Technical Report No. 108

HERBAGE DYNAMICS ON A MIXED PRAIRIE GRASSLAND NEAR HAYS, KANSAS

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ABSTRACT

Specific objectives of the project included: (i) to estimate the net primary production of shoot and roots, (ii) to estimate standing dead and mulch standing crops, and (iii) to estimate the caloric content of biomass components. Data were collected from an ungrazed and a grazed site on a typical *Andropogon-Bouteloua* community. Peak standing crop of green herbage varied from 222 g/m^2 on the ungrazed prairie (July 17) to 243 g/m^2 on the grazed area (July 2). Average productivity rate varied from 2.10 g/m^2/day on the grazed area. Average standing dead for the ungrazed treatment was 123 g/m^2 while for the grazed treatment it was 84 g/m^2. Mulch estimates varied from a mean of 1,031 g/m^2 on the ungrazed to 375 g/m^2 on the grazed. Peak root standing crops of 1,500 to 1,600 g/m^2 occurred in summer and low root standing crops of 446 to 454 g/m^2 occurred during fall and early winter.

Further analysis of data will allow us to attempt estimates of compartmental transfer rates and also report calorific data.

INTRODUCTION

Ecology today is predicated on a comprehensive understanding of the structure and function of ecosystems. Such knowledge is essential if predictive models are to be developed which will govern decisions on the management of these ecosystems.

The mixed prairie ecosystem was first described by Clements (1916) using dominant species as criteria for community delineation. Most ecological studies following Clements' initial work concentrated upon structural features of the grassland ecosystem. Only recently have investigators undertaken the task of studying the functional aspects of grassland systems, namely energy flow and nutrient cycling.

This project, coordinated and financed by the Grassland Biome of the International Biological Program, was designed to study selected functional attributes of a mixed prairie grassland near Hays, Kansas. The study site was a part of the Comprehensive Network of the Grassland Biome Project.

Specific objectives of the project included: (i) to estimate the net primary production of shoots and roots, (ii) to estimate standing dead and mulch standing crops, and (iii) to estimate the caloric content of biomass components.

DESCRIPTION OF STUDY AREA

The site selected for study in this project is typical of the grasslands located between the shortgrass plains of Colorado and the true prairie of Kansas. It is dominated by an *Andropogon-Bouteloua* community.

The basic design of the study consisted of a grazed and ungrazed treatment, with two replicates. Both treatments are located on similar community types. Large grazing herbivores were excluded from both sites during the study.

The topography of the site is characterized by steep to gentle slopes bordering a central drainage. Geologically, the area contains strata of the Cretaceous Age, particularly materials of the Niobrara Formation. The prominent stratum exposed is the Fort Hays Limestone which is capped on the uplands by Loveland Loess. Climatalogical features of the site include: a 22 to 24 inch annual precipitation, a 160 to 170 day growing season, and a 50°F mean annual temperature.

The ungrazed community of the site is typical of much of the surrounding grassland and is dominated by *Andropogon gerardi, Andropogon scoparius*, and *Bouteloua curtipendula*. Other grasses found include *Bouteloua gracilis, B. hirsuta, Sorghastrum nutans, Panicum virgatum,* and *Sporobolus asper*. Some common forbs are *Schrankia uncinata, Echinacea angustifolia* and *Aster oblongifolius*. The soils supporting the community are immature and shallow, with only an A to C horizon development.

The grazed treatment dominants are *Bouteloua curtipendula* and *B. gracilis*. Other grasses formed on this site are *Buchloe dactyloides, Aristida longiseta,* and *Agropyron smithii*. Some common forbs are *Echinacea angustifolia, Gutierrezia sarothral, Psoralea tenuiflora,* and *Yucca glauca*. Soils under this community are also shallow with A to C horizon development.

METHODS AND PROCEDURES

The methods used in this study followed the outline in the IBP manual of methods for the Comprehensive Network. A few modifications were made in cases in which it was impractical or impossible to follow IBP guidelines.

Aboveground Biomass

Aboveground biomass refers to standing live and standing dead plant material. Sampling sites were located randomly within replicates at the beginning of each sampling period. Aboveground biomass was sampled biweekly during the period of active growth and monthly during the dormant season. Quadrat size was $1/2m^2$ with five quadrats clipped in each replicate. The dry weight rank method was utilized through September and then abandoned due to high variability in the data.

The vegetation was clipped by species in the field, then dried for 24 hours at 65°C in the laboratory, and then weighed to the nearest .01 g. After weighing, five samples of major species, both live and dead, were selected randomly and analyzed in an oxygen bomb calorimeter to determine calorific content.

Mulch

The quadrats used for aboveground biomass harvesting were also used for collecting mulch. The majority of the litter was collected by hand and the rest by use of a vacuum cleaner. Two 20 g subsamples of mulch from each quadrat were taken in the laboratory and ashed at 600°C for four hours. The rest of the mulch was separated from the inorganic material by the flotation method, then dried and weighed. Subsamples were analyzed for caloric content in the same manner as aboveground biomass.

Belowground Biomass

Roots and soil organic matter were collected by means of 2.5 cm cores taken at three points in each harvest quadrat. Samples were taken at 0 to 5, 5 to 10, and 10 to 15 cm depths. These depths were combined to give a total of three root samples and three organic matter samples for each depth. The roots were washed over a 32-mesh screen to remove soil particles. These samples were dried, weighed, and analyzed for caloric content. Organic matter samples were sent to the IBP laboratory at Colorado State University for analysis.

Climate

A meteorological station was established at the grazed treatment to record the following items at weekly intervals:

(i) Average wind velocity per week

(ii) Relative humidity

(iii) Air temperature

(iv) Soil temperature

(v) Precipitation

(vi) Solar radiation

RESULTS AND DISCUSSION

Green Herbage Compartment

The community peak standing crop of green herbage of 222 g/m^2 was reached on July 17, 1970 on the ungrazed treatment. This was not significantly different from the peak green standing crop of 243 g/m^2 attained on July 2, 1970 on the grazed treatment (Table 1). There is some

Table 1. Means and 80% confidence limits of total green herbage (g/m^2) for Hays Site.

Month	Ungrazed	Grazed
January 16		
February 15		
March 15		
April 15	2 ± 1	1 ± 1
May 15	73 ± 10	92 ± 6
June 1	79 ± 22	185 ± 43
June 15	171 ± 19	170 ± 21
July 2	164 ± 17	243 ± 29
July 17	222 ± 22	186 ± 20
August 1	220 ± 30	179 ± 22
August 16	191 ± 15	160 ± 14
September 1	123 ± 38	173 ± 35
October 15	34 ± 36	49 ± 13
November 20		
December		

indication that, from April 15, 1970 to June 1, 1970, the grazed treatment made a more rapid growth (approximately 184 g/m^2) while on the ungrazed treatment during the same time period, the green biomass increased only about 77 g/m^2. This may reflect the absence of a thick mulch layer on the grazed site, thus permitting quicker soil warming and more light penetration.

There is considerable variability in the data due to the small number of quadrats harvested. No reliable data were obtained from the dry-weight rank method, and it was discontinued during the 1970 sampling season. No attempt has been made to summarize these data in this report.

Productivity rates estimated for various time periods during the growing season are of the same magnitude as reported in the literature. The major growth period on the grazed treatment occurred between May 15 and June 1 (Table 2). This is two weeks earlier than the peak growth period on the ungrazed treatment. The average productivity rate for the grazed treatment was slightly higher (2.60 $g/m^2/day$) than on the ungrazed treatment (2.10 $g/m^2/day$); however, it is doubtful that this difference is significant.

Standing Dead Compartment

The estimates of standing dead biomass on both treatments fluctuated greatly during the sampling period. The smallest amount of standing dead was found during the summer months (Table 3). This was true for both treatments. However, these summer estimates may be spuriously low. There was less standing dead biomass during the summer, but the magnitude of change from June 1 to July for either treatment is unexplained. One possibility is that standing dead material was transferred to the mulch compartment, but no

Table 2. Green biomass productivity--Hays Site.

Period	Interval (Days)	Peak Standing Crop	Positive Gain	Rate g/m^2/day
Ungrazed Treatment				
March 15-April 15	30	2	2	.07
April 15-May 15	30	73	71	2.37
May 15-June 1	16	79	6	.38
June 1-June 14	14	171	92	6.57
June 14-July 17	33	222	51	1.50
Average productivity to peak standing crop	123	222	222	1.80
Average productivity for growing season	174	222	222	1.28
Grazed Treatment				
March 15-April 15	30	1	1	.03
April 15-May 15	30	92	91	3.00
May 15-June 1	16	184	92	5.71
June 1-July 2	14	242	58	4.10
Average productivity to peak standing crop	90	242	242	2.69
Average productivity for growing season	174	242	242	1.39

Table 3. Means and 80% confidence limits of total standing dead (g/m^2) at Hays Site.

Month	Treatment	
	Ungrazed	Grazed
January 16	114 ± 17	62 ± 12
February 15	224 ± 54	128 ± 44
March 15	234 ± 41	83 ± 29
April 15	184 ± 32	95 ± 18
May 15	Data Missing	Data Missing
June 1	199 ± 63	113 ± 40
June 14	7 ± 5	Data Missing
July 2	19 ± 9	2 ± 1
August 1	15 ± 6	2 ± 2
August 16	5 ± 3	2 ± 2
September 1	121 ± 31	32 ± 11
October 15	156 ± 21	140 ± 22
November 20	197 ± 9	120 ± 11
December		144 ± 31

significant increases were noted in mulch amounts. Based on the standing dead estimates in Table 3, the average standing dead for the ungrazed treatment was 123 g/m^2, while for the grazed treatment it was 84 g/m^2.

The high degree of variability in the standing dead data (Table 4) hinders the interpretation of standing dead dynamics.

Mulch Compartment

Mulch levels remained relatively constant on both treatments for the entire sampling period (Table 5). The mean mulch level for the ungrazed treatment was 1,031 g/m^2, while for the grazed treatment, the mulch level was significantly lower at 375 g/m^2. Such a differential is not expected, since the grazed treatment was moderately grazed prior to exclusion and has been excluded for only one growing season.

Root Compartment

Mean root biomass (0 to 15 cm) are given in Table 6 for the grazed and ungrazed treatments. These estimates are subject to high variation and are thus difficult to interpret. Peak root standing crops of about 1,600 g/m^2 (ungrazed treatment) and 1,500 g/m^2 (grazed treatment) occurred in the summer growing season. Low root standing crops occurred during the fall and early winter months (454 g/m^2--ungrazed treatment; 446 g/m^2--grazed treatment). Based on these values, an annual productivity estimate of approximately 1,200 g/m^2 has been obtained. This would mean a very high turnover rate for both treatments.

Appendices

Tabulated material in the appendices consists of a species list and selected meteorological data for the site.

Table 4. Means and coefficients of variation (g/m^2) for green herbage, standing dead, and total biomass. Ungrazed treatment, Hays Site.

Month	Total Green		Total Standing Dead		(Green + S.D.) Total Biomass	
	Mean	C.V.	Mean	C.V.	Mean	C.V.
January 16			114	36	114	36
February 15			224	55	224	55
March 15			234	40	234	40
April 15	2	154	183	39	186	38
May 15	73	31			73	31
June 1	79	65	199	72	139	54
June 14	171	26	7	174	167	41
July 2	164	62	19	104	165	42
July 17	222	23	6	161	229	24
August 1	220	31	15	16	117	34
August 16	191	17	5	127	96	18
September 1	123	71	121	60	240	30
October 15			156	31	163	32
November 20			197	11	197	11
December						

Table 4. (Continued). Grazed treatment.

Month	Total Green		Total Standing Dead		(Green + S.D.) Total Biomass	
	Mean	C.V.	Mean	C.V.	Mean	C.V.
January 16			62	48	62	48
February 15			128	78	128	78
March 15			83	80	83	80
April 15	1	137	95	43	90	55
May 15	92	16			92	16
June 1	184	53	113	81	143	66
June 14	170	28			170	28
July 2	164	24	2	122	243	27
July 17	222	23	11	161	186	24
August 1	220	31	2	207	162	18
August 16	191	17	2	207	162	18
September 1	173	47	32	81	198	53
October 15	34	240	140	36	189	16
November 20			120	21	120	21
December 18			144	31	144	31

Table 5. Mean mulch (g/m^2) estimates and coefficients of variation for ungrazed and grazed treatments--Hays Site.

Month	Ungrazed		Grazed	
	$\bar{X}$	C.V.	$\bar{X}$	C.V.
January 16	1,043	40	247	7
February 15	1,160	54	401	22
March 15	1,178	41	537	68
April 15	1,091	36	568	70
May 15	479	54	346	25
June 1	1,251	20	730	24
June 14	1,134	45	403	33
July 2	832	29	435	46
July 17	985	21	451	8
August 1	1,195	32	203	39
August 16	1,067	33	184	70
September 1	1,148	24	238	40
October 15	1,004	35	211	42
November 20	992	28	165	55

Table 6. Mean root biomass (g/m^2) for 0 to 15 cm depth, Hays Site.

Month	Treatment	
	Ungrazed	Grazed
January	798	1,052
February	769	815
March	1,368	753
April	937	983
May	1,375	1,212
June	1,934	1,753
July	1,861	1,790
August	1,439	1,322
September	528	412
October	463	431
November	408	408
December	418	532

SUMMARY

This report is a preliminary analysis of data collected on the Hays Site. We have included only productivity and standing crop estimates. Attempts at estimating compartmental transfer rates are still in the initial stages. It is anticipated that these estimates will be forthcoming in a graduate student's thesis. Also, calorific data will be reported in the thesis.

Our primary conclusion is that, if reliable estimates of above- and belowground biomass are to be obtained, the sampling intensity must be much greater. Since increasing the destructive harvest sampling would stress the ecosystem unduly, a double sampling scheme combining harvest and weight estimate plots seems appropriate.

LITERATURE CITED

Clements, F. E. 1916. Plant succession: An analysis of the development of vegetation. Carnegie Inst. of Washington Publ. 242 p.

APPENDIX I

Species List Appendix

Hays Site IBP

SYMBOL	SCIENTIFIC NAME
Grasses	
AGSM	*Agropyron smithii*
ANGE	*Andropogon gerardi*
ANSC	*Andropogon scoparius*
ARLO	*Aristida longesita*
BOCU	*Bouteloua curtipendula*
BOGR	*Bouteloua gracilis*
BOHI	*Bouteloua hirsuta*
BRJA	*Bromus japonicus*
BUDA	*Buchloe dactyloides*
CHVE	*Chloris verticillata*
PAVI	*Panicum virgatum*
SONU	*Sorghastrum nutans*
SPAS	*Sporobolus asper*
SPPI	*Sporobolus pilosus*
SPCR	*Sporobolus cryptandrus*
Forbs	
AMPS	*Ambrosia psilostachya*
AMCA	*Amorpha canescens*
ARPU	*Aristida purpurea*
ARTE	*Arenaria texana*
ASAR	*Aster arenosus*
ASFE	*Aster fendleri*
ASMO	*Astragalus mollissimus*
ASMU	*Aster multiflorus*
ASOB	*Aster oblongifolius*
ASPU	*Asclepias pumila*
ASVI	*Asclepias viridis*
CAIN	*Callirhoe involucrata*
CIOC	*Cirsium ochrocentrum*
CIUN	*Cirsium undulatum*

ECAN	*Echinaceae angustifolia*
ERAS	*Erysium asperum*
ERRA	*Erigeron racemosus*
EUMA	*Euphorbia marginata*
EVPI	*Evolvulus pilosus*
GACO	*Gaura coccinea*
GRSQ	*Grindelia squarrosa*
GUSA	*Gutierrezia sarothrae*
HEAN	*Helianthus annuus*
HEHI	*Hedeoma hispida*
HEMA	*Helianthus maximiliana*
HOAN	*Houstonia angustifolia*
HOPU	*Hordeum pusillum*
KUGL	*Kuhnia glutinosa*
LECA	*Leptilon canadensis*
LEOV	*Lesquerella ovalifolia*
LIPU	*Liatris punctata*
LYJU	*Lygodesmia juncea*
MACO	*Malvastrum coccineum*
MEAL	*Melilotus alba*
MEOF	*Melilotus officinalis*
OEFR	*Oenothera freemontii*
OELA	*Oenothera lavandulaefolia*
OESE	*Oenothera serrulata*
ONOC	*Onosmodium occidentale*
OXST	*Oxalis stricta*
PAJA	*Paronychia jamesii*
PEPU	*Petalostemon purpureur*
POAL	*Polygala alba*
PSCU	*Psoralea cuspidata*
PSES	*Psoralea esculenta*
PSTE	*Psoralea tenuiflora*
RACO	*Ratibida columnifera*
SCRE	*Scutellaria resinosa*
SCUN	*Schrankia uncinata*
SEPL	*Senecio plattensis*
SIHY	*Sitanion hystrix*
SISP	*Silphium speciosum*

SOMI	*Solidago missouriensis*
SOMO	*Solidago molliss*
SORI	*Solidago rigida*
STLI	*Stenosiphon linifolius*
TEST	*Tetraneuris stenophylla*
THGR	*Thelesperma gracile*
TRRA	*Tragia ramosa*
VEBI	*Verbena bipinnatifida*
VEST	*Verbena stricta*
YUGL	*Yucca glauca*

Sedges

CAGR	*Carex gravida*
CASP	*Carex* spp.

APPENDIX II

APPENDIX TABLES

Appendix Table 1. Daily precipitation for 1970. January-May compiled from records of the Fort Hays Experiment Station, Hays, Kansas. June-December data are from the IBP meteorological station.

Day	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
1			T	.33	.19	.42							
2			.01	.02			.04						
3			.01									T	
4						.30						T	
5													
6			.05										
7								.22					
8		T											
9											.19		
10			T									T	
11			T			.33	1.11					T	
12				.05									
13					T				.58				
14			T		.70	2.20			.16				
15						1.33			T	.05			
16			.18	1.14				.79	.70			T	
17	T		T	.05					.02			T	
18	T		.07	.08		1.47							
19	T		T										
20													
21	.06			.10				.70				T	
22	T										T	T	
23					1.10								
24									1.03				
25			.05		.26								
26				T						.04			
27							.42			.16			
28			.21										
29					.01		.04						
30			.13										
31			.33		T								
Total	.06	T	1.04	1.77	1.96	6.05	1.61	1.71	2.49	.25	.19	T	17.13
Longtime Average													22.81

Appendix Table 2. Average wind velocity in miles per hour at weekly intervals specified.

Month	Dates and Wind Velocity					Monthly Average
January	No Data					
February	Jan. 29-5 5.86	6-12 5.46	13-19 6.81	20-26 5.99		5.88
March	Feb. 27-5 6.9	6-12 8.0	13-19 5.19	20-26 7.9		6.99
April	Mar. 27-3 6.85	4-9 6.79	10-16 10.32	17-23 9.23	24-30 7.01	8.04
May	1-7 9.03	8-14 6.76	15-21 8.99	22-28 6.17		7.73
June	May 29-4 6.87	5-11 6.85	12-18 6.85	19-25 4.91		6.37
July	June 26-2 7.26	3-9 3.69	10-16 1.07	17-23 5.84	24-30 7.3	4.93
August	July 31-6 5.13	7-14 5.23	15-21 4.61	22-28 4.34		4.82
September	Aug. 29-4 5.96	5-11 7.67	12-18 6.27	19-24 8.86		7.19
October	Sept. 25-2 4.42	3-9 9.99	12-18 7.39	20-28 7.69		7.32
November	Oct. 29-5 7.42	6.12 5.42	13-19 6.13	20-26 7.41		6.59
December	Nov. 27-5 8.46	6-12 5.31	13-19 6.28	20-31 4.97		6.25
				Yearly Average		6.55

Appendix Table 3. Daily maximum and minimum temperatures for 1970.

	January		February		March		April		May		June	
Day	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	37	20	52	19	50	32	33	30	62	32	68	58
2	33	5	23	9	70	38	50	22	72	32	67	58
3	40	14	40	26	56	22	40	28	81	42	68	52
4	40	8	43	28	56	30	52	23	84	43	70	50
5	18	6	54	16	60	32	71	20	87	47	86	48
6	27	-2	61	26	56	30	76	33	88	48	92	55
7	21	-1	63	26	73	30	79	40	84	56	88	56
8	18	-9	54	20	80	37	64	43	82	49	87	64
9	35	-5	54	16	31	30	77	34	78	54	88	64
10	37	20	61	27	36	20	79	35	86	48	95	62
11	43	23	41	22	32	22	80	49	88	64	76	60
12	46	12	56	12	40	22	51	41	94	59	81	53
13	59	15	32	18	35	15[a/]	54	33	65	61	88	54
14	45	18	38	14	49	16	58	29	64	29	86	63
15	49	17	50	28	35	20	71	50	73	40	92	62
16	18	17	69	22	34	26	70	39	85	43	88	62
17	9	8	88	31	34	22	58	41	92	50	92	64
18	13	2	37	35	32	30	74	37	94	60	84	58
19	19	9	55	11	43	24	61	24	93	68	74	48
20	19	13	61	16	46	19	58	35	93	78[a/]	72	44
21	26	6	64	30	60	18	66	30	90	58	78	42
22	54	20	62	30	56	31	69	49	88	57	70	46
23	66	33	58	28	71	27	71	34	88	60	78	52
24	54	32	63	20	66	19	64	32	82	60	82	50
25	64	37	49	20	46	35	76	41	80	56	95	70
26	60	24	56	21	52	18	81	50	87	60	90	64
27	61	20	59	24	36	30	89	56	84	60	90	60
28	51	35	45	40	38	3	85	46	74	60	94	70
29	41	18			36	17	75	52	83	58	100	72
30	48	14			34	32	51	48	86	60	92	73
31	46	24	—	—	33	29	—	—	66	56	93	74
Monthly Average	38	14	52	22	49	25	66	38	85	53	84	56
Average	26		37		37		52		69		70	
Longtime Average	41	16	46	19	56	27	67	39	76	49	86	60
Average	29		32		42		53		63		73	

Appendix Table 3. (Continued)

	July		August		September		October		November		December	
Day	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	97	71	108	68	92	66	87	49	51	33	69	37
2	101	67	110	76	94	67	86	44	42	31	60	22
3	92	60	104	72	94	60	70	42	40	31	58	38
4	88	52	110	80	88	53	87	48	50	34	65	17
5	84	55	105	78	98	70	85	60	65	22	45	25
6	93	60	108	80	102	74	85	60	73	27	55	19
7	94	64	108	74	93	54	67	65	68	36	63	22
8	96	70	94	72	94	60	57	34	65	50	66	24
9	94	70	90	72	82	72	55	32	57	38	48	30
10	97	68	94	68	77	43	61	37	68	28	38	37
11	84	64	92	60	94	45	50	45	43	37	36	18
12	88	66	100	59	57	54	70	31	45	22	49	13
13	95	70	100	60	45	60	60	36	39	33	52	10
14	99	68	101	63	56	50	48	40	38	29	55	17
15	88	64	98	65	50	42	55	34	55	12	43	30
16	92	60	84	65	66	52	58	26	66	23	52	18
17	100	62	101	66	59	48	47	40	64	32	57	23
18	108	75	104	65	80	58	52	44	62	24	27	27
19	90	68	98	68	88	62	55	45	50	38	32	6
20	75	55	71	61	94	71	69	41	61	25	34	15
21	80	58	78	61[a]	78	60	74	39	60	25	29	25
22	84	50	86	64	57	55	66	37	27	19	58	25
23	88	55	90	55	54	50	69	50	28	10	37	6
24	82	62	93	57	82	41	73	34	48	16	43	10
25	96	78	99	59	60	52	66	50	67	35	41	3
26	100	70	104	62	68	36	44	43	34	26	47	18
27	97	66	103	72[a]	80	48	50	33	38	24	52	24
28	96	70	100	66	82	43	56	28	42	17	44	13
29	104	70	92	60	82	46	59	28	67	20	57	19
30	108	68	96	62	81	48	60	41	73	37	46	17
31	112	75	93	63	—	—	46	34	—	—	61	14
Monthly Average	94	65	97	61	78	55	63	41	52	28	49	20
Average	79		79		66		52		39		34	
Longtime Average	93	65	92	64	83	55	71	42	56	28	44	19
Average	79		78		69		56		42		31	

[a] These figures are from the Fort Hays Experiment Station due to a malfunction in our equipment from March 15 to May 20.

Appendix Table 4. Daily percent relative humidity for 1970.

Day	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	a/		90	60	82	80					76	38
2			90	80	80	50					66	30
3			90	68	78	40					76	38
4			80	50	60	26					76	33
5			75	45	66	30					73	30
6			82	42	74	26					60	30
7			70	28	76	18					70	28
8			76	30	50	20					66	34
9			60	30	76	50					72	36
10			70	30	77	42					70	24
11			80	49	73	58					70	56
12			81	36	73	48					78	50
13			77	50	b/						74	30
14			82	48							74	49
15			82	44							76	47
16			72	18							75	38
17			74	42							74	38
18			80	50							72	50
19			89	42							90	50
20			92	32					b/		82	50
21			75	35					65	38	86	44
22			86	42					74	32	86	50
23			90	52					73	48	88	38
24			86	42					74	32	82	46
25			90	40					74	33	76	42
26			65	25					72	35	82	44
27			64	34					74	40	84	40
28		a/	82	56					70	52	b/	
29	80	50							75	36		
30	85	52							74	36		
31	80	58							75	56		

Appendix Table 4. (Continued)

Day	July		August		September		October		November		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1			78	32	66	32	55	26	61	34	56	30
2	70	38	68	28	67	28	54	18	60	32	43	20
3	76	40	70	30	68	27	66	28	68	50	51	30
4	88	42	62	30	68	32	57	32	66	42	62	28
5	82	46	64	30	65	22	68	32	65	33	50	41
6	85	30	60	28	54	20	69	30	66	22	57	44
7	85	46	70	26	52	19	72	55	54	22	58	41
8	90	44	72	40	60	22	72	57	56	26	56	20
9	60	38	72	39	60	23	62	26	58	30	38	22
10	74	34	68	32	50	18	64	34	64	24	40	18
11	75	48	70	30	58	50	69	52	70	40	52	30
12	72	44	70	25	70	68	70	28	70	40	62	48
13	70	36	54	22	70	62	65	40	70	50	70	38
14	60	31	76	40	68	44	72	50	72	28	65	20
15	64	36	88	36	68	66	70	28	75	25	72	40
16	60	40	78	38	66	57	67	28	50	20	60	30
17	74	30	84	42	66	46	69	54	64	30	63	28
18	46	25	80	36	65	46	70	52	65	30	62	25
19	72	36	85	32	66	40	60	52	68	34	74	30
20	74	40	61	30	60	30	72	36	65	40	72	40
21	76	34	b/		67	34	70	30	70	23	70	25
22	76	34			70	50	69	38	64	33	70	30
23	60	30			70	55	69	34	44	28	68	28
24	68	36			67	32	64	18	36	23	72	40
25	58	30			60	32	67	15	68	34	68	30
26	50	28			66	24	70	30	66	53	65	40
27	68	32	b/		60	24	68	34	70	42	68	38
28	68	30	48	34	54	24	68	25	68	32	66	30
29	76	26	52	25	78	24	50	25	65	20	72	42
30	75	30	62	28	67	32	60	22	34	20	68	30
31	70	30	62	30			55	32				

a/ From January 1 to January 28 the station was not established.
b/ From March 15 to May 20 and from June 29 to July 1, data are not available due to a malfunction of the hygrothermograph.

Appendix Table 5. Daily percent relative humidity for 1970.

Day	January Max.	January Min.	February Max.	February Min.	March Max.	March Min.	April Max.	April Min.	May Max.	May Min.	June Max.	June Min.
1	a/		90	60	82	80					76	38
2			90	80	80	50					66	30
3			90	68	78	40					76	38
4			80	50	60	26					76	33
5			75	45	66	30					73	30
6			82	42	74	26					60	30
7			70	28	76	18					70	28
8			76	30	50	20					66	34
9			60	30	76	50					72	36
10			70	30	77	42					70	24
11			80	49	73	58					70	56
12			81	36	73	48					78	50
13			77	50	b/						74	30
14			82	48							74	49
15			82	44							76	47
16			72	18							75	38
17			74	42							74	38
18			80	50							72	50
19			89	42							90	50
20			92	32					b/		82	50
21			75	35					65	38	86	44
22			86	42					74	32	86	50
23			90	52					73	48	88	38
24			86	42					74	32	82	46
25			90	40					74	33	76	42
26			65	25					72	35	82	44
27			64	34					74	40	84	40
28	a/		82	56					70	52	b/	
29	80	50							75	36		
30	85	52							74	36		
31	80	58							75	56		

a/ From January 1 to January 28 the station was not established.
b/ From March 15 to May 20 and from June 29 to July 1 data are not available due to a malfunction of the hygrothermograph.

Appendix Table 6. Daily, monthly, and seasonal evaporation from a free-water surface for the 1970 growing season; compiled from records of the Fort Hays Experiment Station, Hays, Kansas.

Day	Evaporation in Inches						
	April	May	June	July	Aug.	Sept.	Seasonal
1	.00	.19	.09	.40	.30	.35	
2	.03	.22	.28	.42	.40	.26	
3	.12	.26	.18	.37	.43	.30	
4	.12	.14	.15	.32	.37	.21	
5	.15	.25	.19	.37	.50	.45	
6	.12	.32	.22	.28	.47	.63	
7	.34	.37	.38	.20	.32	.28	
8	.24	.22	.43	.33	.26	.32	
9	.16	.26	.34	.26	.30	.44	
10	.18	.19	.31	.67	.25	.31	
11	.20	.28	.44	.22	.28	.38	
12	.36	.24	.35	.23	.34	.14	
13	.24	.26	.28	.30	.45	.05	
14	.21	.19	.45	.44	.46	.01	
15	.21	.16	.26	.23	.31	.06	
16	.13	.24	.24	.42	.12	.00	
17	.15	.28	.30	.47	.34	.00	
18	.17	.34	.63	.44	.33	.09	
19	.24	.39	.22	.34	.29	.18	
20	.08	.37	.35	.03	.10	.44	
21	.14	.31	.24	.38	.11	.26	
22	.32	.44	.26	.37	.25	.19	
23	.10	.11	.27	.34	.30	.08	
24	.21	.24	.36	.24	.29	.18	
25	.10	.21	.26	.39	.27	.21	
26	.21	.25	.29	.51	.42	.14	
27	.33	.27	.55	.30	.49	.12	
28	.35	.15	.47	.32	.57	.20	
29	.25	.16	.33	.41	.45	.20	
30	.16	.33	.31	.35	.22	.10	
31		.21		.35	.35		
Monthly total	5.62	7.85	9.43	10.70	10.34	6.58	50.52
Monthly daily average	.18	.25	.31	.35	.33	.22	
64-year average (1907-1970)	5.73	6.84	8.63	10.21	9.33	7.22	47.96

APPENDIX III

FIELD DATA

Aboveground Biomass Data

Aboveground biomass data collected in 1970 at the Hays Site is Grassland Biome data set A2U0006. Data were collected on Form NREL-01. A copy of the form and an example of the data follow.

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET - ABOVEGROUND BIOMASS

[illegible]	SITE	INITIALS	DATE Day	Mo	Yr	TREATMENT	REPLICATE	PLOT SIZE	QUADRAT	CLIP-RANK	GROWTH FM.	GENUS	SPECIES	SUBSPECIES	PHENOLOGY	RANK	SACK NO.	DRY WT.	SPECIAL	DRY WT. SP.
-2	3-4	5-7	8-9	10-11	12-13	14	15	16-19	21-23	25	27	29-30	31-32	34	36-37	39-40	42-45	47-52	54-57	59-

…TA TYPE
- Aboveground Biomass
- Litter
- Belowground Biomass
- Vertebrate - Live Trapping
- Vertebrate - Snap Trapping
- Vertebrate - Collection
- Avian Flush Census
- Avian Road Count
- Avian Road Count Summary
- Avian Collection - Internal
- Avian Collection - External
- Avian Collection - Plumage
- Invertebrate
- Microbiology - Decomposition
- Microbiology - Nitrogen
- Microbiology - Biomass
- Microbiology - Root Decomposition
- Microbiology - Respiration

…TE
- Ale
- Bison
- Bridger
- Cottonwood
- Dickinson
- Hays
- Hopland
- Jornada
- Osage
- Pantex
- Pawnee

…EATMENT
- Ungrazed
- Lightly grazed
- Moderately grazed
- Heavily grazed
- Grazed 1969, ungrazed 1970

PHENOLOGY
- 01 Germinated or sprouted
- 02 Early vegetation
- 03 Prebud
- 04 Bud stage
- 05 Early bloom
- 06 Mid-bloom
- 07 Full bloom
- 08 Late bloom
- 09 Milk stage
- 10 Dough stage
- 11 Ripe seed
- 12 Past ripe
- 13 Stem cured
- 14 Vegetative regrowth
- 15 Regrowth flowering
- 16 Regrowth ripe seed
- 17 Standing dead
- 18 Winter dormant

CLIP RANK
- 1 Harvested
- 2 Harvested and ranked
- 3 Ranked

GROWTH FORM
- 1 Perennial grass
- 2 Annual grass
- 3 Sedge, rush, etc.
- 4 Annual forb
- 5 Biennial forb
- 6 Perennial forb
- 7 Half-shrub
- 8 Shrub
- 9 Tree
- 0 Miscellaneous

*** EXAMPLE OF DATA ***

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890


0106LT 21077011 .71
                         1 2 1 ANGE     03  1         54.36
                         1 2 1 PAVT     03  2         18.26
                         1 2 6 PSTE     08  3         15.12
                         1 2 1 ROCU     03  4          5.20
                         1 2 6 SCUN     08  5         10.35
                         1 2 6 AMPS     03  6          4.89
                         1 2 6 SOMT     03  7          0.66
                         1 2 6 CIUN     03  8          0.46
                         2 2 1 ANGE     03  1         25.58
                         2 2 1 ANSC     03  2         48.86
                         2 2 6 SCUN     08  3         12.87
                         2 2 1 ROCU     03  4          6.55
                         2 2 6 ECAN     02  5          2.28
                         2 2 6 MEAL     06  6          1.73
                         2 2 6 SOMT     03  9          0.83
                         2 2 6 ASOR     03  8          0.62
                         2 2 6 OFSE     03 10          1.78
                         2 2 6 STLT     03 11          0.43
                         2 2 1 ANSC     17 12          3.40
                         2 2 1 SONU     03  7          2.90
                         3 2 1 ANGE     03  1         38.04
                         3 2 1 ANSC     03  2         23.60
                         3 2 6 PSTE     08  3         10.89
                         3 2 6 SCUN     08  4         10.17
                         3 2 6 ECAN     03  6          1.58
                         3 2 6 THGR     08  7          0.99
                         3 2 6 SOMT     03  8          0.79
                         3 2 6 OFSE     03  9          0.44
                         3 2 6 ANSC     17 10          2.73
                         3 2 6 PAVT     03  5          4.16
                         4 2 6 SORT     03  1         16.48
                         4 2 1 ANGE     03  2         46.09
                         4 2 6 SCUN     08  3          5.10
                         4 2 1 ROCU     08  4          6.19
                         4 2 6 PSTE     08  5          3.79
                         4 2 6 HOAN     06  5          0.66
```

4	2	7	OESE	04	7	0.69
4	2	6	ECAN	02	8	0.59
5	2	1	ANSC	03	1	82.88
5	2	1	ANGE	03	2	7.74
5	2	6	PSTE	08	3	6.54
5	2	6	SCUN	09	5	5.06
5	2	6	ECAN	02	6	1.90
5	2	6	ASOR	03	7	3.02
5	2	6	SCRE	08	8	1.26
5	2	6	STLT	02	9	0.96
5	2	8	AMCA	02	10	0.60
5	2	1	ANSC	17	4	17.28
5	2	1	BOCU	03	10	12.56
6	3	1	ANGE	02	1	
6	3	6	SCUN	10	2	
6	3	6	AMPS	03	3	
6	3	1	BOCU	06	4	
6	3	6	LTPU	02	5	
6	3	6	MEAL	09	6	
6	3	6	PSTE	08	7	
6	3	6	SOPT	02	8	
6	3	6	STLT	05	9	
7	3	1	ANGE	02	1	
7	3	6	SOPT	02	2	
7	3	1	ANSC	02	3	
7	3	6	PSTE	08	4	
7	3	1	SONU	03	5	
7	3	1	ANSC	17	6	
7	3	6	SCUN	10	7	
7	3	6	SCRE	08	8	
7	3	6	STLT	05	9	
7	3	6	SPPT	02	10	
8	3	6	ECAN	02	1	
8	3	1	ANGE	03	2	
8	3	6	PSTE	08	3	
8	3	6	OESE	12	4	
8	3	1	ANSC	03	5	
9	3	6	ASAR	12	1	
9	3	1	ANSC	03	2	
9	3	1	BOCU	05	3	
9	3	1	ANSC	17	4	
9	3	6	SOPT	02	5	
9	3	6	STLT	05	6	
9	3	6	OESE	12	7	
9	3	6	MEAL	08	8	
9	3	6	PSTE	08	9	

Belowground Biomass Data

Belowground biomass data collected in 1970 at the Hays Site is Grassland Biome data set A2U0026. Data were collected on Form NREL-03. A copy of the form and an example of the data follow.

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET - BELOWGROUND BIOMASS

SITE	INITIALS	DATE			TREATMENT	REPLICATE	PLOT SIZE	QUADRAT	CORE DIAM.	HORIZON	TOP DEPTH	BOTTOM DEP.	LENGTH	WASH WT.	DRY WT.	ASH WT.	CROWN DRY WT.
		Day	Mo	Yr													
3-4	5-7	8-9	10-11	12-13	14	15	16-19	21-23	25-27	29	31-33	35-37	39-41	43-47	49-54	56-61	63-68

DATA TYPE
- 01 Aboveground Biomass
- 02 Litter
- 03 Belowground Biomass
- 10 Vertebrate - Live Trapping
- 11 Vertebrate - Snap Trapping
- 12 Vertebrate - Collection
- 20 Avian Flush Census
- 21 Avian Road Count
- 22 Avian Road Count Summary
- 23 Avian Collection - Internal
- 24 Avian Collection - External
- 25 Avian Collection - Plumage
- 30 Invertebrate
- 40 Microbiology - Decomposition
- 41 Microbiology - Nitrogen
- 42 Microbiology - Biomass
- 43 Microbiology - Root Decomposition
- 44 Microbiology - Respiration

SITE
- 01 Ale
- 02 Bison
- 03 Bridger
- 04 Cottonwood
- 05 Dickinson
- 06 Hays
- 07 Hopland
- 08 Jornada
- 09 Osage
- 10 Pantex
- 11 Pawnee

TREATMENT
- 1 Ungrazed
- 2 Lightly grazed
- 3 Moderately grazed
- 4 Heavily grazed
- 5 Grazed 1969, ungrazed 1970
- 6
- 7
- 8
- 9

HORIZON
- 1 AO
- 2 A
- 3 B
- 4 C

*** EXAMPLE OF DATA ***

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

0306DP 15057011.707   1 3.4 2    0   5   5         .910
                      1 3.4 2    5  10   5         .320
                      1 3.4 2   10  15   5         .528
                      2 3.4 2    0   5   5        3.002
                      2 3.4 2    5  10   5         .394
                      2 3.4 2   10  15   5         .177
                      3 3.4 2    0   5   5        1.223
                      3 3.4 2    5  10   5         .333
                      3 3.4 2   10  15   5         .291
                      4 3.4 2    0   5   5         .879
                      4 3.4 2    5  10   5         .593
                      4 3.4 2   10  15   5         .369
                      5 3.4 2    0   5   5         .338
                      5 3.4 2    5  10   5         .378
                      5 3.4 2   10  15   5         .493
0306DP 15057012.707   1 3.4 2    0   5   5         .936
                      1 3.4 2    5  10   5         .806
                      1 3.4 2   10  15   5         .307
                      2 3.4 2    0   5   5         .987
                      2 3.4 2    5  10   5         .705
                      2 3.4 2   10  15   5         .784
                      3 3.4 2    0   5   5         .486
                      3 3.4 2    5  10   5         .835
                      3 3.4 2   10  15   5         .709
                      4 3.4 2    0   5   5         .785
                      4 3.4 2    5  10   5         .885
                      4 3.4 2   10  15   5         .297
                      5 3.4 2    0   5   5         .859
                      5 3.4 2    5  10   5         .813
                      5 3.4 2   10  15   5         .485
0306BN 01057051.707   1 3.4 2    0   5   5         .677
                      1 3.4 2    5  10   5         .501
                      1 3.4 2   10  15   5         .381
                      2 3.4 2    0   5   5         .723
                      2 3.4 2    5  10   5         .331
                      2 3.4 2   10  15   5         .399
                      3 3.4 2    0   5   5        1.115
                      3 3.4 2    5  10   5         .403
                      3 3.4 2   10  15   5         .364
                      4 3.4 2    0   5   5        1.060
                      4 3.4 2    5  10   5         .556
                      4 3.4 2   10  15   5         .300
```

	5	3.4	2	0	5	5	1.404
	5	3.4	2	5	10	5	.572
	5	3.4	2	10	15	5	.424
0306BN 01057052.707	1	3.4	2	0	5	5	.311
	1	3.4	2	5	10	5	.623
	1	3.4	2	10	15	5	.734
	2	3.4	2	0	5	5	.770
	2	3.4	2	5	10	5	.346
	2	3.4	2	10	15	5	.566
	3	3.4	2	0	5	5	.926
	3	3.4	2	5	10	5	.774
	3	3.4	2	10	15	5	.630
	4	3.4	2	0	5	5	.194
	4	3.4	2	5	10	5	.832
	4	3.4	2	10	15	5	.334
	5	3.4	2	0	5	5	1.176
	5	3.4	2	5	10	5	.550
	5	3.4	2	10	15	5	.439