J. F. Cline
D. W. Uresk
and
W. H. Rickard
Ecosystems Department
Battelle Northwest Laboratories
Richland, Washington 99352

Plants and Soil of a Sagebrush Community on the Hanford Reservation[1]

Abstract

This study defines a sagebrush/cheatgrass community on the Hanford Reservation, Benton County, Washington. Twenty-seven herbaceous species were observed. The average understory cover was 38 percent. Cheatgrass, an annual grass, was the dominant species and provided 18 percent of the herbaceous cover. Sagebrush was the conspicuous shrub, providing 15 to 20 percent of the total cover. Biomass production of the herbaceous species was approximately 40 g/m^2. Soil analysis and the mineral composition of the vegetation were measured and evaluated.

Introduction

The Hanford Reservation, Benton County, Washington, lies within the boundaries of the sagebrush vegetation zone (Daubenmire, 1970). However, the land on the Hanford Reservation located west of the Columbia River can be mapped as three different vegetation types (Fig. 1). The sagebrush-bitterbrush/cheatgrass type occupies a triangular shaped area with its apex near the old Hanford townsite and extends southward to the Horn Rapids bend of the Yakima River. The sagebrush/bluebunch wheatgrass vegetation type is confined to the Rattlesnake Hills at elevations of above 900 ft. The vegetation between these two is designated as the sagebrush/cheatgrass vegetation type. This latter type occupies much of the area of Hanford Reservation. It differs from the sagebrush/bitterbrush by lacking bitterbrush and the absence of bluebunch wheatgrass distinguishes it from the sagebrush/bluebunch wheatgrass type. This paper describes the sagebrush/cheatgrass vegetation type that is not regarded in pristine condition by Daubenmire because it contains large amounts of cheatgrass *(Bromus tectorum),* an alien plant characteristic of man-induced disturbances, such as grazing by domestic cattle and sheep. Nevertheless, this vegetation type is important on the Hanford Reservation because nuclear energy facilities are a major long-term use of some of the land.

The purpose of this investigation was to describe the vegetation and the surface soil of a sagebrush/cheatgrass community located near the chemical separation facilities known as the 200 East and 200 West areas but well inside the boundaries of access control zones. The area has been protected from grazing livestock since 1943.

Methods Employed

The experimental design consisted of two stands designated as Site I and Site II located centrally in the sagebrush/cheatgrass vegetation type at an elevation of 700 ft above sea level (Fig. 2). Each site contained two replicates consisting of four 50-mm tran-

[1] Work performed for the Atlantic Richfield Hanford Company under United States Energy Research and Development Administration contract E(45-1)-2130.

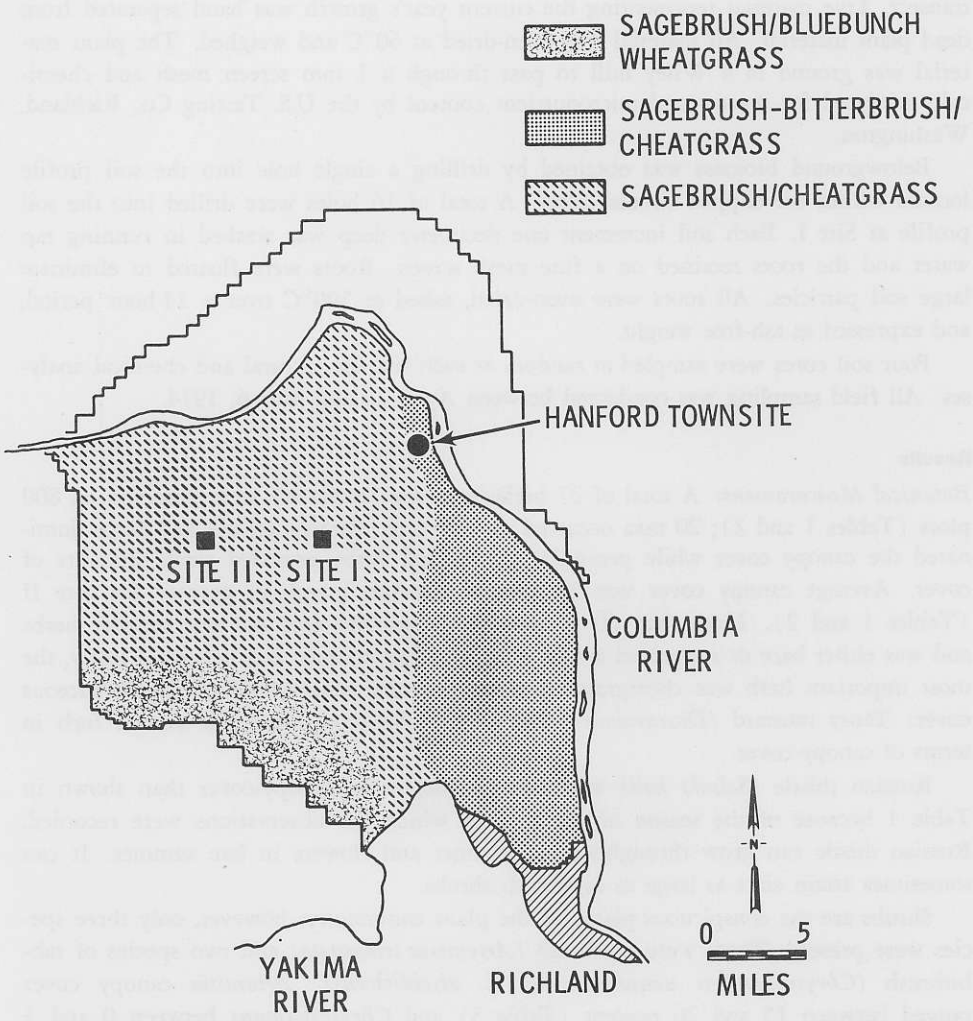

Figure 1. Geographic extent of three major vegetation types and the location of study sites I and II on the Hanford Reservation.

sects arranged parallel to each other and systematically spaced at 30-m intervals. Shrub density was estimated by counting all individuals rooted inside a 10 x 50 m (500 m^2) study plot in each replicated area. Each shrub was measured for long and short diameters and also extreme shoot height from ground level. Canopy cover provided by herbaceous taxa was measured by reading fifty 2 x 5 dm plot frames systematically spaced at one-meter intervals on each line transect. In all, 400 plots were read at each site. Cover for each taxon was ocularly estimated using a modified method of canopy cover analysis developed by Daubenmire (1959). Modified classification numbers were 1 $<$ 5 percent, 2 $=$ 5-15 percent, 3 $=$ 15-25 percent, 4 $=$ 25-50 percent, 5 $=$ 50-75 percent, and 6 $=$ 75-100 percent.

Aboveground biomass was estimated by hand-clipping herbaceous plants located within a 0.5 m^2 circular plot. Four plots were systematically spaced along each line

transect. Live material representing the current year's growth was hand separated from dead plant material. All material was oven-dried at 60°C and weighed. The plant material was ground in a Wiley mill to pass through a 1 mm screen mesh and chemically analyzed for macro- and micronutrient content by the U.S. Testing Co., Richland, Washington.

Belowground biomass was obtained by drilling a single hole into the soil profile located within the clipped circular plots. A total of 16 holes were drilled into the soil profile at Site I. Each soil increment one decimeter deep was washed in running tap water and the roots retained on a fine mesh screen. Roots were floated to eliminate large soil particles. All roots were oven-dried, ashed at 500°C over a 24-hour period, and expressed as ash-free weight.

Four soil cores were sampled at random at each site for textural and chemical analyses. All field sampling was conducted between April 24 and May 6, 1974.

Results

Botanical Measurement: A total of 27 herbaceous species (taxa) were observed on 800 plots (Tables 1 and 2); 20 taxa occurred on each site. Annual grasses and forbs dominated the canopy cover while perennial grasses and forbs provided small amounts of cover. Average canopy cover was 37 percent for Site I and 39 percent for Site II (Tables 1 and 2). More than 60 percent of the ground area did not support herbs and was either bare or supported a thin crust of algae, mosses, and lichens. Clearly, the most important herb was cheatgrass. It alone provided almost half of the herbaceous cover. Tansy mustard *(Descurainia pinnata)* was the most important annual forb in terms of canopy-cover.

Russian thistle *(Salsola kali)* was more important to canopy-cover than shown in Table 1 because of the season of the year in which the observations were recorded. Russian thistle can grow throughout the summer and flowers in late summer. It can sometimes attain sizes as large as sagebrush shrubs.

Shrubs are the conspicuous plants of the plant community; however, only three species were present. These were sagebrush *(Artemisia tridentata)* and two species of rabbitbrush *(Chrysothamnus nauseosus* and *C. viscidiflorus). Artemisia* canopy cover ranged between 15 and 26 percent (Table 3) and *Chrysothamnus* between 0 and 3 percent. The average number of shrubs was 243 $\pm$ 98/1000 m^2 (Table 3). Site I suported 376 and Site II 110 shrubs. Site I with the greatest shrub density had the shortest statured plants with small canopy areas. At either site, less canopy cover was provided by shrubs than by associated herbs.

The live biomass (net primary production) of herbs by species is shown in Table 4. The data were obtained only for Site I, but results are not expected to be much different at Site II. The total aboveground biomass, excluding shrubs, was measured at 40 g/m^2 dry weight of which almost half, 18 grams, was provided by cheatgrass. No estimates of shrub weight were obtained in this study.

Total root mass, which includes roots from shrubs in the upper meter of soil profile, was estimated at 368 g/m^2. More than half was located in the upper 3 dm of soil profile (Fig. 3).

Mineral Content of Plants: The concentrations of macronutrients in the tissues of important grass and forb species are shown in Table 5. On the average, micro- and ma-

TABLE 1. Canopy cover provided by herbaceous taxa at study site I.

Taxa	T_1[1]	T_2	T_3	T_4	Ave[1] Rep 1 $\bar{X}$	T_1	T_2	T_3	T_4	Ave Rep 2 $\bar{X}$	Ave Rep 1&2 $\bar{X} \pm$ SE.
Annual Grasses											
Bromus tectorum	13.0	15.7	25.6	16.7	17.8	10.3	9.1	12.4	19.4	12.8	15.3 ± 0.9
Festuca octoflora	1.9	2.0	3.1	2.5	2.4	6.0	6.2	6.3	4.1	5.7	4.0 ± 0.7
Annual Forbs											
Descurainia pinnata	7.5	9.1	10.9	11.7	9.8	9.1	4.8	8.4	2.9	6.3	8.0 ± 1.0
Microsteris gracilis	1.5	4.9	3.1	2.7	3.1	3.7	2.5	5.4	2.0	3.4	3.2 ± 0.5
Cryptantha circumscissa	2.1	1.7	1.4	1.8	1.7	0.9	2.5	1.7	2.3	1.9	1.8 ± 0.2
Cryptantha pterocarya	1.2	0.05	0.8	0.5	0.6	0.9	0.5	0.5	0	0.5	0.6 ± 0.1
Phacelia linearis	0.05	0	0	0	0.01	0.2	0.8	0.7	0.05	0.5	0.02 ± 0.1
Erysimum asperum	1.6	0	0	0	0.4	0	0	0	0	0	0.2 ± 0.2
Salsola kali	0.05	0.3	0.1	0.1	0.1	0.05	0.5	0	0	0.1	0.1 ± 0.1
Sisymbrium altissimum	0	0	0	0	0	0.2	0	0	0	0.05	0.03 ± 0.03
Amsinckia lycopsoides	0.35	0.1	0	0	0.1	0	0	0	0	0	0.05 ± 0.04
Perennial Grasses											
Poa sandbergii	4.6	1.8	1.6	2.7	2.7	1.0	1.0	1.0	0.3	0.8	1.7 ± 0.5
Perennial Forbs											
Phlox longiflora	0.2	0	0	0	0.1	1.8	1.2	2.2	0	1.3	0.7 ± 0.3
Cymopterus terebinthinus	0.05	0	0	0	0.01	0.8	1.2	0	0	0.5	0.3 ± 0.2
Eriogonum spp.	0.5	0	0	0.1	0.2	0.3	1.3	0.2	0.6	0.6	0.4 ± 0.2
Balsamorhiza careyana	1.0	0	0	0	0.3	0.2	0	0	0	0.05	0.2 ± 0.1
Brodiaea douglasii	0	0	0	0	0	0.1	0.1	0.05	0	0.1	0.03 ± 0.02
Commandra pallida	0	0	0	0	0	0.2	0.05	0	0	0.1	0.03 ± 0.02
Oenothera pallida	0	0	0	0	0	0.1	0.05	0	0	0.04	0.02 ± 0.01
Calochortus macrocarpus	0	0	0	0	0	0.05	0.1	0.15	0	0.1	0.04 ± 0.02
Total Cover	35.7	35.6	46.6	38.7	39.2	35.9	31.9	39.0	31.6	34.8	36.9
Number of Species — 20											

[1] T = Transects, Rep = Replicate

TABLE 2. Canopy coverage provided by herbaceous taxa at study site II.

Taxa	T_1[1]	T_2	T_3	T_4	Ave[1] Rep 1 $\bar{X}$	T_1	T_2	T_3	T_4	Ave Rep 2 $\bar{X}$	Ave Rep 1&2 $\bar{X} \pm$ SE.
Annual Grasses											
Bromus tectorum	20.8	24.2	20.8	21.9	21.9	26.2	27.7	15.0	18.2	21.8	21.9 ± 1.1
Festuca octoflora	2.8	2.3	6.1	2.9	3.5	0.9	0.7	3.0	1.4	1.5	2.4 ± 0.6
Annual Forbs											
Descurainia pinnata	2.2	2.1	1.2	2.7	2.0	9.3	4.1	1.9	3.6	4.7	3.4 ± 0.9
Cryptantha circumscissa	2.1	1.9	1.6	10.8	4.1	1.0	1.5	1.7	1.8	1.5	2.8 ± 1.2
Sisymbrium altissimum	0.3	0	0.1	0	0.1	3.5	5.7	1.5	0.2	2.5	1.4 ± 0.8
Salsola kali	0.1	0	0	0	0.02	0.02	0.2	0.6	0.4	0.35	0.2 ± 0.1
Cryptantha pterocarya	0.8	0.3	1.1	3.3	1.4	0.4	0	0	0	0.1	0.7 ± 0.4
Microsteris gracilis	0	0	0	0	0	0.1	0.1	0	0	0.05	0.03 ± 0.02
Perennial Grasses											
Stipa comata	13.0	2.7	3.6	1.4	7.9	0	0	0	0	0	2.0 ± 1.6
Agropyron dasytachyum	0	0	0	0	0	0.4	5.1	0	0	0	0.7 ± 0.6
Poa canbyi	1.5	0	0	0	0.4	0	0	0	0	0	0.2 ± 0.2
Poa sandbergii	0	0	1.8	0.3	0.5	0	0	0	0	0	0.3 ±00.2
Sitanion hystrix	0	0	0	0	0	0.05	0	0	0	0	<0.1
Perennial Forbs											
Cymopterus terebinthinus	1.2	0	7.9	7.8	4.2	0	0	0	0	0	2.0 ± 1.3
Erigeron sp.	0.1	0.9	0.4	0.1	0.4	0.1	0.2	0.1	0.1	0.1	0.3 ± 0.1
Aster canescens	0.3	0	0	0	0.08	0.4	0.4	0.2	0.7	0.4	0.3 ± 0.1
Oenothera pallida	0	0	0	0	0	0.1	0	0	0	0.03	0.01 ± 0.01
Calochortus macrocarpus	0.1	0	0	0	0.03	0	0	0	0	0	0.01 ± 0.01
Lupinus sp.	0	0	0	0	0	0	0	2.0	0	0.5	0.3 ± 0.3
Phlox longifolia	0.1	0	0.1	0	0	0	0	0	0	0	<0.1
Total Cover %	45.4	34.4	44.7	51.2	46.2	42.6	45.7	26.0	26.4	33.5	38.9 ±
Number of taxa — 20											

[1] T = Transect, Rep = Replicate

TABLE 3. Average shrub measurements of canopy cover, height, and area (L x W) and density for Sites I and II.

Taxa	Site I Rep 1[1]	Site I Rep 2	Site I $\bar{X}$	Site II Rep 1	Site II Rep 2	Site II $\bar{X}$
			Canopy Coverage (%)			
Artemisia	26.3	25.4	25.8	21.2	15.3	18.2
SE	±5.7	±5.7	±4.3	±3.5	±3.8	±2.7
Chrysothamnus	0	0.8	0.4	0.5	2.7	1.6
		±0.8	±0.4	±0.5	±1.3	±0.7
			Height (cm)			
Artemisia	102	78	85	95	116	104
SE	±3	±2	±1	±5	±4	±4
			Area (L x W) cm^2			
Artemisia	14200	6720	10450	23100	25880	24350
SE	±960	±360	±420	±2390	±2630	±1760
			Number of Shrubs Per 1000 m^2			
Artemisia	226	518	372	94	76	84
Chrysothamnus	0	8	4	14	36	26
TOTAL	226	526	376	108	112	110

[1] Rep = Replicate

TABLE 4. Aboveground live biomass g/m^2 of herbaceous plant taxa (mean ± SE) or replicates at Site I on the 200-Area Plateau, Hanford Reservation, 1974.

Taxa	Rep 1[1]	Rep 2	Mean
Annual grasses			
Bromus tectorum	19 ± 4.6	17 ± 3.7	18
Festuca octoflora	3.0 ± 1.1	10 ± 2.3	6.6
Total	22	27	25
Perennial grasses			
Agropyron spicatum	0	3.6 ± 3.6	1.8
Sitanion hystrix	3.6 ± 3.6	0	1.8
Poa sandbergii	1.3 ± 0.5	0.8 ± 0.4	1.0
Total	4.9	3.4	3.8
Perennial forbs			
Erigeron filifolius	0.01 ± 0.01	0.01 ± 0.01	0.01
Brodiaea douglasii	0	0.01 ± 0.01	
Calochortus macrocarpus	0	0.94	0.48
Total	0.01	0.96	0.49
Annual forbs			
Descurainia pinnata	6.4 ± 1.6	5.1 ± 1.2	5.7
Microsteris gracilis	2.0 ± 1.4	2.8 ± 1.1	2.4
Cryptantha circumscissa	2.7 ± 1.4	1.2 ± 0.5	2.0
Phlox longifolia	0	0.76 ± 0.76	0.38
Cryptantha pterocarya	0.41 ± 0.26	0.05 ± 0.03	0.23
Phacelia linearis	0.01 ± 0.01	0.30 ± 0.15	0.15
Amsinckia lycopsoides	0.05 ± 0.05	0	0.03
Salsola kali	0.10 ± 0.06	0.06 ± 0.04	0.08
Sisymbrium altissimum	0	0.20 ± 0.02	0.10
Total	12	10	11
Total herbs g/m^2	39 ± 6.4	41 ± 5.9	40 ± 4.3

[1] Rep = Replicate

cronutrient content was greater in forbs than in grasses. This finding is particularly evident in potassium and calcium contents. Nitrogen content was similar in forb and grass tissues.

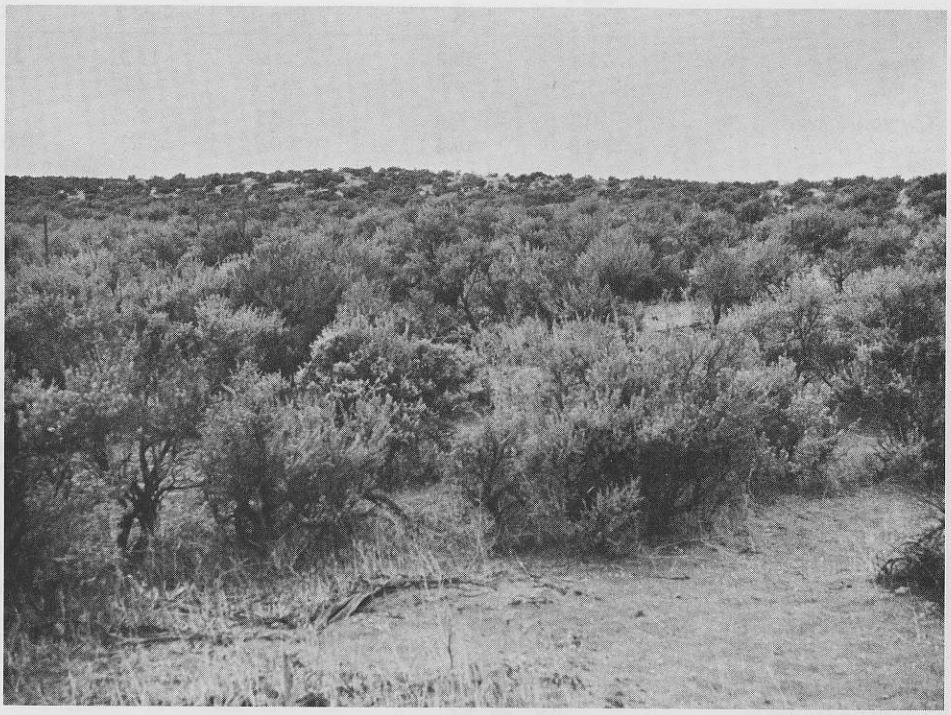

Figure 2. Sagebrush/cheatgrass vegetation type representative of the study area on the Hanford Reservation.

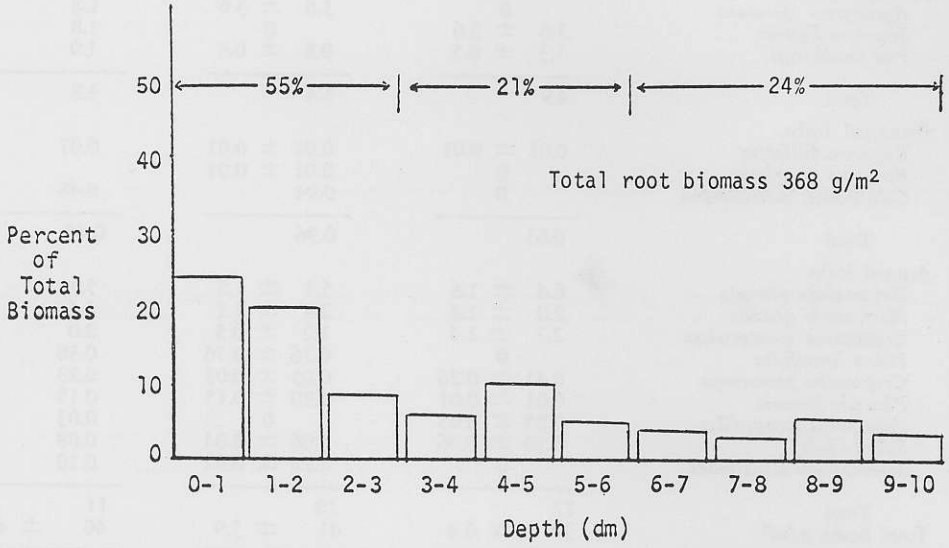

Figure 3. Distribution of roots (live and dead) in the upper meter of soil profile in a sagebrush-cheatgrass community at Site I.

TABLE 5. Mineral nutrient content of herbaceous plant taxa from Site I.

Taxa	Macronutrients (% Dry Wt.) N	P	K	Ca	Mg	Na	S	Micronutrients (% Dry Wt.) Fe	Mn	B	Cu	Zn
Grasses												
Bromus tectorum	0.92	0.17	1.17	0.43	0.16	0.03	0.10	0.04	0.004	0.001	0.0003	0.001
Festuca octoflora	0.93	0.14	0.65	0.40	0.13	0.02	0.14	0.04	0.006	0.002	0.0002	0.002
Poa sandbergii	1.17	0.18	0.75	0.40	0.12	0.05	0.13	0.05	0.004	0.002	0.0003	0.001
Average	1.00	0.16	0.86	0.41	0.14	0.03	0.02	0.04	0.005	0.002	0.0003	0.001
Forbs												
Descurainia pinnata	1.34	0.29	1.13	1.16	0.26	0.04	0.31	0.03	0.002	0.003	0.0005	0.002
Microsteris gracilis	0.71	0.19	0.88	1.49	0.27	0.08	0.14	0.21	0.006	0.003	0.0004	0.002
Cryptantha circumscissa	1.13	0.38	1.08	5.40	0.41	0.06	0.13	0.13	0.007	0.006	0.0004	0.002
Cryptantha pterocarya	1.09	0.14	2.14	1.73	0.17	0.05	0.12	0.06	0.005	0.005	0.0003	0.001
Average	1.07	0.25	1.31	2.44	0.28	0.06	0.17	0.11	0.005	0.004	0.0004	0.002

Soil Properties: Soil texture is important to plant growth because it determines to a large extent the water-holding capacity of a given volume of soil and also its cation exchange capacity. Soils were similar in texture, *i.e.,* sandy loams at both sites (Table 6). Sand dominated the three textural classes followed by silt and clay. Clay-sized particles were scarce, making up only 1 percent of the texture size classes. These data imply that the moisture-holding capacity and cation exchange of the soil profile are low. Also, these sandy soils are subject to serious wind erosion when disturbed (Hinds and Sauer, 1974).

The pH values of surface soils are alkaline, and alkalinity increases with profile depth (Table 6). Soluble salts are low, indicating that salinity (excess salts) is not a hinderance to plant growth, at least in the upper soil. Organic matter is low, indicative of low soil nitrogen levels.

Discussion

The sagebrush/cheatgrass community described is probably very much like the community that existed prior to 1943 when the Hanford Reservation was established. The major vegetational change has been the incorporation of weeds of European origin into the plant community. The most successful of these European weeds is cheatgrass, and it has probably been a member of the plant community for a century. This grass was an important plant on Benton County rangelands a half century ago (St. John and Jones, 1928). Cheatgrass is so well adapted to the climatic and soil conditions of the Hanford Reservation that it is prudent to consider the species as an integral part of the flora and to make use of its pioneering aggressiveness in revegetating disturbed land.

The number of plant species in the study area was less when compared to other kinds of natural plant communities in eastern Washington and the annual production of dry land matter is also less (Daubenmire, 1970; Rickard, 1975; Cline and Rickard, 1973). The low species diversity is attributed to the generally level terrain, *i.e.,* habitat homogeneity and the low annual precipitation which over a 30-year period has averaged only 6.3 inches. Sandy soils having a low water-holding capacity and available nutrients will influence diversity.

Sagebrush, the important shrub community, is not palatable to livestock. The most important livestock forage species, in terms of palatability and abundance, is *Bromus*

TABLE 6. Average chemical and physical properties of soil from Sites I and II.

	Soil Depth (dm)						
	0-1	1-2	2-3	3-4	4-5	5-6	Avg
Texture							
% Sand	59	62	67	63	57	57	61
% Silt	40	37	32	36	42	42	38
% Clay	1	1	1	1	1	1	1
Organic Matter							
%	0.68	0.45	0.35	0.43	0.43	0.50	0.47
Elec. Cond.							
mmhos/cm	0.25	0.20	0.24	0.29	0.21	0.30	0.25
pH	7.5	7.6	7.7	7.9	7.9	8.1	7.8

tectorum. However, the grazing season is short. If one-half of the herbaceous production could be ingested by livestock, an intake of about 200 kg of dry matter per ha (200 lbs per acre) is potentially available as livestock forage. The conclusion is that species diversity and net productivity and livestock grazing capacity is inherently lower here than other steppe plant communities of eastern Washington.

In the absence of livestock, the most important mammalian herbivore on the study site is the black-tailed hare *(Lepus californicus).* A study of the dietary habits of black-tailed hares on the Hanford Reservation (Uresk *et al.,* 1975) indicates that cheatgrass was not eaten by hares; shrubs were sparingly eaten, with rabbitbrush being taken in preference to sagebrush. Perennial forbs, such as yarrow *(Achillea millefolium)* and turpentine cymopterus *(Cymopterus terebinthinus),* plants sparsely represented in the community, were the preferred hare foods.

Two kinds of environmental stresses can be expected to be imposed on this community in the future. These are: (1) fire and (2) mechanical soil disturbances. Fire can be naturally induced by lightning or ignited by man. Burning destroys sagebrush plants but perennial grasses and forbs generally survive and send out new shoots. At least some seeds of annuals survive the burning and provide a crop during the year of post-burning. Recolonization of the burned areas may also be accomplished by seed imported from surrounding surviving vegetation.

Mechanical disturbances, such as imposed in the construction activities of this area, effectively destroy all existing vegetation. Russian thistle is one of the most aggressive of the early invaders and may dominate in the first year, but thereafter cheatgrass assumes dominance and it resists invasion by native plants and Salsola. Daubenmire (1975) describes cheatgrass as dominating the vegetation of an abandoned agricultural field for 52 years with little invasion by native perennials although nearby seed sources were available. Of the shrubby species, rabbitbrush is more aggressive than sagebrush in terms of invading disturbed soils.

Unless there are major changes in land use, such as irrigated agriculture, livestock grazing, or new construction activities associated with Hanford Reservation industrial activities, the plant community described here is expected to maintain essentially the same species composition and productivity as described herein in the forseeable future, *i.e.,* 20-30 years. Wildfire is the most likely disturbance to be expected as it is not induced by man. From a longer-term point of view, change in climate, whether wetter or drier, would have a profound impact upon plant species composition and primary productivity.

Acknowledgment

The authors wish to thank Virginia A. Uresk for helpful suggestions and technical advice during this study.

Literature Cited

Cline, J. F., and W. H. Rickard. 1973. Herbage yields in relation to soil water and assimilated nitrogen. J. Range Manage. 26: 296-298.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northw Sci. 33: 43-64.

————. 1970. Steppe vegetation of Washington. Wash. Agr. Exp. Sta. Tech. Bull. 62: 131.

————. 1975. Plant succession on abandoned fields and fire influences in a steppe area in southeastern Washington. Northw. Sci. 49: 36-48.

Hinds, W. T., and R. H. Sauer. 1975. Soil erodibility, soil erosion, and revegetation following wildfire in a shrub-steppe community. In: Symposium on Atmosphere-Surface Exchange of

Particulate and Gaseous Pollutants, R. J. Engelmann and G. A. Sehmel (coordinators). (Conf-740921). NTIS, Springfield, Virginia.
Rickard, W. H. 1975. Vegetation of knob and kettle topography in southcentral Washington. Northw. Sci. 49: 147-152.
St. John, J., and G. N. Jones. 1928. An annotated catalogue of vascular plants of Benton County, Washington. Northw. Sci. 2: 73-93.
Uresk, D. W., J. F. Cline, and W. H. Rickard. 1975. Diets of Black-tailed Hares on the Hanford Reservation, BNWL-1931, Battelle-Northwest, Richland, Washington.

Received December 10, 1975.
Accepted for publication June 29, 1976.

Association News

Plans for the spring meeting of the Association are going forward with increased speed. All indications are that president Ken Holmes and his many able helpers at Oregon College of Education are putting the finishing touches on a fine meeting.

There will be separate sessions in Botany, Chemistry-Physics, Geology-Geography, Science Education, Forestry, Zoology, Social Science, and Soil and Water. And don't forget the featured symposium on "Coastline Environment of the Pacific Northwest."

If you haven't sent your dues in, please do so soon.

Please encourage your colleagues and graduate students to attend the meeting.

DATE: March 24-25-26, 1977

SPONSOR: Oregon College of Education

PLACE: Monmouth, Oregon

Milton M Mosher,
Secretary