i>Eurotia lanata</i> (Pursh) Moq.
FEOC	<i>Festuca octoflora</i> Walt.
GACO	<i>Gaura coccinea</i> Nutt. ex. Pursh
GILA	<i>Gilia laxiflora</i> (Court.) Osterh.
HYLU	<i>Hymenopappus lugens</i> Greene
LARE	<i>Lappula redowskii</i> (Hornem.) Greene
LEDE	<i>Lepidium densiflorum</i> Schrader
LIIN	<i>Lithospermum incisum</i> Lehm.
MUTO	<i>Muhlenbergia torreyi</i> (Kunth) Hitchc.
QECO	<i>Oenothera coronopifolia</i> Torr. + Gray
OPPO	<i>Opuntia polyacantha</i> Haw.
ORHY	<i>Oryzopsis hymenoides</i> (Roem. + Schult.) Ricker
PLPU	<i>Plantago purshii</i> Roem. + Schult.
PSTE	<i>Psoralea tenuiflora</i> Pursh
SAKA	<i>Salsola kali tenuifolia</i> Tausch
SIHY	<i>Sitanion hystrix</i> (Nutt.) J.G. Smith
SPCO	<i>Sphaeralcea coccinea</i> (Pursh) Rydb.
SPCR	<i>Sporobolus cryptandrus</i> (Torr.) A. Gray
STCO	<i>Stipa comata</i> Trin. and Rupr.
THME	<i>Thelesperma megapotamicum</i> (Spreng.) Kuntze
TOSE	<i>Townsendia sericea</i> Hook.
TROC	<i>Tradescantia occidentalis</i> (Britt.) Smyth