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Biomass and Shoot Production in an Undisturbed Sagebrush-Bunchgrass Community

Abstract

Total biomass in an undisturbed sagebrush-bunchgrass community was 1572 g dry weight per m^2 with 422 g aboveground and 1150 g belowground. Sagebrush contributed 127 g. Grass crowns, litter, and standing dead herbaceous plants contributed 233 g and the living shoots of herbs contributed 62 g per m^2. Twenty-five percent of the belowground biomass was in the upper decimeter of soil profile and 41 percent was in the surface two decimeters. Over a 4-yr period, herbaceous shoot production averaged 62 g per m^2 per yr with a range of 50-69 g. About 10 g per m^2 per yr was estimated to be produced by sagebrush.

Herbaceous shoot and shrub production in the sagebrush-bunchgrass community was at the low end of the scale of values cited in the literature for other kinds of semi-arid grassland communities in the western United States.

Introduction

The vegetation of the semi-arid Columbia Basin region of interior Washington State under pre-settlement conditions consisted in a large part of vast stands of the *Artemisia tridentata/Agropyron spicatum* association (Daubenmire 1970). Following settlement by European people about 150 years ago much of the land formerly occupied by native plant communities has been under cultivation for dryland wheat and irrigated crops. A few remnant stands of native plant communities can be found, but these are mostly confined to steep slopes or other places with extremely rocky soil. Only a few of the remnant stands have not been subjected to years of grazing by domestic livestock. Some of the undisturbed remnant stands have been described in terms of plant species composition, canopy cover, climate, and soil properties (Daubenmire 1970). However, there is relatively little information concerning biomass and aboveground productivity in undisturbed communities. There is an increasing societal desire to obtain more crop and meat production from semi-arid lands, and it is important to document the status of native plant communities before they become further modified by man's land management practices (Coupland 1979).

This study determined above and belowground biomass and some of the dynamic aspects of production in a relatively undisturbed sagebrush-bunchgrass community using harvest-sample methods. This is the most complete data set of its kind for the sagebrush-bunchgrass region.

Location and History of the Study Site

The study community is located on the United States Department of Energy's 1400 km^2 Hanford Site in Benton Co., Washington, T10N R26E S35 at an elevation 390 m above mean sea level. The community had been grazed by livestock prior to government ownership in 1943, but since then the land has not had livestock grazing. The scarcity of *Bromus tectorum* (an aggressive, alien, annual grass) was regarded as evidence of the undisturbed status of the community (Daubenmire 1975). Wildfires were not known for the study site in the years before 1943; however, a part of the community was burned by a wildfire in August 1973 which caused a minor relocation of sampling plots in 1974.

Methods Employed

Two 300x300 m study plots were established in a homogeneous stand of vegetation representative of the *Artemisia tridentata/Agropyron spicatum* association. Inside the two study plots six smaller areas each 15x30 m (blocks) were randomly located and marked. Periodically throughout the spring growing season of 1971, 1972, 1973, and 1974 two 0.5 m^2 frames were randomly located within each block. Each circular frame was hand clipped of all aboveground plant material five times between March and June. Both 300x300 m plots were sampled in 1971, but in the years 1972, 1973, and 1974 only one of the study plots was sampled. In 1972, 1973, and 1974 eight blocks were sampled using 16 frames (as compared to 24 frames in 1971).

Live shoots were separated from dead shoots according to five botanical categories: shrubs, perennial grasses, annual grasses, perennial forbs, annual forbs, and half-shrubs. The harvested material was oven dried at 50°C and weighed. Results are expressed in grams dry weight per m^2. Grass crowns were cut off at ground level using a metal hack saw blade. The crown material was washed to remove attached soil particles, dried, and weighed. Results are expressed in grams dry weight per m^2. Litter was vacuumed from the ground, dried, and weighed. Aliquots of litter were burned in a muffle furnace to determine ash content. Litter weights are expressed in grams per m^2 with ash concentrations subtracted from the total dry weight.

Sagebrush shrubs were clipped and separated into leaves, standing live wood, standing dead wood, and wood litter. Results are expressed in grams dry weight per m^2.

Soil cores were taken at 1 dm depth intervals to a depth of 0.8 m from a location near the center of each circular frame. The soil cores were washed over a fine mesh screen to separate soil particles from roots, and the roots were floated to segregate soil particles from root tissues. The washed roots were dried and weighed. Aliquots of roots were burned in a muffle furnace to determine their ash content. Root biomass is expressed in grams per m^2 with ash weights subtracted from the total dry weight. Belowground biomass was sampled only at the beginning and at the end of the spring growing seasons.

Results and Discussion

The community consisted of short-statured sagebrush shrubs, *Artemisia tridentata,* widely scattered in an understory layer dominated by perennial bunchgrasses, especially bluebunch wheatgrass, *Agropyron spicatum.* Other perennial bunchgrasses were *Poa sandbergii, Poa cusickii,* and *Stipa thurberiana.* Semi-woody half shrubs were important in the herb layer, especially *Erigeron filifolius, Phlox longifolia,* and *Antennaria dimorpha.* Perennial forbs were represented by scattered individuals of *Lomatium macrocarpum, Lupinus laxiflorus, Astragalus purshii, Brodiaea douglasii, Calochortus macrocarpus,* and others. Annual grasses and forbs were minor constituents of the community and were represented by *Draba verna, Microsteris gracilis, Plantago patagonica, Vulpia octoflora,* and *Descurainea pinnata.*

At the beginning of the spring growing season in each of the four study years, shoot biomass of herbs ranged between 8 and 18 g per m^2, indicating fall and winter growth (Table 1). Live shoot biomass peaked in late May or early June and ranged from 50-69 g per m^2 over the 4-year period. The perennial grasses dominated shoot biomass at all sampling times (Fig. 1). Seventy-seven percent of the aboveground herb biomass was contributed by perennial grasses, half-shrubs contributed 16 percent, and perennial forbs contributed 5 percent. Annuals, mostly six weeks' fescue, *Vulpia octoflora,* contributed less than 2 percent.

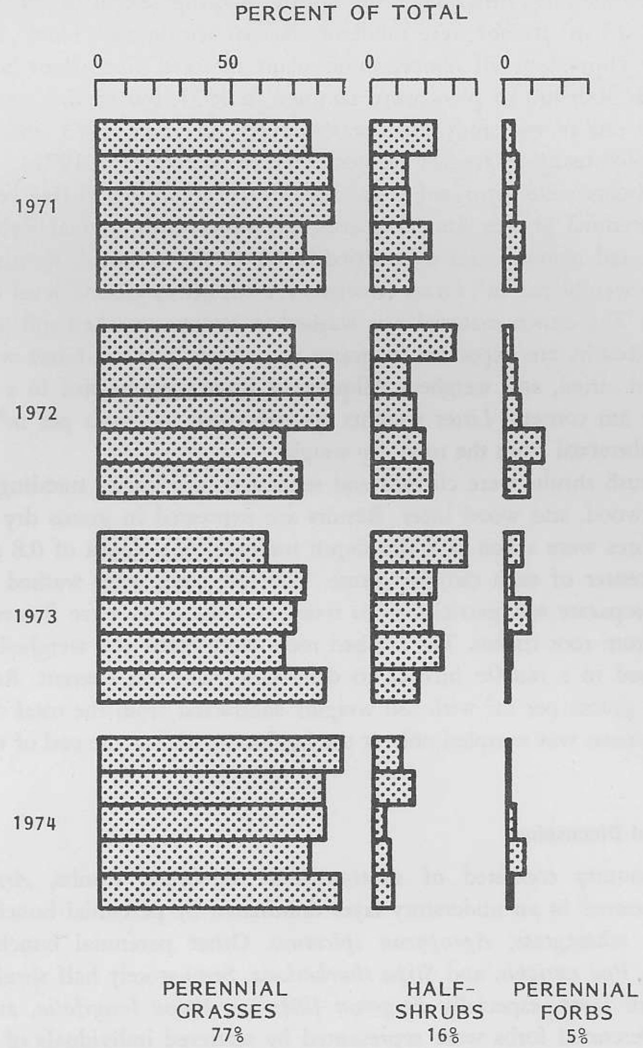

Figure 1. Percentages of perennial grasses, half-shrubs, and perennial forbs in a sagebrush-bunchgrass community at five harvest periods in each of four consecutive years, 1971-1974.

TABLE 1. Dry weights of live herbaceous shoots (g per m² ± SE) in a sagebrush-bunchgrass community in the years 1971-1974.

	Mar 22	Apr 8	Apr 28	May 24	Jun 15
			1971		
Perennial grasses	12±1.0	20±1.6	40±4.4	46±1.5	45±6.5
Perennial forbs	0.37±0.14	0.78±0.21	1.2±0.40	3.3±1.3	2.1±0.85
Annual grasses	0.03±0.03	0.05±0.03	0.43±0.22	0.23±0.07	0
Annual forbs	0	0.01±0.01	0	0	0
Half-shrubs	3.6±0.91	2.8±0.91	6.1±2.2	13±4.1	8.0±0.93
Total herbs	16±1.7	24±2.4	48±5.0	63±4.3	56±5.7
	Mar 6	Mar 28	Apr 17	May 8	May 30
			1972		
Perennial grasses	6.1±0.57	21±2.2	26±2.8	28±5.6	46±7.4
Perennial forbs	0.16±0.05	0.55±0.15	1.1±0.34	5.1±1.7	4.9±2.4
Annual grasses	0	Trace	0.17±0.05	1.1±0.21	0
Annual forbs	0	0.06±0.03	Trace	Trace	Trace
Half-shrubs	2.6±0.94	2.9±0.64	4.2±1.6	7.6±2.6	14±6.3
Total herbs	8.8±0.97	25±2.2	31±3.4	42±5.9	65±3.6
	Mar 19	Apr 9	Apr 30	May 21	Jun 11
			1973		
Perennial grasses	11±1.3	27±3.1	36±4.5	28±5.3	41±6.0
Perennial forbs	1.1±0.44	0.90±0.67	4.1±1.8	0.73±0.02	Trace
Annual grasses	0	0.21±0.10	0.32±0.10	0	0
Annual forbs	Trace	0.07±0.02	0.11±0.10	0	0
Half-shrubs	6.2±2.1	8.2±3.3	11±4.9	11±4.4	8.6±3.6
Total herbs	18±1.8	36±4.6	51±7.2	41±8.0	50±5.2
	Feb 26	Mar 25	Apr 15	May 8	Jun 6
			1974		
Perennial grasses	15±2.2	21±2.0	41±4.1	54±7.7	54±11
Perennial forbs	0.15±0.08	0.25±0.06	1.6±1.0	4.5±3.6	2.1±1.2
Annual grasses	Trace	0.09±0.06	2.4±0.40	4.8±0.75	0
Annual forbs	0.16±0.04	0.94±0.25	2.1±0.54	1.4±0.09	0.94±0.91
Half-shrubs	1.7±0.85	4.1±1.9	2.6±1.4	4.2±2.0	3.9±2.2
Total herbs	17±2.1	26±2.1	50±1.4	69±9.3	61±9.0

TABLE 2. Dry weights (g per m² dry wt ± SE) of grass crowns, standing dead plants and litter in a sagebrush-bunchgrass community in the years 1971-1974

	22 Mar	8 Apr	28 Apr	24 May	15 Jun	Avg.	Total Wt.
			1971				
Crowns	39± 9.0	43± 7.7	72±12	59± 8.0	56± 8.5	54	
Standing dead	90± 9.6	81± 9.5	100±15	80± 9.1	72±10	85	300
Litter	M	M	M	158±17	165±16	161	
	7 Mar	28 Mar	17 Apr	10 May	31 May		
			1972				
Crowns	96± 9.3	106±12	69±81	81± 8.0	123±11	95	
Standing dead	80±12	78±15	63±12	50±93	75± 7.7	69	282
Litter	101±13	123±14	113±15	98±11	156± 9.6	118	
	19 Mar	9 Apr	30 Apr	21 May	11 Jun		
			1973				
Crowns	69± 7.1	101±10	98±10	93±18	132±16	99	
Standing dead	96±18	81± 8.9	100±17	78±15	114±17	94	327
Litter	125±24	117±14	112±18	139±15	175±21	134	
	26 Feb	25 Mar	15 Apr	8 May	6 Jun		
			1974				
Crowns	81±13	101±11	95± 8.8	86±17	83± 9.5	89	
Standing dead	105±20	71± 5.5	94±13	61±12	73±13	81	293
Litter	152±27	110±13	123±16	111±18	117±20	123	

M = missing datum

Grass crowns, standing dead herbaceous material, and the litter components of the community showed no consistent change in biomass from the beginning to the end of the spring growing season (Table 2). Litter averaged 134, grass crowns, 84, and standing dead herbage, 82, g per m^2. Sagebrush shrubs contributed 70 g per m^2. Wood litter was the greatest single contributor to woody biomass at 57 g per m^2.

About 25 percent of the root biomass was in the upper decimeter of soil profile and 41 percent in the upper 2 decimeters (Table 4). At the beginning of the spring growing season root biomass in the upper 8 decimeters was 880 g per m^2, and 114 g per m^2 at the end of the spring growing season.

TABLE 3. Dry weights (g per $m^2 \pm$ SE) of sagebrush shrubs in a sagebrush-bunchgrass community in the years 1971-1973.

	Mar 22	Apr 8	Apr 28	May 24	June 15	Avg.	Total
			—1971—				
Leaves	4.4± 1.2	4.3± 1.3	2.7± 0.9	11 ± 5.0	5.7± 1.7	5.6	
Livewood	46 ±15	38 ±11	11 ± 2	47 ±22	36 ±12	36	148
Deadwood	50 ±17	18 ± 6	35 ± 7	57 ±17	60 ±15	44	
Wood Litter	41 ±13	74 ±33	45 ±13	60 ±17	88 ±28	62	
	Mar 6	Mar 28	Apr 17	May 8	May 30		
			—1972—				
Leaves	1.4± 1.1	1.0± 0.8	28 ±21	51 ±50	12 ±12	19	
Livewood	20 ±14	3.8± 2.3	12 ± 9.3	12 ± 8.8	0.6± 0.6	9.7	100
Deadwood	36 ±25	0	22 ±12	0	0	12	
Wood Litter	68 ±25	97 ±32	23 ± 5	48 ±18	52 ±20	58	
	Mar 19	Apr 9	Apr 30	May 21	Jun 11		
			—1973—				
Leaves	5.8± 3.0	1.5± 1.4	3.9± 3.0	8.1± 3.0	5.4± 5.4	4.9	
Livewood	113 ±94	2.4± 2.3	9.3± 6.8	33 ±17	47 ±47	41	132
Deadwood	17 ± 7.6	15 ±12	42 ±22	42 ±37	69 ±47	37	
Wood Litter	35 ±16	97 ±39	47 ±21	36 ±16	30 ± 9	49	

TABLE 4. Dry weight of roots (g per $m^2 \pm$ SE) in a sagebrush-bunchgrass community in the years 1972-1974.

Soil Depth dm	1972 6 Mar	1973 19 Mar	1974 26 Feb	Avg.	%
0-1	155±15	274±31	297±40	242	27
1-2	115±28	117± 5	142±17	125	14
2-3	101±26	103± 2	95±16	100	11
3-4	113±21	108± 3	95±10	105	12
4-5	101±13	100± 4	81± 8	94	11
5-6	74±12	95± 3	91± 7	87	10
6-7	57± 6	81± 3	69± 7	69	8
7-8	58± 7	66± 3	53± 6	59	7
Total	774	944	923	881	100
	30 May	11 Jun	8 May		
0-1	282±32	359±85	216±35	286	25
1-2	229±25	193±26	143±17	188	16
2-3	167±17	150±20	98± 9	139	12
3-4	166±22	135±11	85± 4	127	11
4-5	170±18	121±10	87± 7	126	11
5-6	166±16	108± 7	67± 7	114	10
6-7	126±12	92± 8	58± 8	92	8
7-8	118±14	68± 5	41± 6	76	7
Total	1424	1226	795	1147	100

Aboveground biomass at peak production in the spring was 490 g per m^2 and belowground biomass was 1150 (Table 5). Total biomass was 1600 g per m^2. Aboveground production in the sagebrush-bunchgrass community was at the low end of the scale of production for other kinds of grass-dominated communities in semi-arid regions of western North America (Table 6).

It was expected that annual herbage production would show a direct relationship between high and low precipitation years. High precipitation years were expected to show high plant production and low years, low production. The relationship between precipitation (Oct.-May) and peak herbage production is shown below.

	1971	1972	1973	1974
Precipitation (cm)	21.4	17.4	12.9	36.2
Production (g per m^2)	63	65	50	69
Efficiency (g per m^2/ppt cm)	2.9	3.7	3.9	1.9

TABLE 5. Summary of biomass components in a sagebrush-bunchgrass community.

TOTAL BIOMASS 1600 g per m^2			
ABOVEGROUND BIOMASS 490 g per m^2			
HERBS		SAGEBRUSH	
Liveshoots	62	Leaves	10
Standing dead	82	Livewood	29
Grass crowns	84	Deadwood	31
Litter	134	Wood litter	57
Total	360	Total	130
BELOWGROUND BIOMASS 1150 g per m^2			

TABLE 6. Live aboveground biomass in steppe communities in the western United States (Lauenroth 1979).

<100 g/m^2		101-200 g/m^2		201-300 g/m^2	
Albion, MT	42	*SE Washington	104	Bismark, ND	203
Sundance, WY	76	*SE Washington	115	San Joaquin, CA	224
Ardmore, SD	86	Las Cruces, NM	115	Dickinson, ND	224
*Richland, WA	82	Sydney, MT	122	Hopland, CA	228
**Richland, WA	70	***Rexburg, ID	123	St. Lanatius, MT	230
		Newtown, ND	144	Hays, KN	234
Average	71	Santa Rita, NM	144	Long Valley, SD	250
		Nunn, CO	145	Amarillo, TX	257
		San Jose, CA	166	Norman, OK	265
				Throckmorton, TX	280
		Average	120	Cottonwood, SD	282
				Boulder, CO	298
				Average	248

301-400 g/m^2		>400 g/m^2	
Vermillion, SD	353	Paskuska, OK	567
Cresco, IA	369	Columbia, MO	634
Urbana, IL	373		
Manhatten, KN	387	Average	600
Average	370		

*Daubenmire 1970
**This study
***Pearson 1965

These data show that the lowest precipitation year, 1973, had the lowest production, and that the high precipitation year, 1974, had the greatest productivity. However, there was relatively little difference in production in the years 1971, 1972, and 1974. Overall the variation in production was not as great as the variation in precipitation. This indicates that the sagebrush-bunchgrass community had some level of stability over a reasonably broad range of precipitation. The data also show that the community efficiency ratio is greatest during low precipitation years and least in high precipitation years. This suggests that water losses by physical processes (i.e., runoff, infiltration, evaporation) are greatest during high precipitation years. The fundamental role of sagebrush shrubs in sagebrush-bunchgrass communities is a subject of on-going ecological research. Sagebrush is virtually the only non-aestivating plant in the shrubsteppe community in summer. It has the capacity to use soil water that has penetrated below the rooting depth of grasses (Daubenmire 1970). Mineral nutrients from deep in the soil profile can be brought to the surface by root uptake, deposited in leaves and then returned to the soil via leaf fall (Mack 1977). These sagebrush processed nutrients are eventually available for use by grasses and forbs as they are released from the dead sagebrush leaves by weathering and microbial decomposition processes. Sagebrush wood acts as a sink for nutrients because it is slow to decompose. Dead herbaceous plant tissues decompose more quickly than sagebrush wood but the rate of decomposition has not been adequately studied (Comanor and Staffeldt 1978).

Sagebrush provides nesting sites for small passerine birds that otherwise would not nest in the community (McAdoo and Klebenow 1979). Sagebrush also provides forage for jackrabbits, *Lepus californicus*, mule deer, *Odocoileus hemionus*, and sagegrouse, *Centrocercus urophasianus*. Sagebrush is not palatable to livestock, and most rangeland research has been aimed at developing cost-effective ways of eradicating sagebrush shrubs to enhance the growth and productivity of livestock palatable grasses (Britton and Ralphs 1979, Evans *et al.* 1979).

Acknowledgments

This work was performed under contract DE-AC06-76RL0 1830 with the United States Department of Energy with support from the United States International Biological Programme's Grassland Biome Studies administered through Colorado State University.

The following persons assisted in the field work: C. M. Lee, M. A. Combs, J. F. Cline, D. W. Uresk, and L. Nelson. Their contributions are gratefully acknowledged.

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Received 20 January 1984
Accepted for publication 6 March 1984