LAND REHABILITATION RESEARCH
AT
PACIFIC NORTHWEST LABORATORIES

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Primary Productivity and Grazing Potential of Undisturbed Sagebrush-Bluebunch
Wheatgrass Communities

One of the major goals of rehabilitation of surface mined lands is to establish a self-sustaining vegetative cover. The cover should provide protection against wind and water erosion and provide forage for wildlife and livestock comparable to that of pre-mining conditions.

Although livestock grazing has been practiced in the Western United States for more than a century there is a general paucity of information concerning the primary productivity of western rangelands. In this respect there is less information concerning the productivity of sagebrush-bluebunch wheatgrass than in the shortgrass prairie regions of the Western United States (Figure 1). Both regions were exploited by cattle grazing for many years before it was realized that quantitative information would be needed to sustain and manage a livestock industry in the west. Especially lacking is information on primary productivity of western rangelands under ungrazed conditions. One of the few places left in the sagebrush-bluebunch wheatgrass region of the United States that has a long history of no grazing is the U. S. ERDA Hanford Reservation in South Central Washington. Here a stand of sagebrush-bluebunch wheatgrass vegetation has been quantitatively sampled for four consecutive years. These data have been collection in conjunction with a controlled cattle grazing study to determine the ability of sagebrush-bluebunch wheatgrass communities to sustain moderate grazing pressure, and

Figure 1

Geographical extent of sagebrush-bunchgrass
vegetation in the United States

Geographical distribution of the sagebrush-bunchgrass
vegetation in the United States.

Figure 1.

to measure weight gains of cattle while on sagebrush-bluebunch wheatgrass pastures, studies on dietary preferences of cattle show that only four species of plants provide almost all the cattle forage. The productivity of these four species measured at peak biomass, g/m², are shown below:

<u>Species</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>Avg.</u>
Bluebunch wheatgrass	42.0 ± 6.0	44.0 ± 7.0	40.0 ± 6.0	44.0 ± 10.0	42.5
Cusick's bluegrass	4.9 ± 1.7	3.0 ± 1.2	2.0 ± 1.8	4.2 ± 3.8	3.5
Thurber's needlegrass	0.8 ± 0.6	1.0 ± 0.7	0.5 ± 0.4	0.7 ± 1.2	1.0
Hawksbeard	0.5 ± 0.5	4.1 ± 2.3	0.2 ± 0.1	1.1 ± 1.1	1.5
Total	48.2	52.1	42.7	51.0	48.5

These data show that about 485 kg/ha of preferred cattle forage are produced on ungrazed sagebrush-bluebunch wheatgrass pastures each year. Although rainfall varied between years, the herbage production was mostly steady and ranged between 420 and 520 kg/ha/yr.

Cattle grazing was practiced by introducing 5 to 8 herd of yearling steers to two 10 ha pastures adjacent to 2 ungrazed "control" pastures. The cattle were introduced into the pasture in April and removed in late May or early June when it was estimated that cattle had removed about half of the available forage. Cattle were weighed as they were introduced to the pasture and again when they were removed. Weights are made after a "shrinking" period. The weight gains of cattle in pounds for 4 consecutive years of grazing are shown below:

<u>Year</u>	<u>wt. gain/acre</u>	<u>daily wt. gain/head</u>
1971	30.5	1.56
1972	21.4	1.55
1973	15.4	1.40
1974	<u>19.3</u>	<u>1.51</u>
Average	21.6	1.50

Of concern to land rehabilitation is what is the impact of grazing on the plant community in terms of altering the species composition; that is, does grazing favor the non-palatable species, e.g., sagebrush? Also is the productivity of the palatable species reduced by removal of green parts during the grazing season.

After two consecutive years of spring grazing by cattle, the plant community was not invaded by aggressive weedy annuals, although the moss-lichen-algae crust was broken up by trampling. Also, the productivity of Agropyron spicatum was reduced by grazing.

<u>Species</u>	<u>Control</u>	<u>Grazing (Release)*</u>
-----Live g/m ² -----		
<u>Agropyron spicatum</u>	40.0 ± 6.0	23.0 ± 2.0
<u>Poa cusickii</u>	0.5 ± 0.3	0.5 ± 0.2
<u>Stipa thurberiana</u>	<u>0.5 ± 0.4</u>	<u>0.7 ± 0.4</u>
Total	41	24.2
-----Standing Dead g/m ² -----		
<u>Agropyron spicatum</u>	105.0 ± 17.0	39.0 ± 4.0
<u>Poa cusickii</u>	2.6 ± 1.5	1.0 ± 0.5
<u>Stipa thurberiana</u>	<u>1.7 ± 1.6</u>	<u>1.0 ± 0.6</u>
Total	109.3	41

*No grazing during the year of measurement.

The amount of standing dead grass was reduced by grazing cattle from 109 to 41 g/m².

The reproductive capacity of the important cattle forage grasses was affected by grazing. This was particularly evident in the case of Cusicks bluegrass, the most palatable and nutritious grass.

<u>Species</u>	<u>Control</u>	<u>Grazing (Release)</u>
-----Flowering culms per clump-----		
<u>Agropyron spicatum</u>	24.8	18.6
<u>Poa cusickii</u>	22.9	3.3
<u>Stipa thurberiana</u>	19.4	13.9
-----Leaf length (cm)-----		
<u>Agropyron spicatum</u>	30.3	24.8**
<u>Poa cusickii</u>	22.4	13.6**
<u>Stipa thurberiana</u>	28.6	22.6**

One of the important findings of this investigation is the low economic value of sagebrush-bluebunch wheatgrass rangeland for cattle grazing. Another important finding is that gross changes in plant communities under moderate grazing intensities are very likely to occur, but only noticeable over a time span of several decades.

Response of Sagebrush-Bluebunch Wheatgrass Communities to Severe Soil Disturbances

Like surface mining, plowing destroys native plant communities. Unlike surface mining, plowing leaves the topsoil in place. However, topsoiling can be a recommended practice in rehabilitation of surface mined lands.

One of the important questions about severe soil disturbances is: How long will it take for natural processes to restore the original plant community? Another question is: Is it really so important to return to the original plant community?

An unusual opportunity is available on the U.S. ERDA Hanford Reservation to study the long-term recovery of plowed ground without the added stresses of livestock grazing. Here productive dry land wheat fields were taken out of production 30 years ago and have been undergoing plant colonization without man-induced perturbations.

After 30 years, native plants have been mostly unable to invade the plowed ground. Instead, these fields are dominated by alien weeds, especially cheatgrass (Table 1). Like the original sagebrush-bluebunch wheatgrass community, these new communities effectively resist soil erosion. They also require no man-induced external input of water, fertilizer, or weed control.

The data presented in Table 2 clearly shows that there are fewer plant species with more diverse growth forms in the native community. However, the alien community is the more productive, averaging 2470 kg/ha/yr of dry matter production as compared to only 880 kg/ha/yr for the native community.

Cheatgrass is a much maligned plant in the United States since its inadvertent introduction from Eurasia more than a century ago. It has spread throughout the semi-arid regions of the Western United States, encouraged by over grazing and other kinds of soil disturbances. It is an important forage plant, palatable to all classes of livestock. It has also proven to be difficult to eradicate. Its aggressiveness is illustrated in its long tenure on the old fields on the Hanford Reservation, and it has been recorded as dominating abandoned fields for 50 years (Daubenmire, 1975). Cheatgrass is important wildlife forage. It is used for chukar partridges and mule deer and the seeds are eaten by pocket mice which, in turn, are important prey items for mammalian and avian predators.

Table 1. Dry weight of plant species at peak biomass expressed as g/m² in unplowed and plowed communities 1971-1974.

Taxa	1971	1972	1973	1974	Avg.
-----Unplowed Community-----					
Perennial Grasses					
<u>Agropyron spicatum</u>	42.0 ± 6.3	44.0 ± 7.2	40.0 ± 6.0	44.0 ± 10.1	42.5
<u>Stipa thurberiana</u>	0.8 ± 0.6	1.0 ± 0.7	0.5 ± 0.4	2.1 ± 2.1	1.1
<u>Poa sandbergii</u>	7.1 ± 0.7	6.4 ± 0.5	4.0 ± 0.1	11.0 ± 1.2	7.1
<u>Poa cusickii</u>	4.9 ± 1.7	3.0 ± 1.2	2.0 ± 1.8	4.2 ± 3.8	3.5
Perennial Forbs					
<u>Astragalus purshii</u>	2.0 ± 1.3	2.6 ± 2.0	2.9 ± 1.8	3.6 ± 3.6	2.8
<u>Calochortus macrocarpus</u>	0.3 ± 0.09	0.1 ± 0.04	0.2 ± 0.1	0.5 ± 0.2	0.3
<u>Crepis atrabarba</u>	0.5 ± 0.50	4.0 ± 2.3	0.2 ± 0.1	0.7 ± 0.5	1.4
<u>Lupinus laxiflorus</u>	0.3 ± 0.26	0.9 ± 0.6	0.2 ± 0.2	0	0.3
<u>Lomatium macrocarpum</u>	0.5 ± 0.18	0.2 ± 0.05	0.6 ± 0.3	0.2 ± 0.2	0.4
<u>Brodiaea douglasii</u>	0.3 ± 0.3	0.4 ± 0.4	0.1 ± 0.1	0.1 ± 0.1	0.16
<u>Townsendia florifer</u>	0.05 ± 0.05	0	0.2 ± 0.2	0	Trace
Annual Grasses					
* <u>Bromus tectorum</u>	0.07 ± 0.07	Trace	0.02 ± 0.02	0.4 ± 0.20	0.12
<u>Festuca spp.</u>	0.36 ± 0.21	1.1 ± 0.20	0.3 ± 0.1	4.3 ± 0.7	1.5
Annual Forbs					
* <u>Draba verna</u>	Trace	0.06 ± 0.03	0.04 ± 0.02	0.7 ± 0.3	0.2
<u>Descurainia pinnata</u>	Trace	0.6 ± 0.6	0.03 ± 0.01	1.3 ± 0.3	0.5
<u>Murostris gracilis</u>	0	0	0	Trace	Trace
<u>Plantago patagonica</u>	0	0	Trace	Trace	Trace
<u>Amsinckia sp.</u>	0	0	0	Trace	Trace
Semi-woody, Sub-shrubs					
<u>Erigeron filifolius</u>	4.2 ± 1.7	4.3 ± 2.3	8.9 ± 4.1	1.0 ± 0.8	4.6
<u>Phlox longifolia</u>	5.6 ± 2.2	2.2 ± 0.9	0.6 ± 0.5	2.0 ± 1.5	2.6
<u>Antennaria dimorpha</u>	3.4 ± 2.8	10.6 ± 6	4.4 ± 3.2	1.4 ± 1.1	4.9
Shrubs					
<u>Artemisia tridentata</u>	---	---	---	10.0 ± 2.6	10.0
TOTAL					84

Table 1 (Cont.)

Taxa	1971	1972	1973	1974	Avg.
-----Plowed Community-----					
Perennial Grasses					
<u>Poa sandbergii</u>	3.2 ± 2.8	0	2.1 ± 2.1	8.4 ± 5.3	3.4
Annual Grasses					
* <u>Bromus tectorum</u>	198.0 ± 12.0	132.0 ± 7.0	166.0 ± 12.0	328.0 ± 16.0	206.0
Annual Forbs					
* <u>Sisymbrium altissimum</u>	17.0 ± 4.0	1.7 ± 0.7	67.0 ± 15.0	68.0 ± 18.0	38.4
<u>Amsinckia</u> sp.	2.0 ± 2.0	0	5.3 ± 3.7	1.4 ± 1.4	2.2
* <u>Holosteum umbellatum</u>	0.1 ± 0.1	0.1 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.2
<u>Descurainia pinnata</u>	0	0.2 ± 0.2	Trace	Trace	Trace
* <u>Draba verna</u>	0	0	0	Trace	Trace
* <u>Erodium cicutarium</u>	0	0	0	Trace	Trace
TOTAL					247.0

*Alien (introduced) species

TABLE __. Canopy cover provided by plant species on
pairs of north and south-facing slopes.
May 1976.

Species	S	N
-----% Cover-----		
Grasses		
Perennial		
<u>Agropyron spicatum</u>	0.20	13.66
<u>Poa cusickii</u>	0	5.98
<u>Poa sandbergii</u>	0.50	28.11
Total perennial grasses	0.70	47.75
Annual		
<u>Bromus tectorum*</u>	13.75	7.72
<u>Festuca sp.</u>	0.09	0.34
Total annual Grass	13.84	8.06
Total Grasses	14.54	55.81
Forbs		
Perennial		
<u>Achillea millifolium</u>	0.01	0.65
<u>Astragalus purshii</u>	0.32	0
<u>Balsamorhiza careyana</u>	0.60	0.39
<u>Calochortus macrocarpus</u>	0	0.23
<u>Crepis atrabarba</u>	0	0.02
<u>Delphinium sp.</u>	0	0.97
<u>Fritellaria pudica</u>	0	0.01
<u>Lomatium grayii</u>	2.27	0.07
<u>Lomatium macrocarpum</u>	0.01	0.84
<u>Phlox longifolia</u>	0	0.17
Total perennial forbs	3.21	3.35
Annual		
<u>Amsinckia lycopsoides</u>	0.24	0.12
<u>Cryptantha circumscissa</u>	0.90	0.11
<u>Descurainia pinnata</u>	0.48	0.65
<u>Draba verna*</u>	0.04	1.15
<u>Epilobium paniculatum</u>	0.02	0.01
<u>Gilia leptomeria</u>	0.30	0.02
<u>Holosteum umbellatum*</u>	0.01	3.59
<u>Layia glandulosa</u>	0.03	0
<u>Latuca serriola</u>	0.24	0.26
<u>Mentzelia albicaulis</u>	0.07	0
<u>Microsteris gracilis</u>	0.22	0.51
<u>Montia sp.</u>	0	0.10
<u>Phacelia sp.</u>	0.17	0.10
<u>Plectritis macrocera</u>	0.25	3.23
<u>Sisymbrium altissimum*</u>	0.02	0.13
Total annual forbs	2.99	9.89
Total Forbs	6.20	13.24

*Alien species

Species	S	N
	-----% Cover-----	
Shrubs		
<u>Artemisia tridentata</u>	0	0.07
<u>Chrysothamnus nauseosus</u>	0	0.30
<u>Eriogonum niveum</u>	0.71	0
<u>Eriogonum sp.</u>	0.42	0.59
<u>Grayia spinosa</u>	0.01	0.74
<u>Lithospermum glabra</u>	0	0.21
<u>Salvia dorrii</u>	2.62	1.09
Total Shrubs	3.76	3.00
TOTAL COVER: ALL SPECIES	24.91	72.03

*Alien species only

Perhaps the time has come to more actively research the virtues of cheatgrass in terms of land rehabilitation and as a forage species for livestock and wildlife.

Plant Cover on Stressful Habitats of Natural Origin

Steep slopes are found throughout the arid and semi-arid regions of the Western United States. Characteristically these slopes have at least some vegetative cover. Poor soil and severe microclimates especially in the south-facing slopes limits the kinds of plant species that can grow on them and also limits their productivity. This investigation compares species composition and canopy-cover provided by plants growing on ten pairs of north and south-facing slopes of similar steepness.

The slopes are of natural origin formed by eroding of the Ringold geologic formation and have been in place for thousands of years. Although the study sites are located off the Hanford Reservation the slopes are in relatively undisturbed condition.

One of the findings of this investigation is that cheatgrass now provides an important part of the vegetation in the south-facing slopes. It also occurs in the north-facing slopes but native plants are more important on these.

It is likely that steep slopes overlies valuable mineral deposits that may be mined in the future. Rehabilitation of steep slopes will require an assessment of the original vegetative conditions. In arid regions it may be necessary to accept a nearly barren steep slope as rehabilitated. This is especially important if the legal land restoration criteria insist upon a return to original contour.

Quantitative descriptions of vegetation of steep, natural slopes in semi-arid or arid areas are scarce in the published literature. The purpose

of this paper is to present our analyses of data on plant species composition and canopy cover of steep north and south slopes.

The climate of the study area is characterized by low precipitation, averaging slightly less than 7 in. annually, nearly all of which falls in the cool part of the year. Summers are hot and dry and winters cold to cool and wet. Vegetative cover was estimated using the Daubenmire (1959) method.

Thirty-seven plant species were recorded from 20 slopes (Table 1). Of these, 23 were common to both slopes, 4 were found only on the south slopes, and 10 were found only on the north slopes. The south slopes had much less cover (25%) than the north slopes (72%).

Cheatgrass provided about 50 percent of the plant cover on the south-facing slopes. Perennial grasses contributed very little to plant cover on the south-facing slopes but provided 66 percent of the cover on north-facing slopes. Clearly the environment of the south-facing slopes does not favor the perennial grasses.

The percent cover on each slope was converted to proportional cover which was used to calculate diversity indices according to Hill (1973):

$$N_a = (p_1^a + p_2^a + p_3^a + \dots + p_n^a)^{1/(1-a)}$$

where N_a is a diversity index, $p_1 \dots p_n$ are the proportional abundances or covers for the n species, and a is the parameter which determined the diversity index calculated:

$a = 0$ Number of species

$a = 1$ Exp (H) (H is Shannon's entropy)

$a = 2$ Reciprocal of Simpson's modified index

For $a = 1$,

$$N_1 = \exp \left(-\sum p_i \ln(p_i) \right) = \exp (H) \quad (\text{Hill 1973})$$

where i progresses from 1 to n .

The Wilcoxon Signed Rank Test was used to test for differences in percent cover for each species, total cover, and the diversity indices because it assumes only that the samples come from the same but unknown distribution (Woolf, 1963).

Diversity is a measure of how many species are present as examination proceeds down to a certain level of rarity (Hill, 1973). It is interesting to note that on the south slopes, B. tectorum was the dominant species because it alone used most of the community resources, whereas on the north slopes, dominance was shared by B. tectorum, P. sandbergii, and A. spicatum, yet the diversity indices N_1 and N_2 were not different. This may mean that the one abundant species on the slope, B. tectorum, is equivalent in community function to the three co-dominant species on the north slopes. With more consideration of rare species as given in the N_1 diversity values, the north slopes have slightly more (S: 4.4%, N: 5.3%) species though the difference is not statistically different. Overall, dominance, as indicated by N_1 and N_2 , appears the same. We can postulate that several factors could account for the contrast in cover and number of species and similarity in numbers of non-rare species.

One factor may be related to the seasonal progression of micro-climate. The region is characterized by hot, dry summers and cool to cold wet winters. Because few rains occur during the late spring and summer, soil water reserves are accumulating during the previous winter (Rickard, 1967). The deeper the soil, the more water available during the spring and summer when temperatures are adequate for rapid growth. The south slopes warm faster in spring so plant growth begins earlier. However, the growing season on the south slopes

is also shorter because the thin soil stores little water. The difference, then, between the slope aspects is the length of growing season. Perhaps those species found only on the north slopes require a longer growing period to mature. Further speculating, fewer species can adapt to the more stressful environment of the south slopes, hence the difference in number of species.

Another factor is the much lower rock content of the soil from the north slope, which suggests this soil is not totally derived from the alluvial parent material but is of aeolian origin. Further speculating, the denser north slope vegetation cover would slow the wind so that dust would be deposited onto the north slopes. In essence, this is a positive feedback system; a more mesic environment leads to more vegetation, leads to more soil, leads to a more mesic environment and a more dense vegetation, and so on.

Presently, most of the vegetative cover on south slopes is provided by the alien annual grass, B. tectorum, which suggests these nearly barren south slopes were even more devoid of vegetative cover before the importation of B. tectorum. The data gathered in this investigation show that steepness per se is not the cause of slope barrenness. The soil and vegetative cover data suggest that the interactions between vegetation and microclimate lead to a more favorable environment with more plant cover on the north slopes, favoring the deposition of fine-textured soil material to further increase the thickness of soil.

Rehabilitation of Surface Mined Lands by Water Harvest

One of the important ecologic concerns about surface mining is the biologic potential for establishing a plant cover to reduce soil erosion and to provide a suitable substrate for the growth of plants. To facilitate the

establishment of vegetative cover, surface mined lands may be legally required to approximate original topography with the placement of topsoil over the spoil in layers of sufficient depths to provide soil water storage and an adequate supply of mineral nutrients.

Most ecologists regard arid landscapes as among the most difficult to restore because of a very stressful plant environment which is characterized by soil drought and by poor soil nutrition, especially low nitrogen. Sometimes soil salts may be present in sufficient quantities as to inhibit the growth of plants except halophytes.

The purpose of the restoration of surface mined lands conducted on the arid Hanford Reservation is to use modern machinery such as that used in removing the overburden from coal seams to create an environment that is more favorable to plant growth than conventional land leveling and topsoiling. The project consists of two parts (1) modifying the topography to accumulate precipitation (water harvest) and (2) the placement of topsoil in sufficient depth to provide soil water storage and mineral nutrition to enable the growth of plants with greater productivity and higher economic value than those plants that can be cultivated under conventional land restoration practices.

Two sets of mound rows resembling spoil banks of strip mines are planned. The first set, perpendicular to our strongest winds, has been completed. The other set, Figure 1, parallel with our strongest winds, is only partially complete due to a work strike. The mounds are 97 m long, 17 m apart (crest to crest) and 2.9 m high. A strip of top soil 4 m wide is placed between the mounds for crop cultivation (Figure 2). The ratio of peak to peak distance to topsoil width, $17/4$, will deliver approximately a fourfold increase in precipitation, if water runoff efficiency from the slopes is 100%.

Figure 2

Runoff efficiency will be tested in three experimental treatments: Butyl rubber sheeting, no treatment (control), and paraffin. In addition, a level ground treatment has also been prepared. The butyl rubber has been installed, and the paraffin treatment, is waiting for equipment to spray the liquid paraffin on the slopes.

Three plant species will be used to test the effectiveness of the slope treatments: winter wheat, Siberian wheatgrass and grapes. These plants are expected to respond to a wide range of soil moisture levels and thus make good indicators of effectiveness of each rainfall harvesting technique. The wheat and wheatgrass have been planted. The grapes will be planted next spring.

The wheat, "Nugains", a soft white winter variety planted extensively in Eastern Washington in regions receiving precipitation as low as 10-12 inches annually was planted October 20, 1976. The soil was prepared by making furrows with a disc; the seed was hand broadcast evenly at the rate of 100 pounds per acre [1354 gm/valley (27 m x 4 m)]. The seeds were covered by discing.

Siberian wheatgrass was planted at the same time and in the same manner. The planting rate for wheatgrass was 6 pounds per acre or 81 gm per valley (27 m x 4 m). This grass is used as cattle forage, but has not been successfully grown in areas as dry as this study site without irrigation.

The third test species, grape, will be planted in the spring. Three varieties have been suggested by our consultant from Washington State University's Irrigated Agricultural Research and Extension Center at Prosser, Washington. The varieties, Concord, Chardonnay and Cabernet Sauvignon, were chosen for their cold and drought hardiness. The consultant will assist in

the culture and care of the grapes as viticulture is best handled by an expert.

Productivity of wheat and wheatgrass will be determined by harvest methods. Grape production will be estimated from length of new growth and weight of material pruned away. Fertilizer requirements will be determined from tissue analysis.

Climatological measurements of precipitation, wind speed, and air temperature will be made at the study site supplemented with periodic measurements of soil moisture and temperature.

A fence is being built to exclude rabbits and mule deer. The fence will be 9 ft high. The lower 4 ft will be 1 in. chicken wire. Barbed wire at 1 ft intervals up to 9 ft will prevent mule deer jumping over the fence. The fence is needed to protect the test plantings from damage.

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